FACULTY OF SCIENCE
Institute for Biodiversity and Ecosystem Dynamics

The value of natural archives for understanding past climate change and human impact

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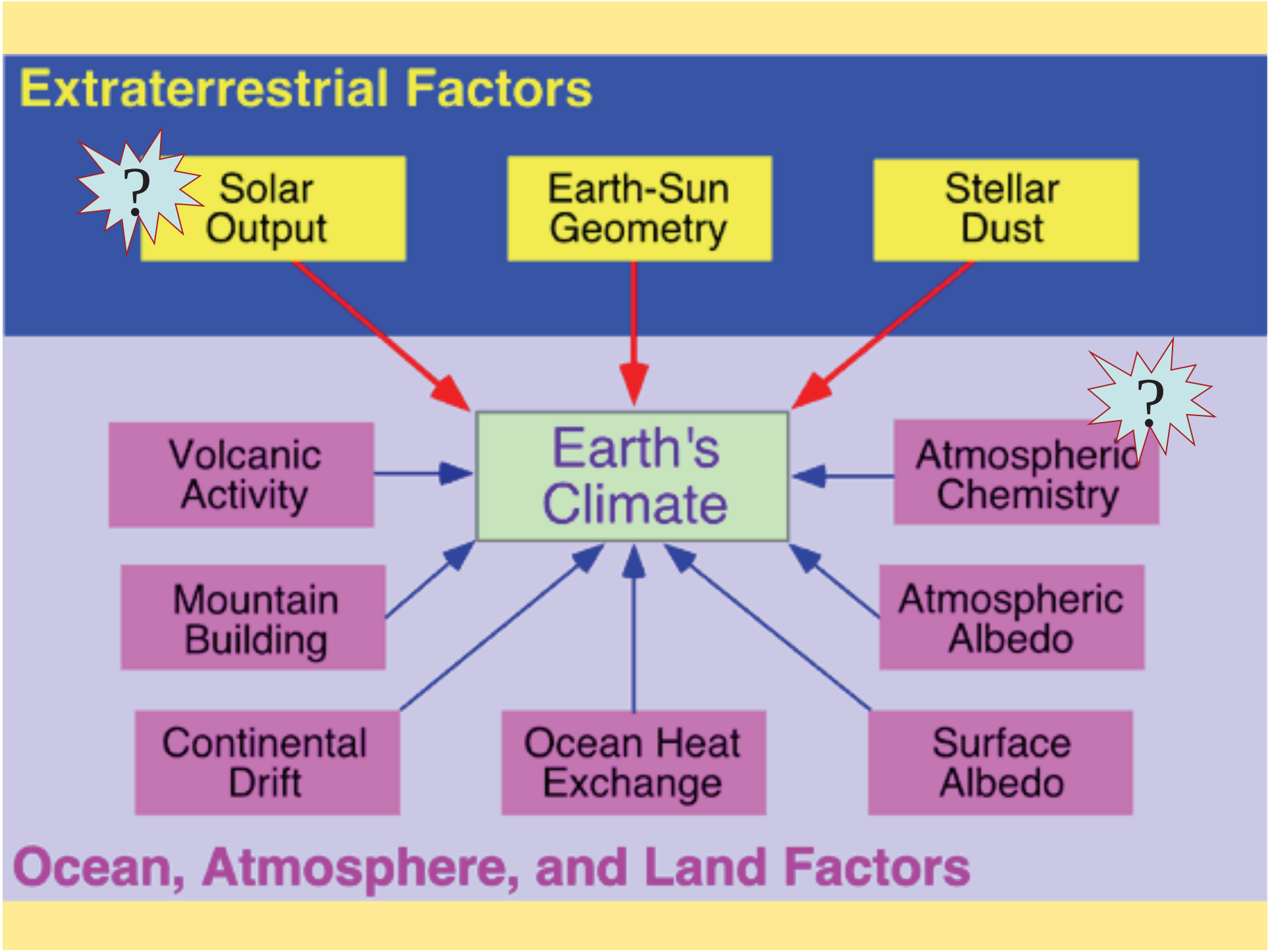
TERENO Workshop (Terrestrial Environmental Observatories)
Potsdam, 24-25 January 2012

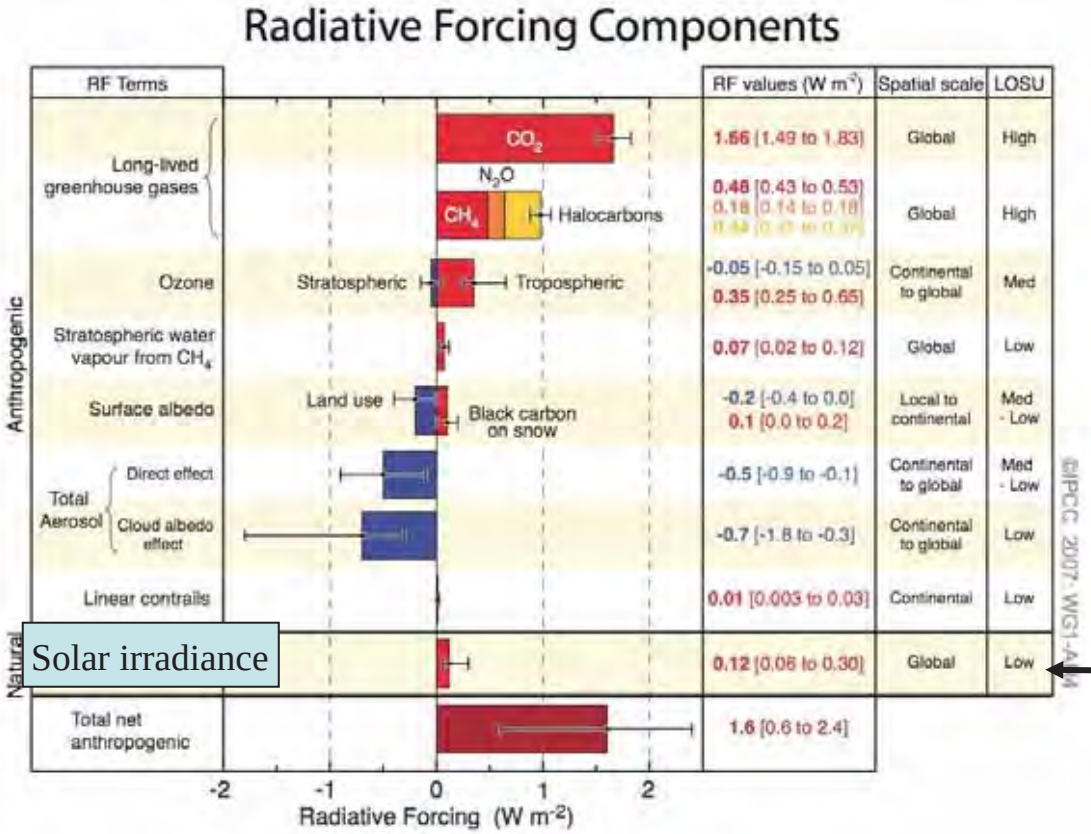
This lecture will be a mix of:

Paleo-evidence (paleo-ecology; archeology) for climate change and indications for an important role of the sun.

Hazards, and the resilience of late Bronze Age farmers and their ability to adjust to the - initially - misfortune of abrupt climate change.

An opinion about future climate change.


Extraterrestrial Factors
?
Solar Output
Earth-Sun Geometry
Stellar Dust
?
Volcanic Activity
Earth's Climate
Atmospheric Chemistry
Mountain Building
Atmospheric Albedo
Continental Drift
Ocean Heat Exchange
Surface Albedo
Ocean, Atmosphere, and Land Factors



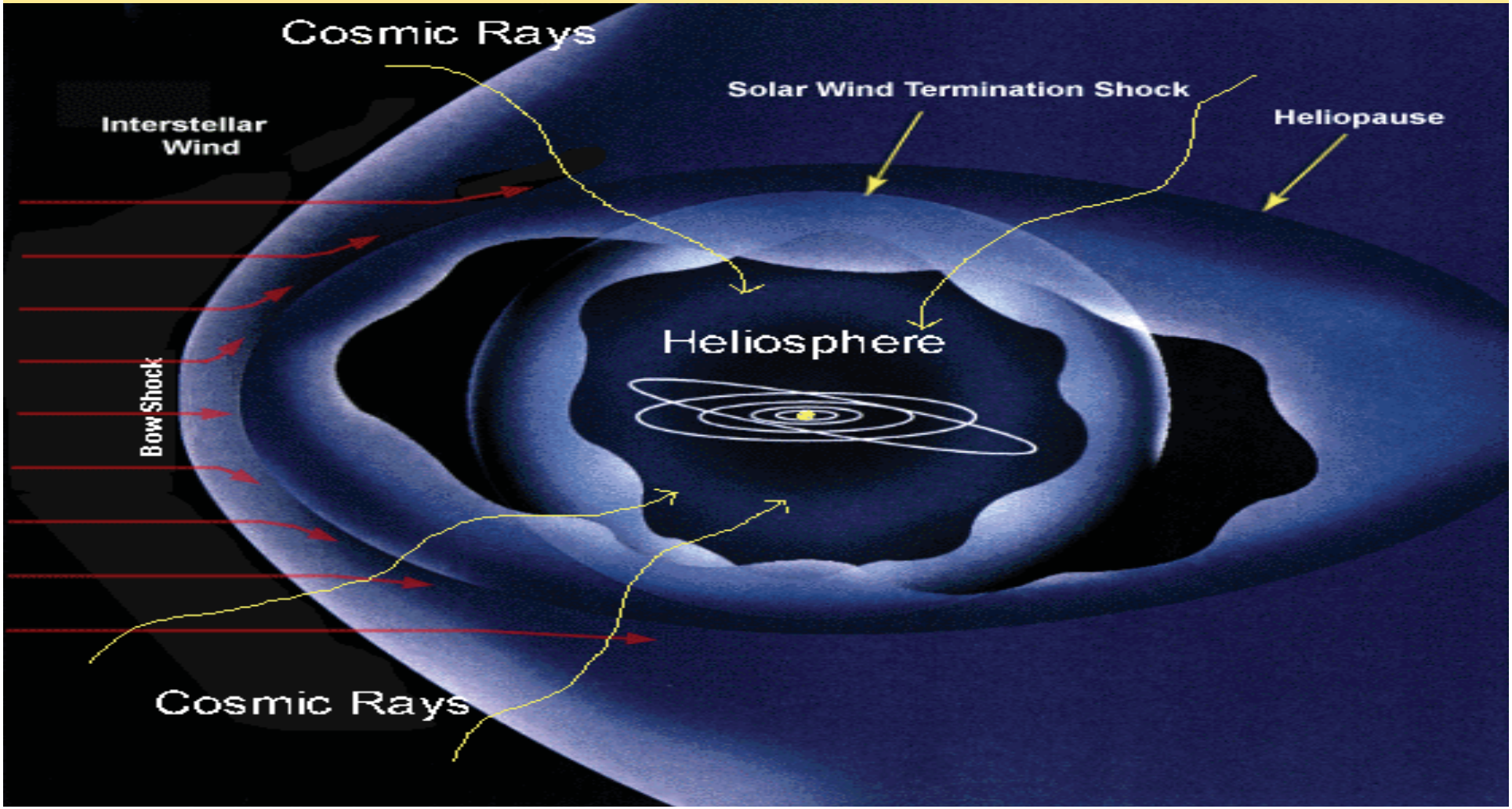
IPCC Fourth Assessment Report
Summary for Policymakers
2007

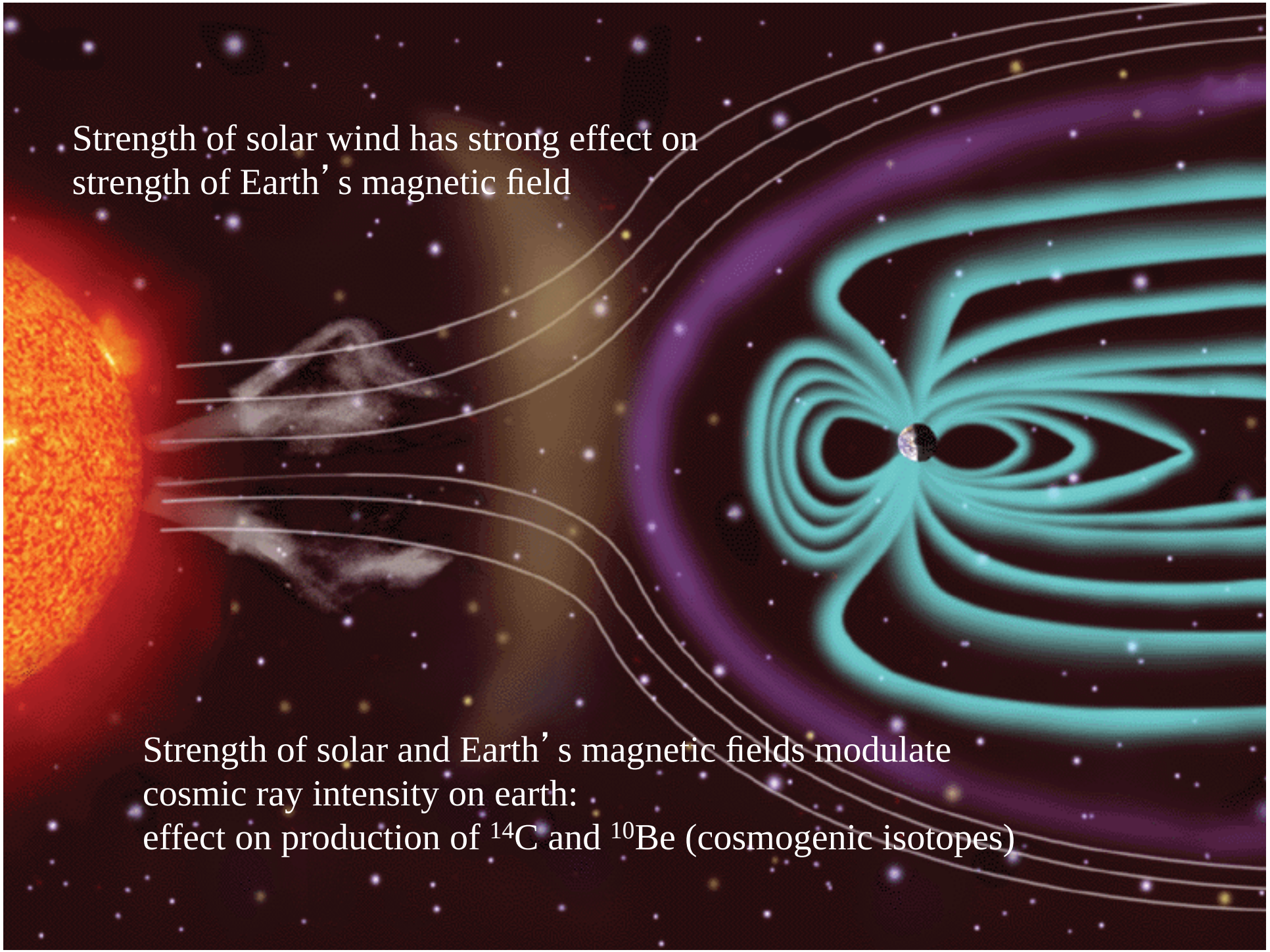
Fluctuations of solar irradiance in W/m^2? Does that make sense?

Level of scientific understanding is still **low**

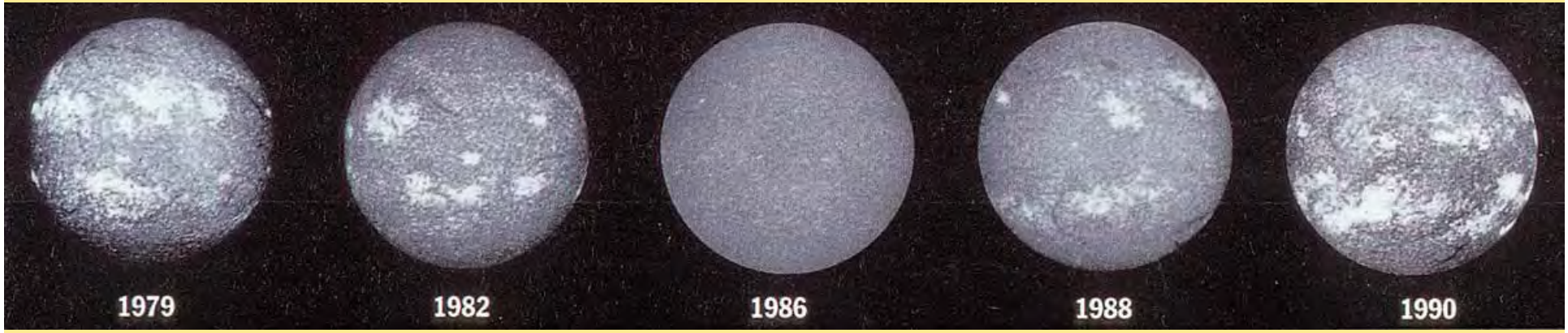
Amplification mechanism(s) for solar activity changes **unknown** and therefore **not taken into account**.

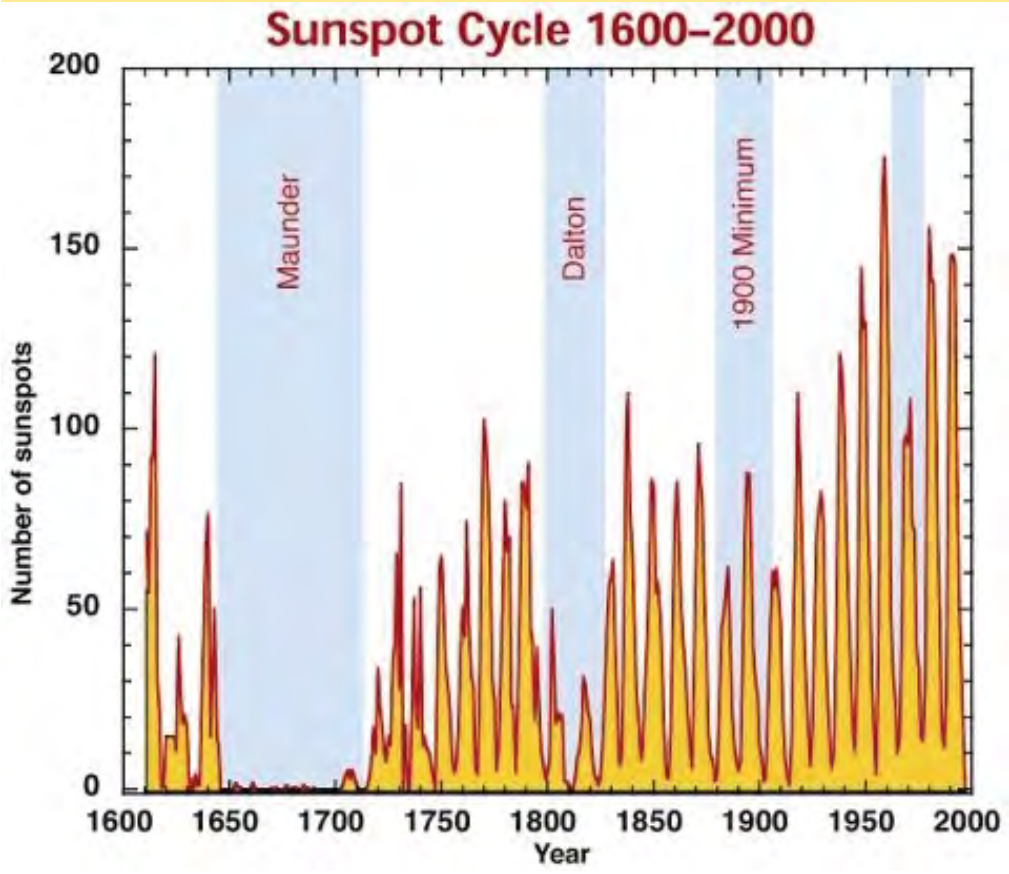
Cosmic ray flux, modulated by sun-ejected magnetized plasma clouds (solar wind), affects production of cosmogenic isotopes ^{14}C and ^{10}Be in Earth's atmosphere

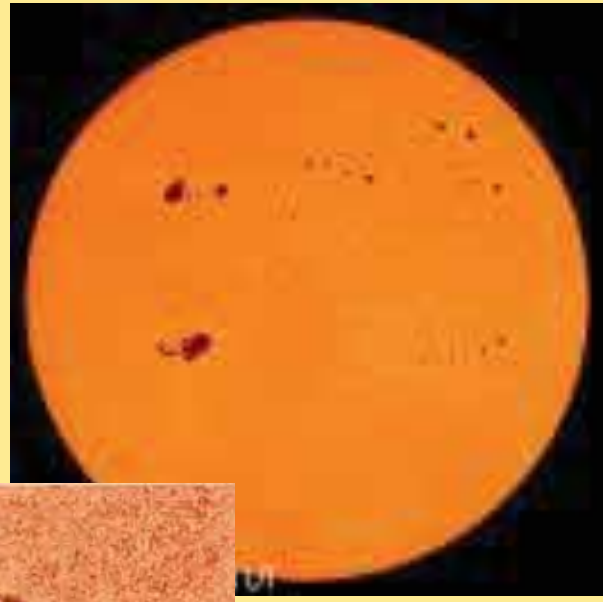


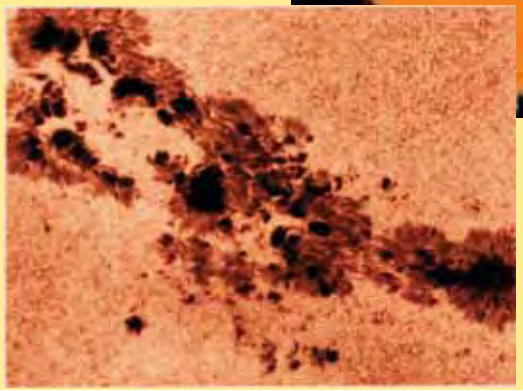

Strength of solar wind has strong effect on
strength of Earth's magnetic field
Strength of solar and Earth's magnetic fields modulate
cosmic ray intensity on earth:
effect on production of ^{14}C and ^{10}Be (cosmogenic isotopes)

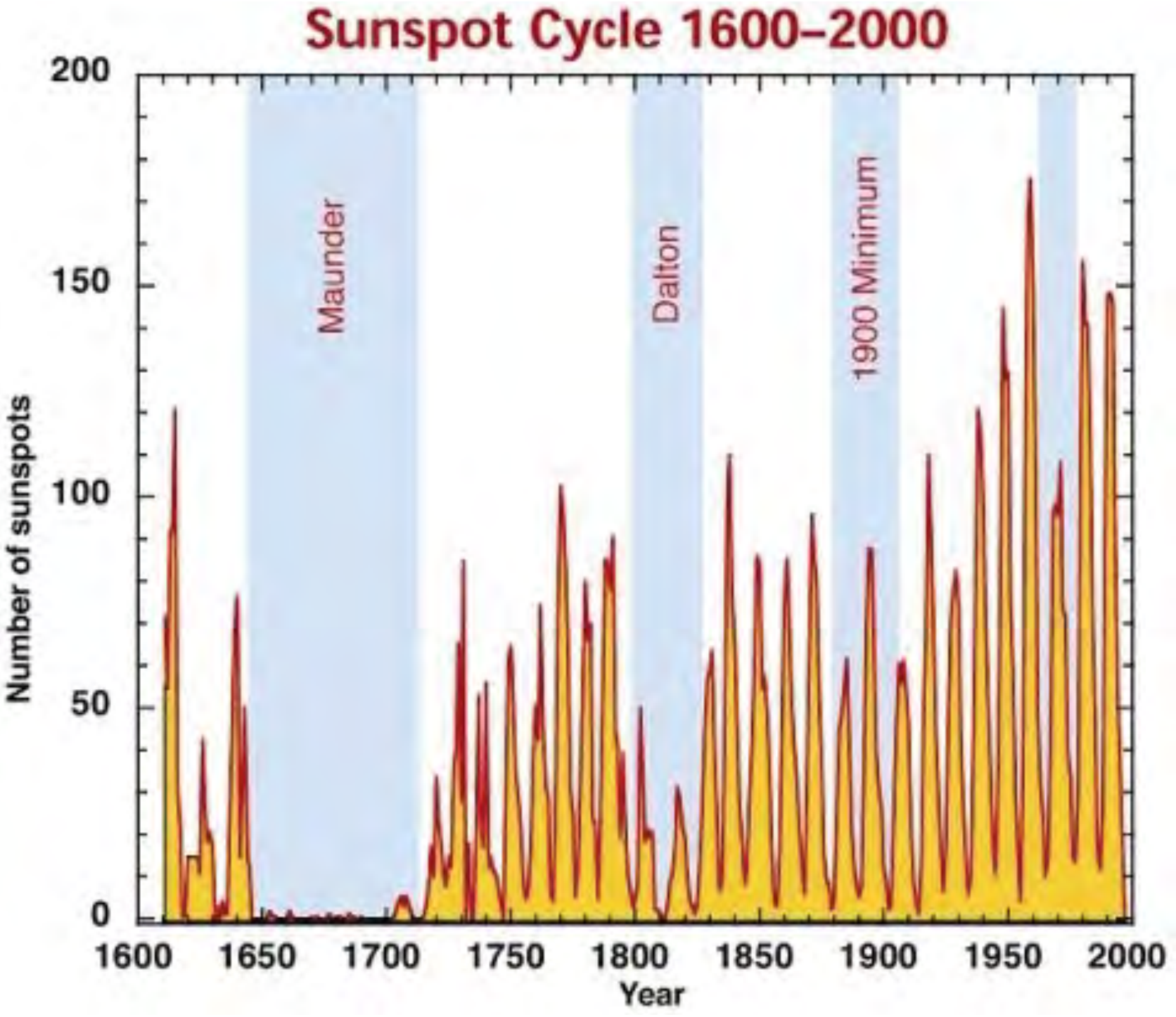
Changing solar activity: cause of major climate changes during the Holocene

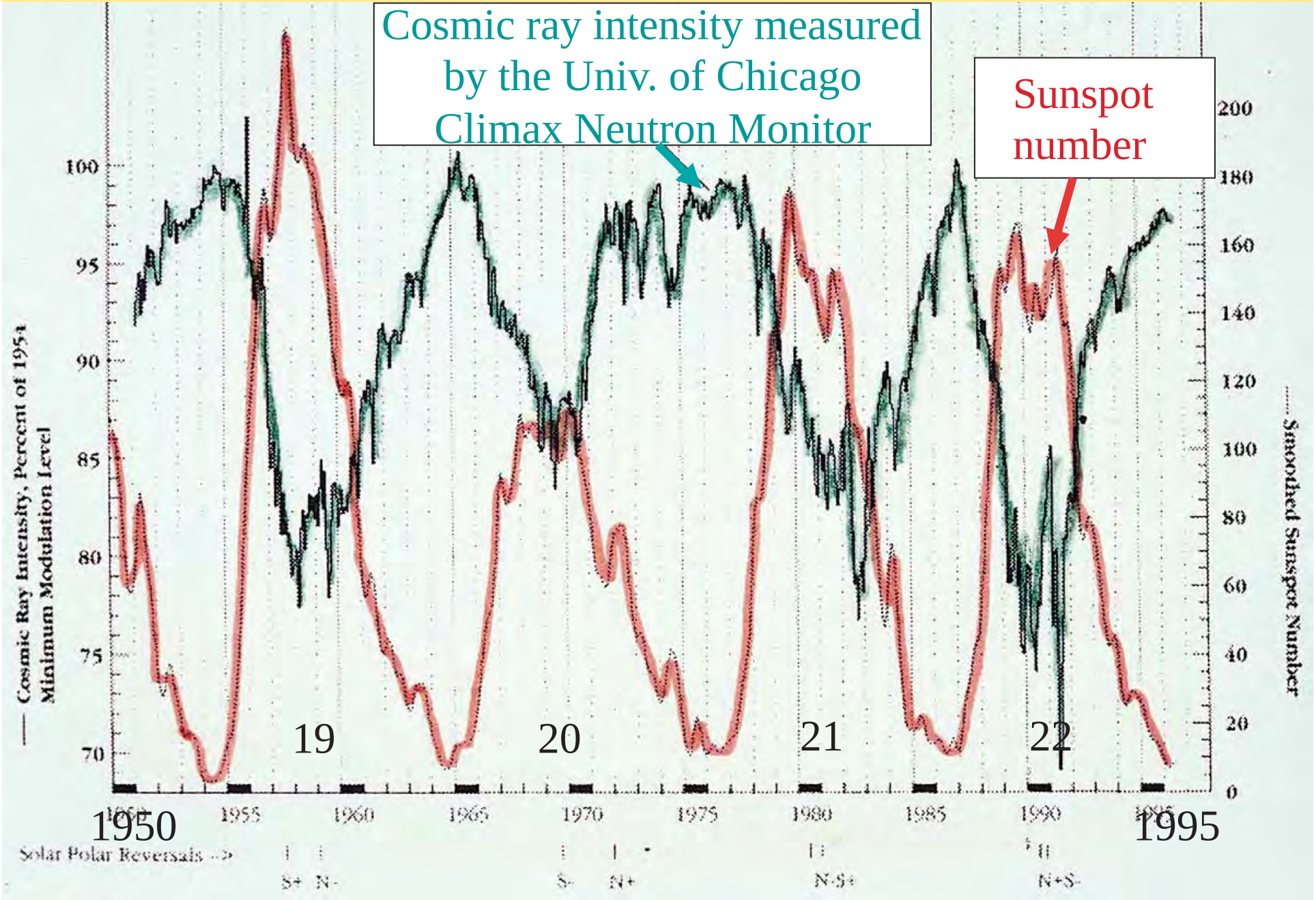




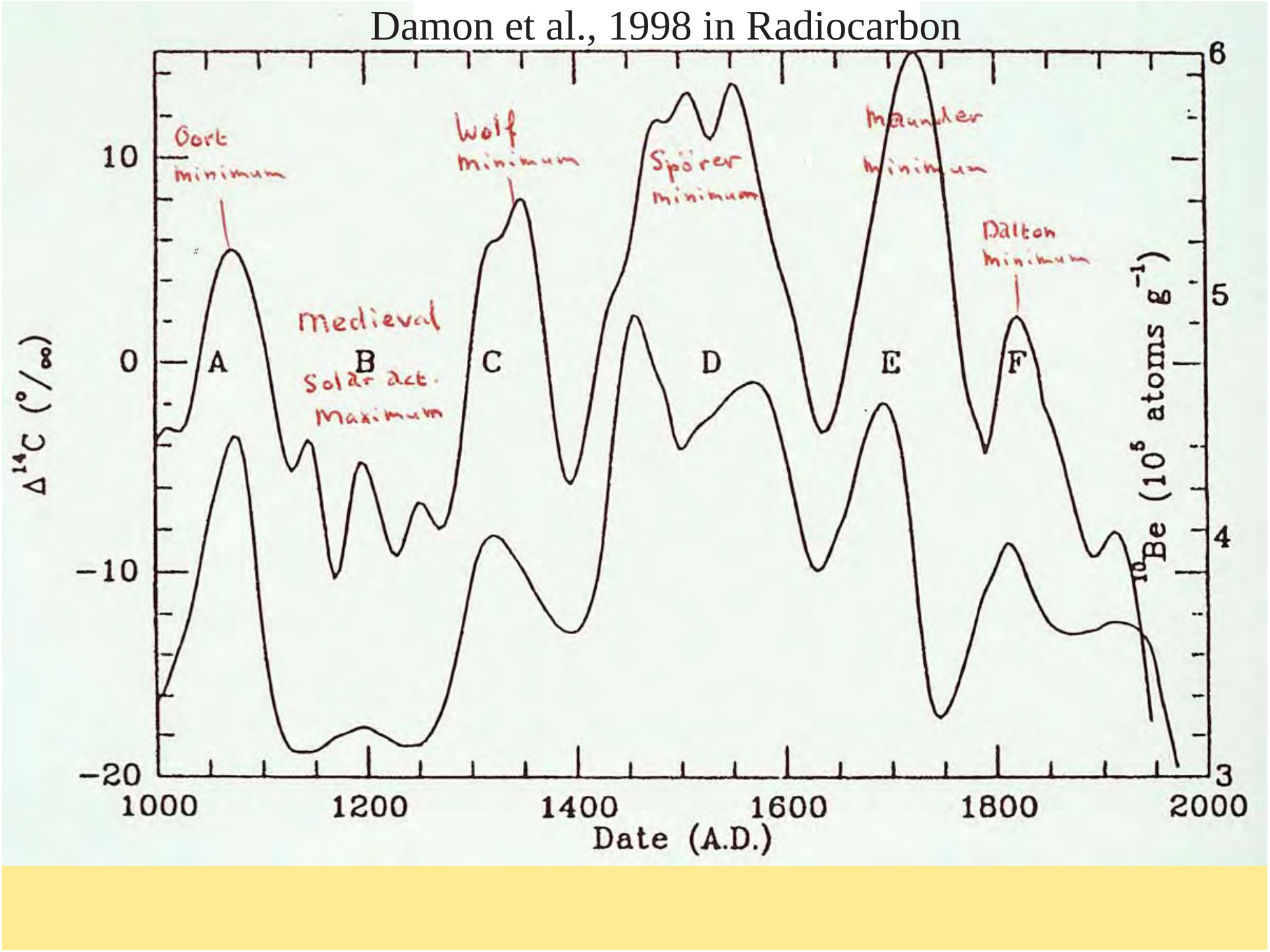





Sunspot Cycle 1600–2000
Number of sunspots
200
150
100
50
0
Maunder
Dalton
1900 Minimum
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year


Cosmic ray intensity measured by the Univ. of Chicago Climax Neutron Monitor
Sunspot number
— Cosmic Ray Intensity, Percent of 1954 Minimum Modulation Level
---- Smoothed Sunspot Number
100
95
90
85
80
75
70
200
180
160
140
120
100
80
60
40
20
0
19
20
21
22
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
Solar Polar Reversals -->
S+ N-
S- N+
N-S+
N+S-

Damon et al., 1998 in Radiocarbon



1947: Libby discovered ^{14}C

6 protons: Carbon

6 neutrons: ^{12}C is stable
7 neutrons: ^{13}C is stable (1%)
8 neutrons: ^{14}C radioactive

^{14}C production: $^{14}N + n \rightarrow {}^{14}C + p$

^{14}C decay: $^{14}C \rightarrow {}^{14}N$ + elektron
(beta particle)

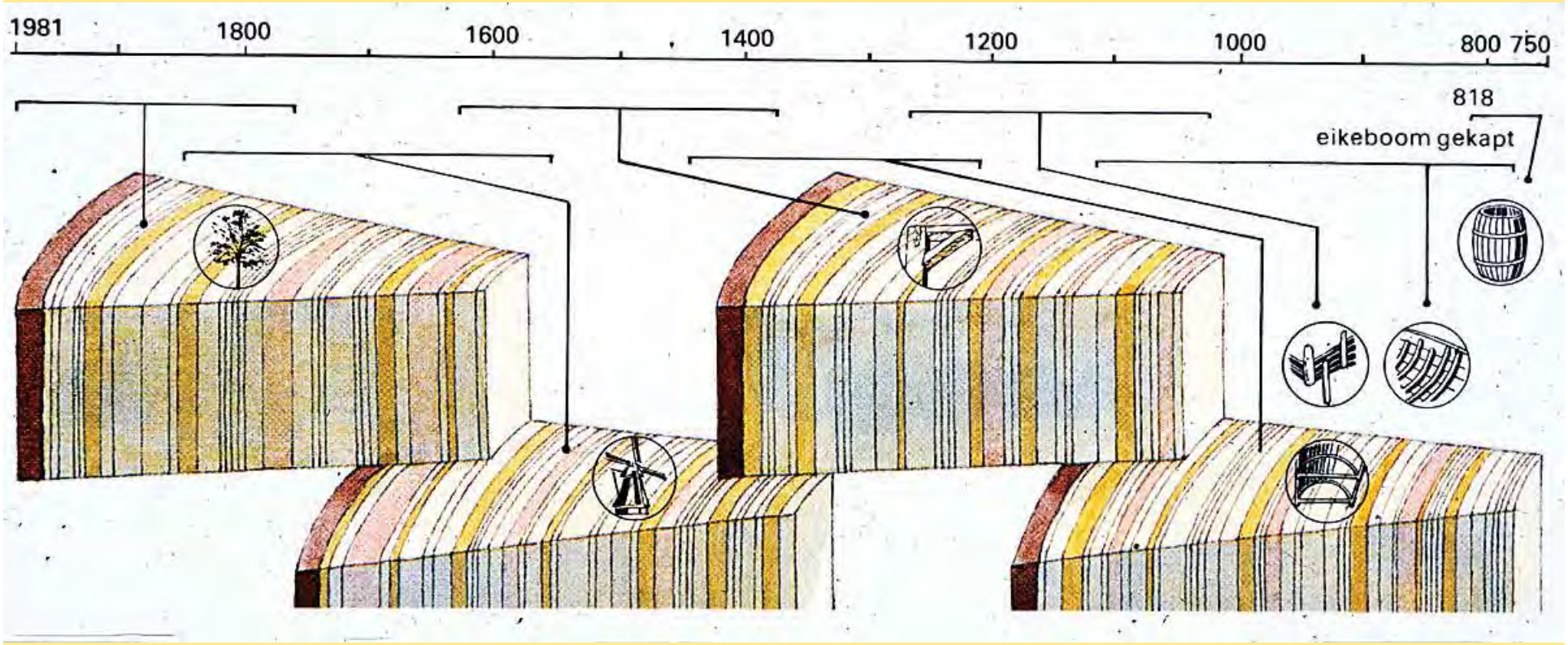
(half-life of 5730 years used to calculate age of organic material)

Cosmogenic isotopes in natural archives show changes of solar activity in the past:

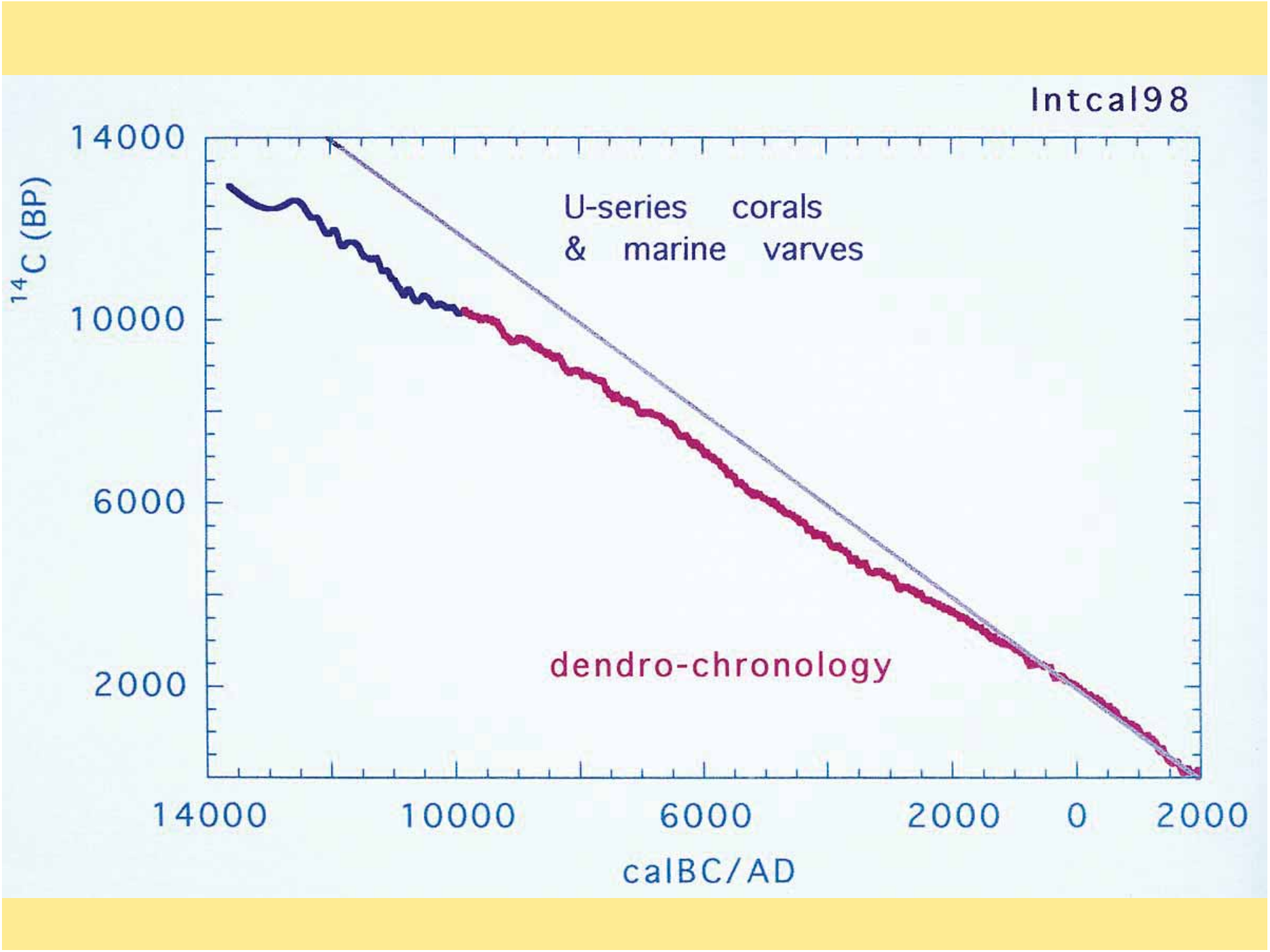
^{14}C (Radiocarbon) in tree rings

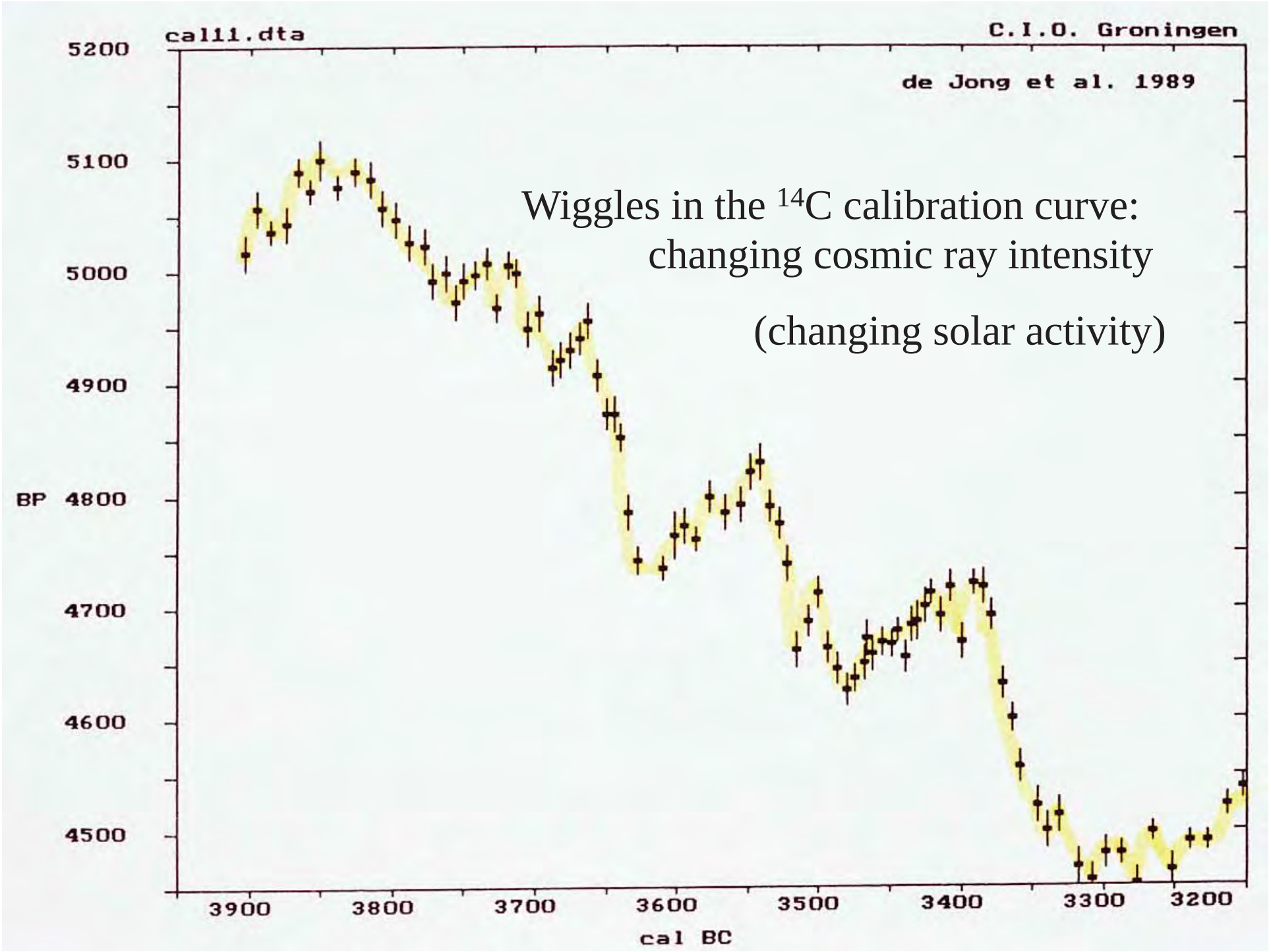
and

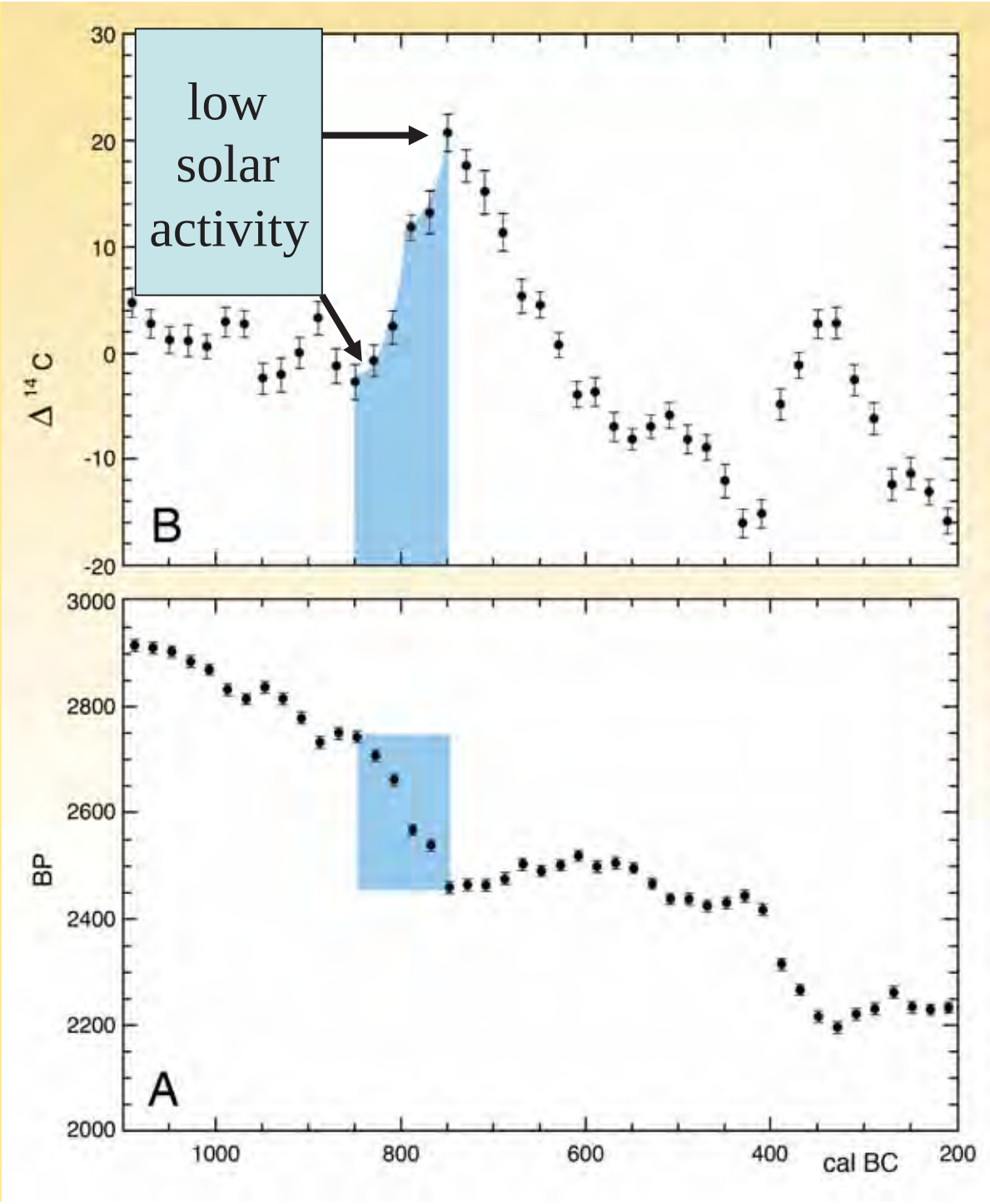
^{10}Be (Beryllium-10) in ice cores



dendrochronology


Intcal98
14000
10000
6000
2000
^{14}C (BP)
U-series corals
& marine varves
dendro-chronology
14000
10000
6000
2000
0
2000
calBC/AD


cal11.dta
C.I.O. Groningen
de Jong et al. 1989
Wiggles in the ^{14}C calibration curve:
changing cosmic ray intensity
(changing solar activity)
5200
5100
5000
4900
BP 4800
4700
4600
4500
3900
3800
3700
3600
3500
3400
3300
3200
cal BC



Delta ^{14}C

correction for radioactive decay

^{14}C calibration curve
1100 - 200 cal BC

Natural archives and the evidence for solar forcing of climate change in the past

Some examples showing that the climate system is hyper-sensitive for relatively small changes in solar activity.

Sectioned stalagmite from Shangdong Cave, China.

Natural archives of climate change in cave deposits

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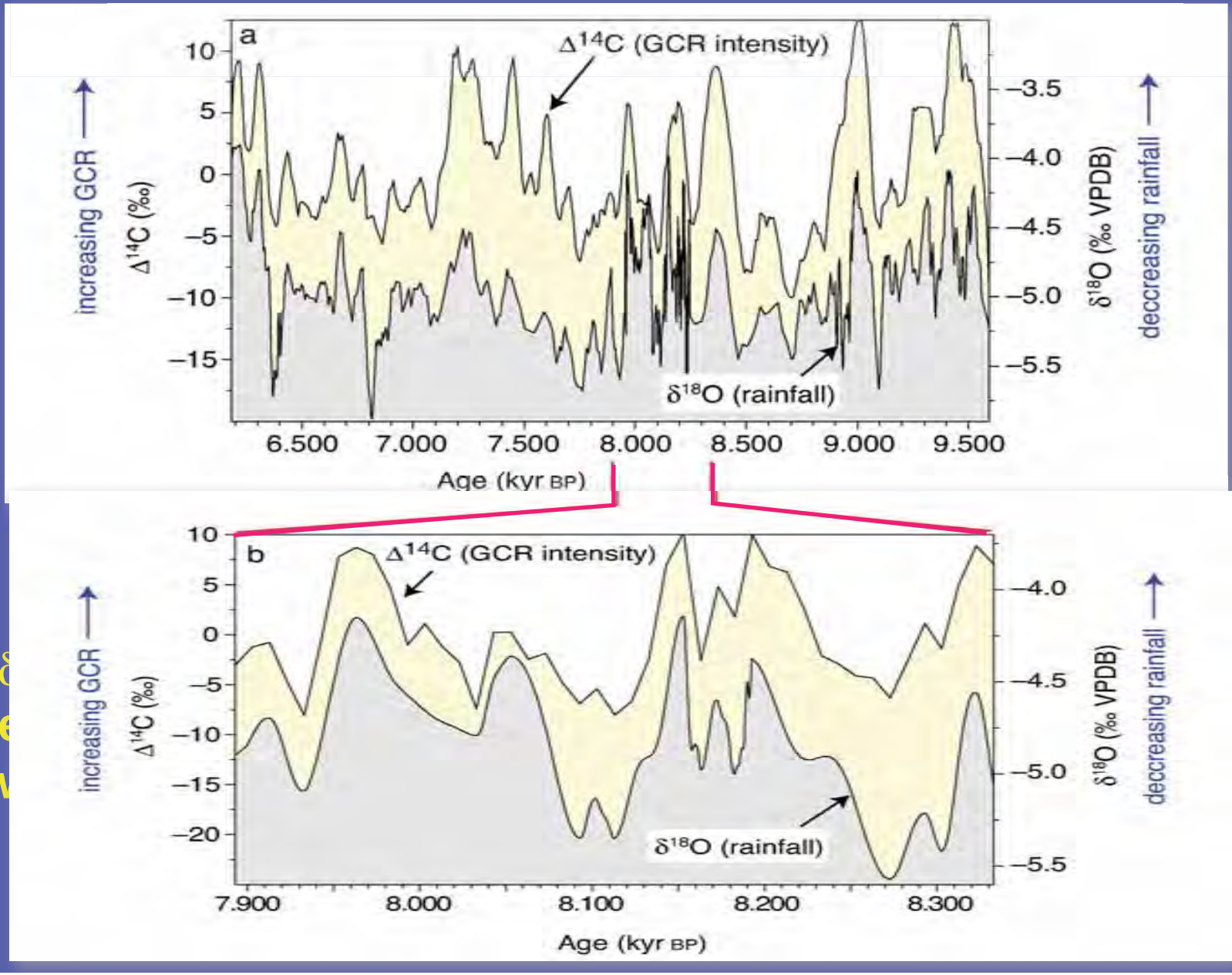
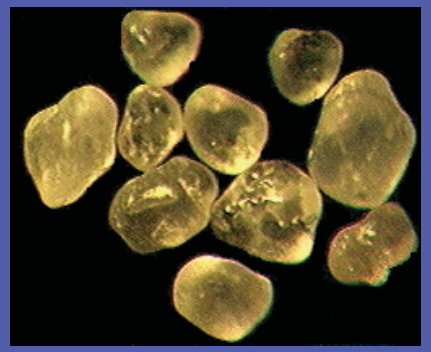
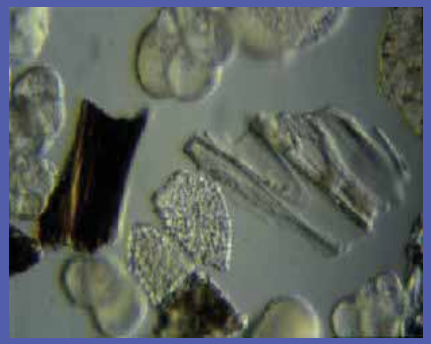
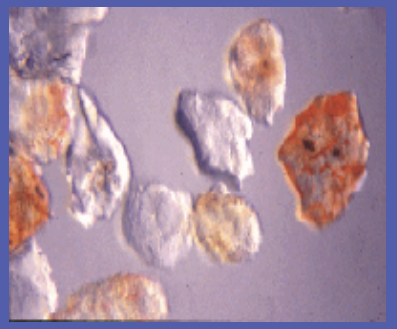
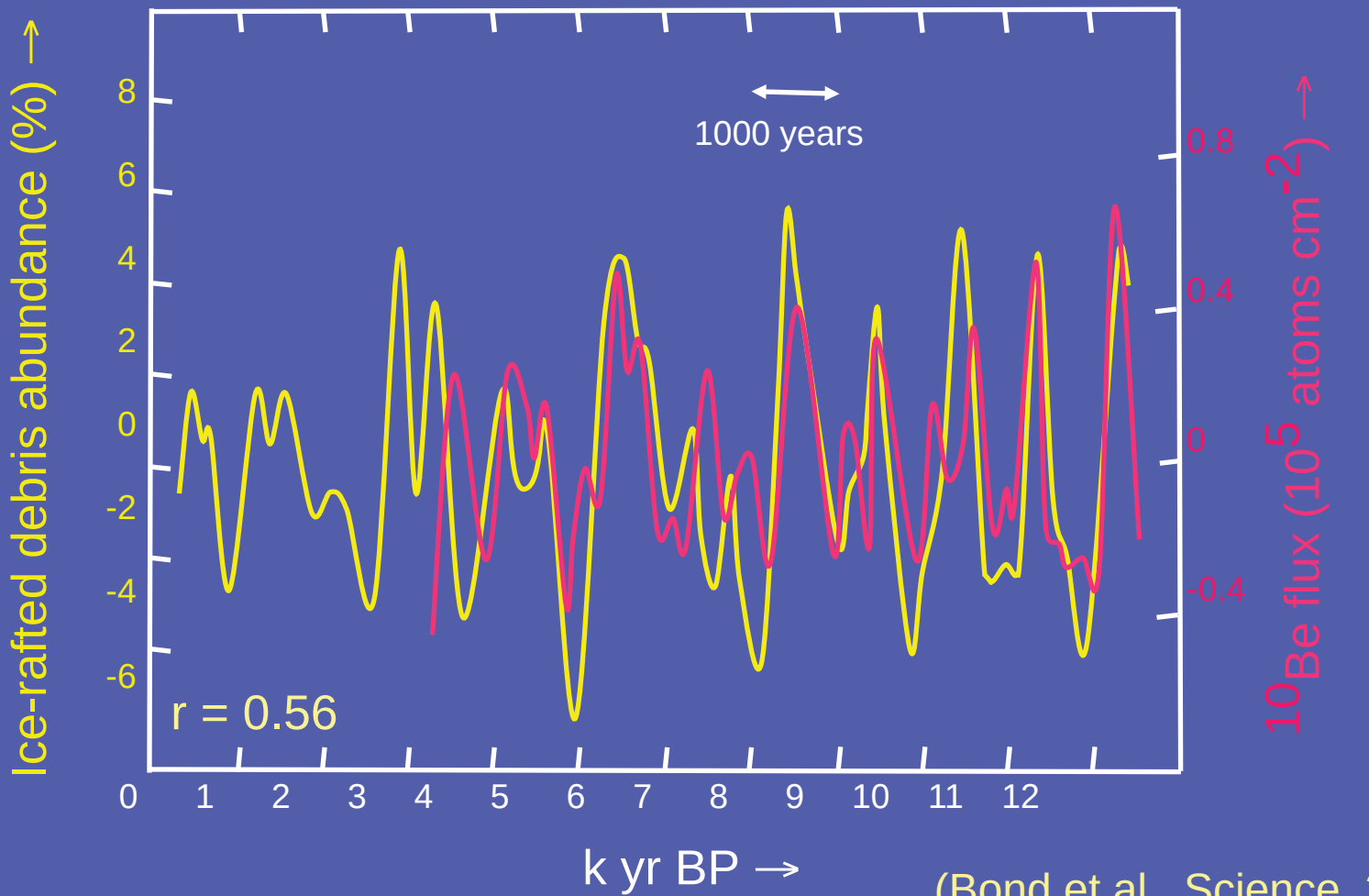
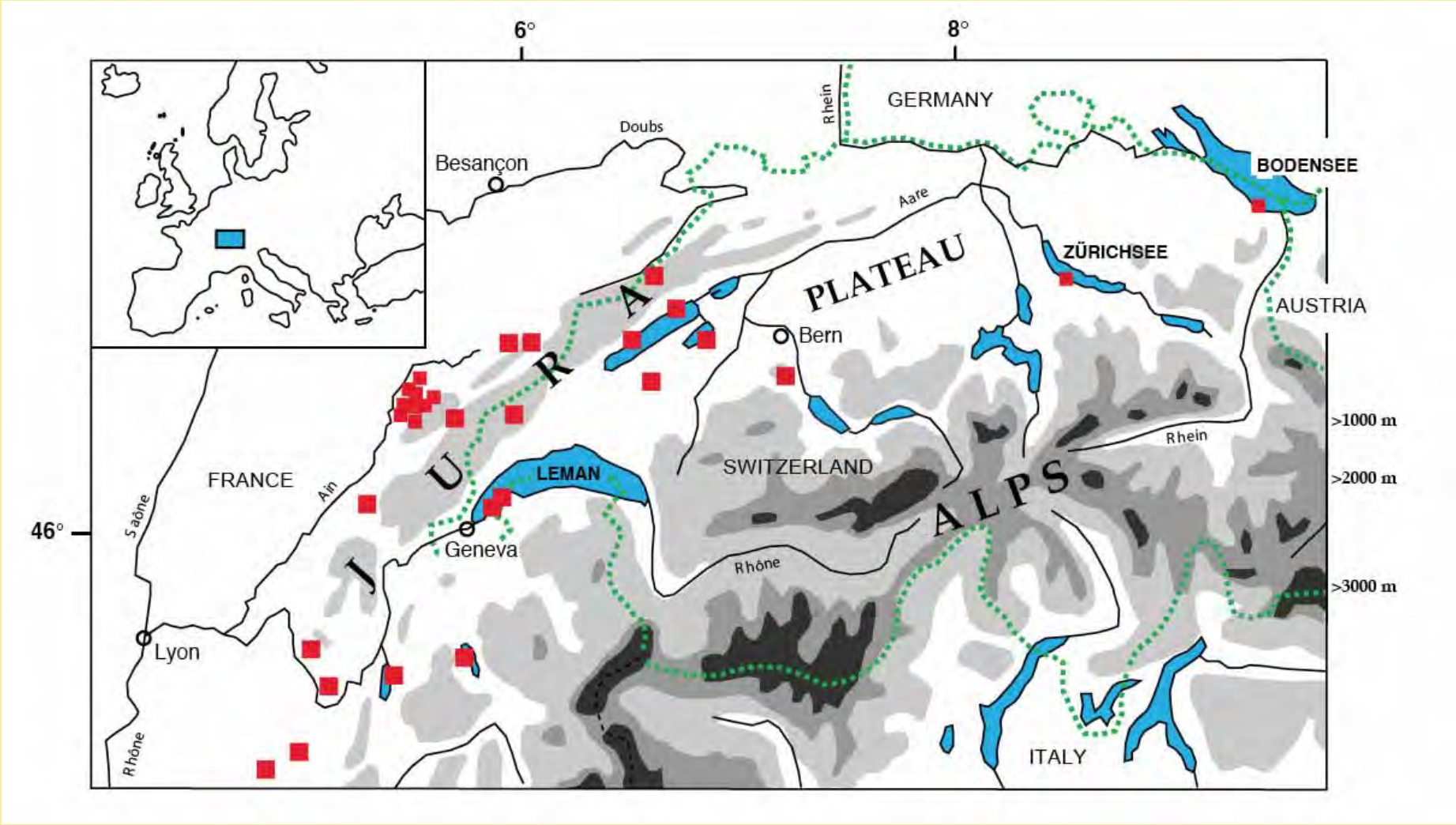
Stalagmite Growth in Oman





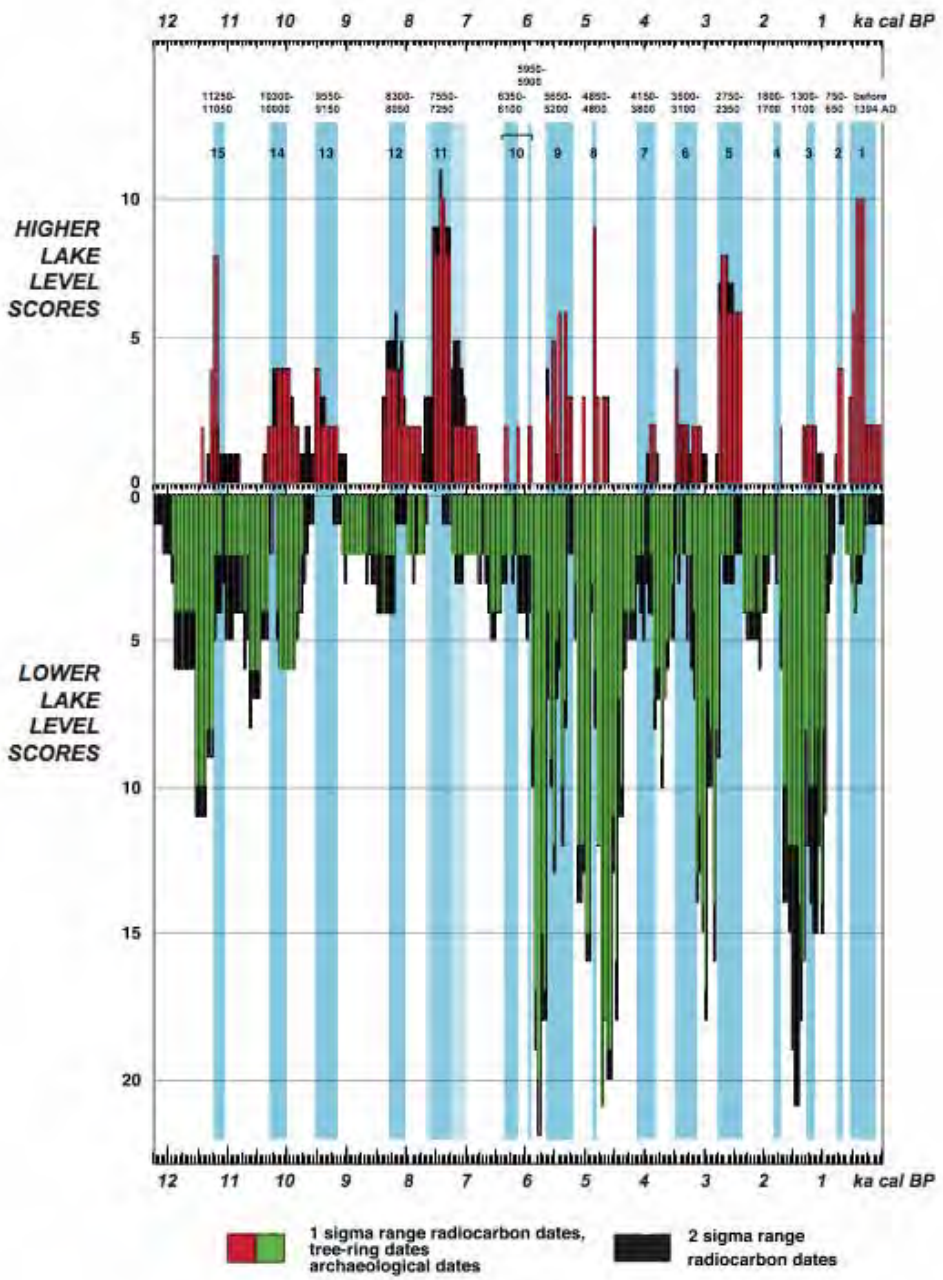
(Bond et al., Science, 2001)

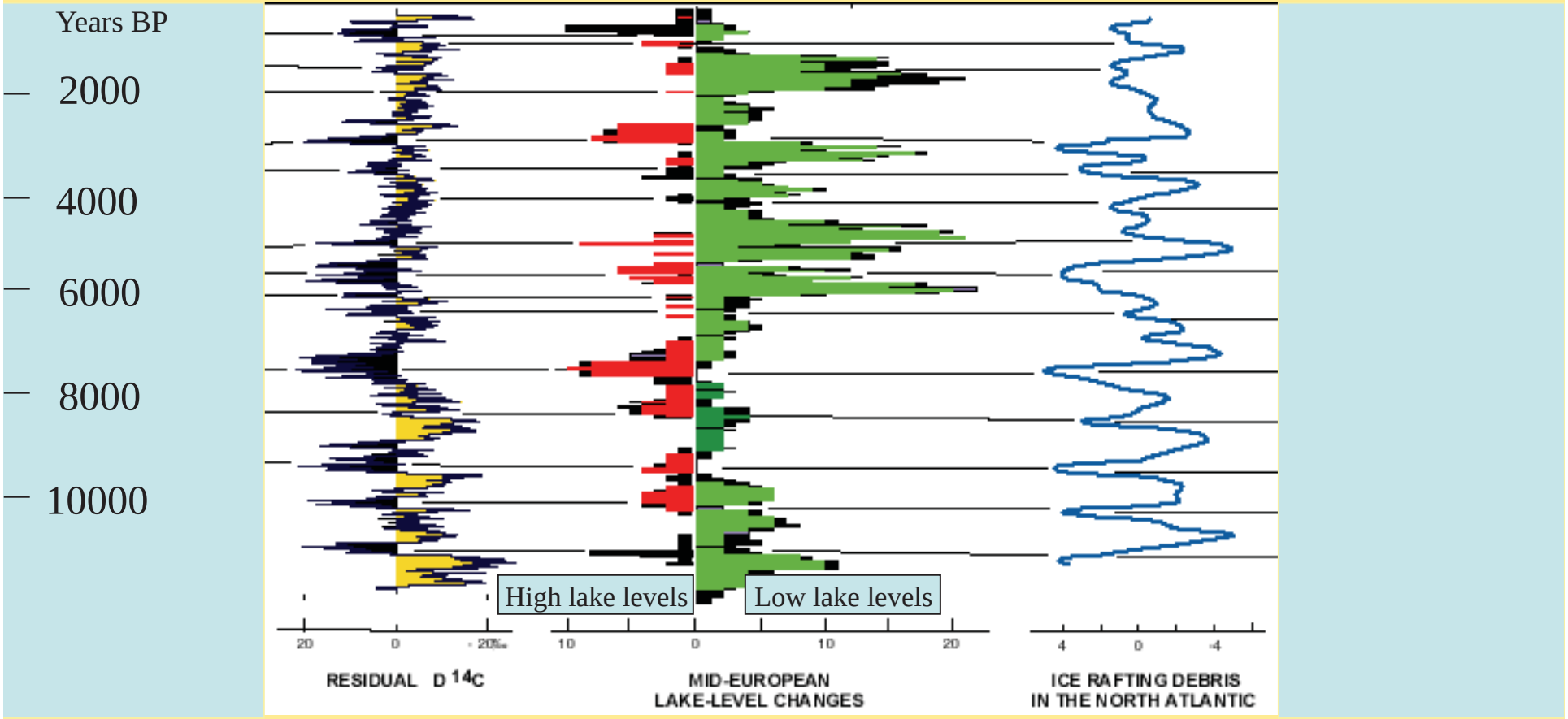


M. Magny, 2007, in Encyclopedia of Quaternary Science, Elsevier

Clusters of ^{14}C and dendrochronological dates for low (green) and high (red) water tables in French and Swiss lakes.

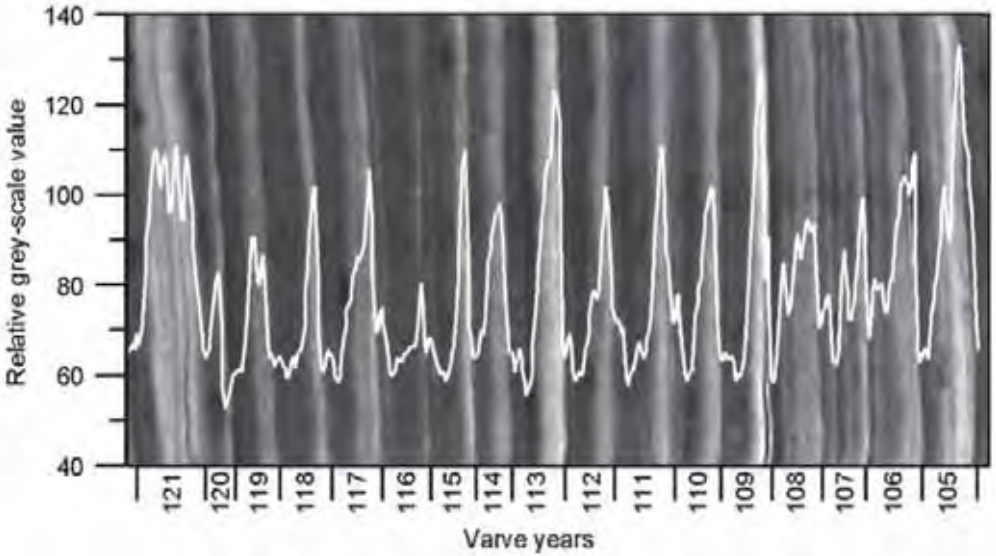
Magny, 2007





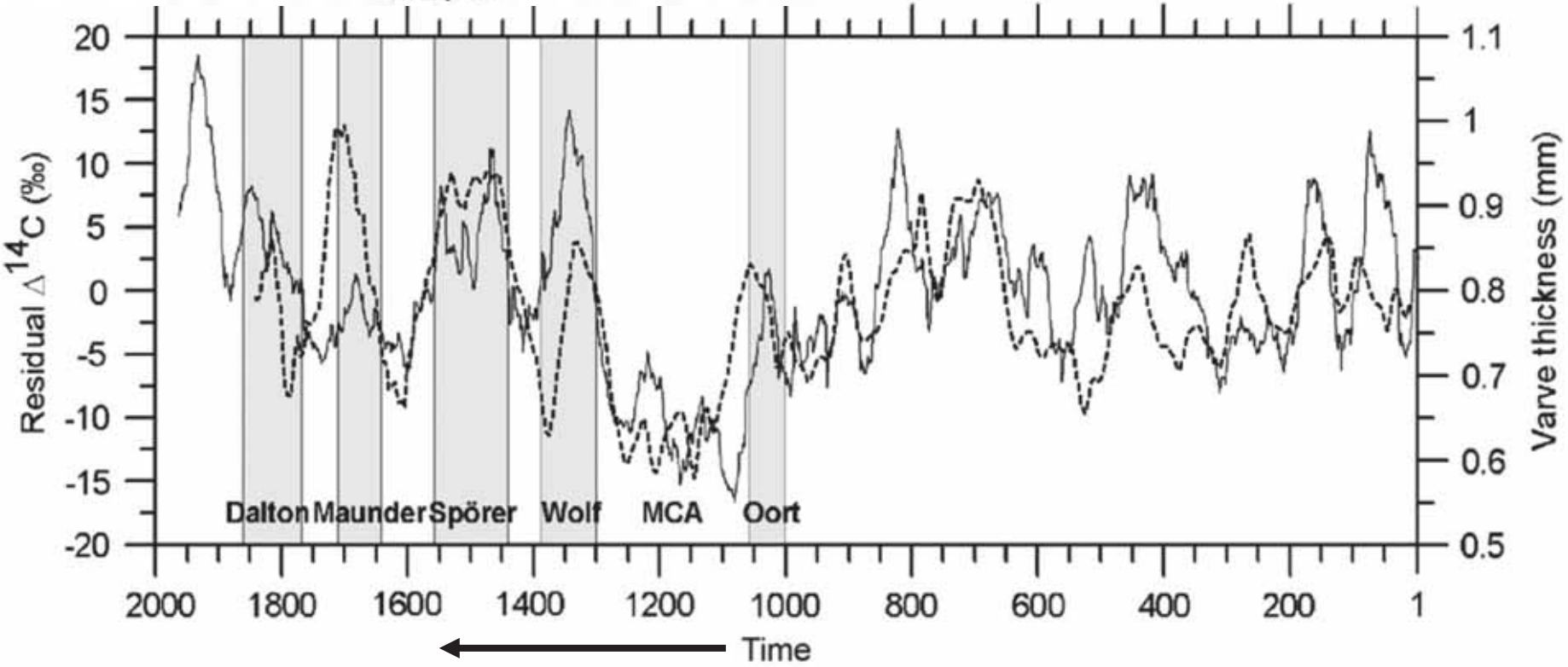
Evidence for solar forcing of climate change from
Mid-European lake sediments and the North Atlantic Ocean

M. Magny, Encyclopedia of Quaternary Science, 2007

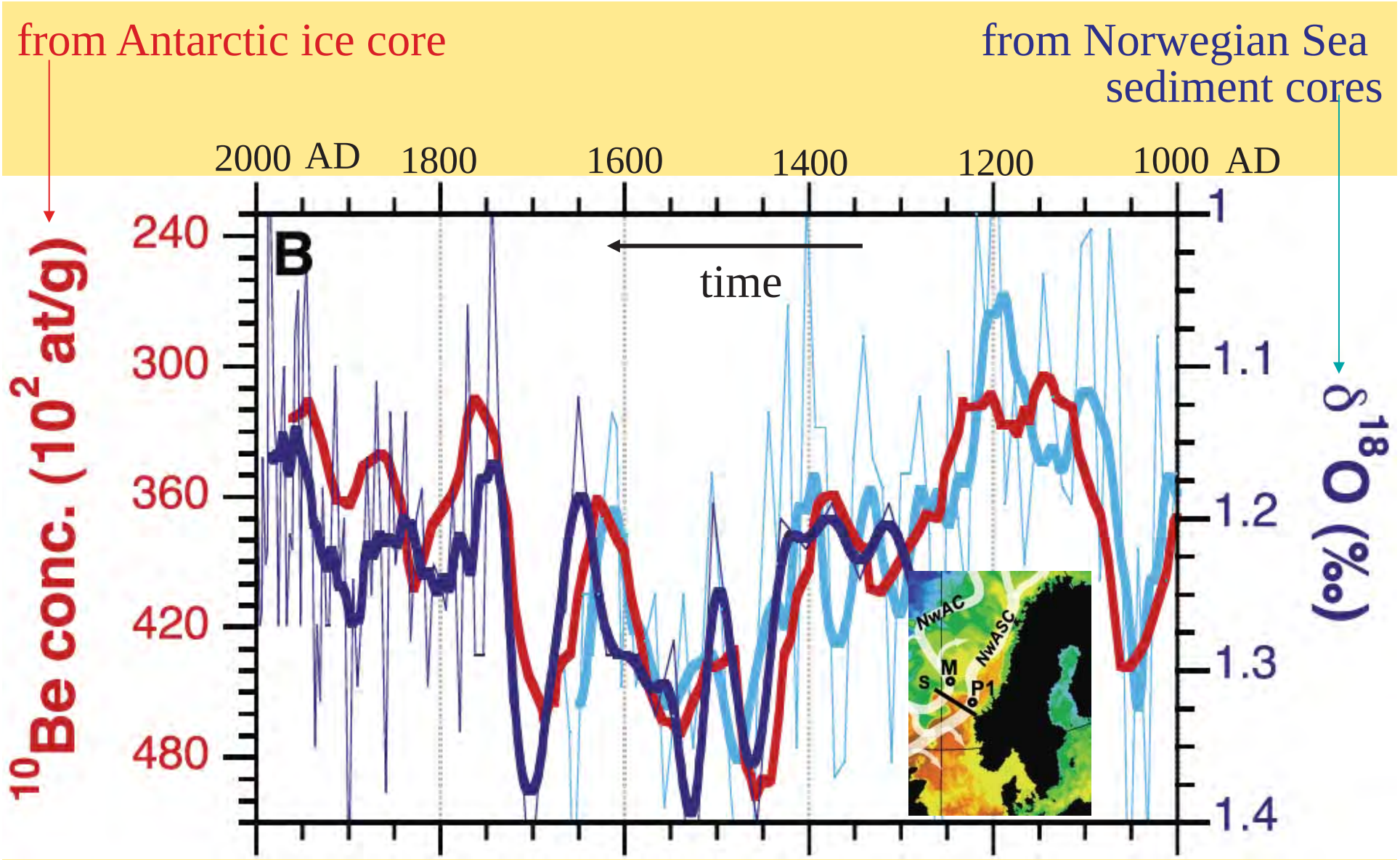


A section of an X-ray image with relative X-ray values plotted against chronology from Lake Lehmilampi

(Haltia-Hovi et al. in QSR 2007)



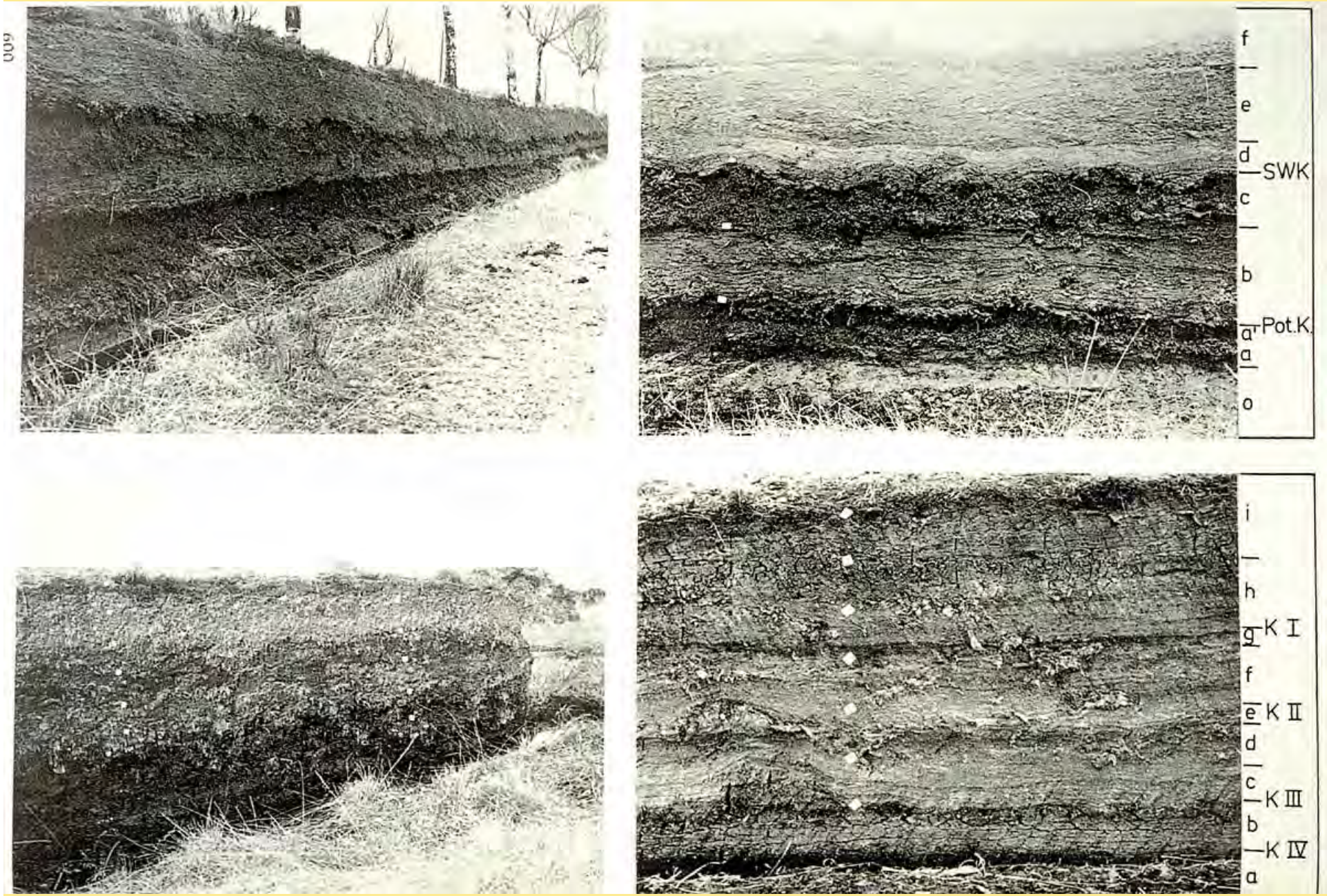
Residual delta ^{14}C (broken line) and varve thickness of Lake Lehmilampi (solid line)



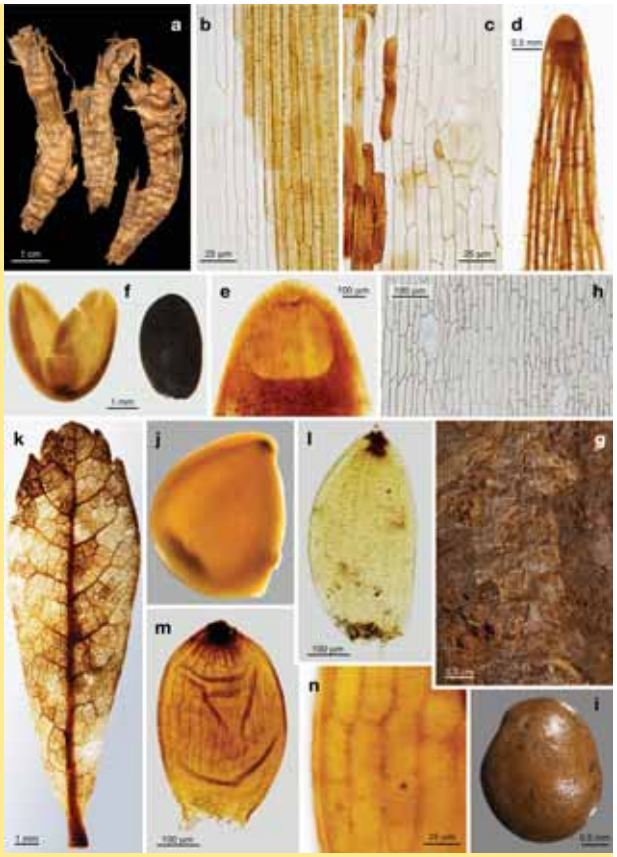
Sejrup et al., 2010. Response of Norwegian sea temperature to solar forcing. Journal of Geophysical Research, vol.115, C12034

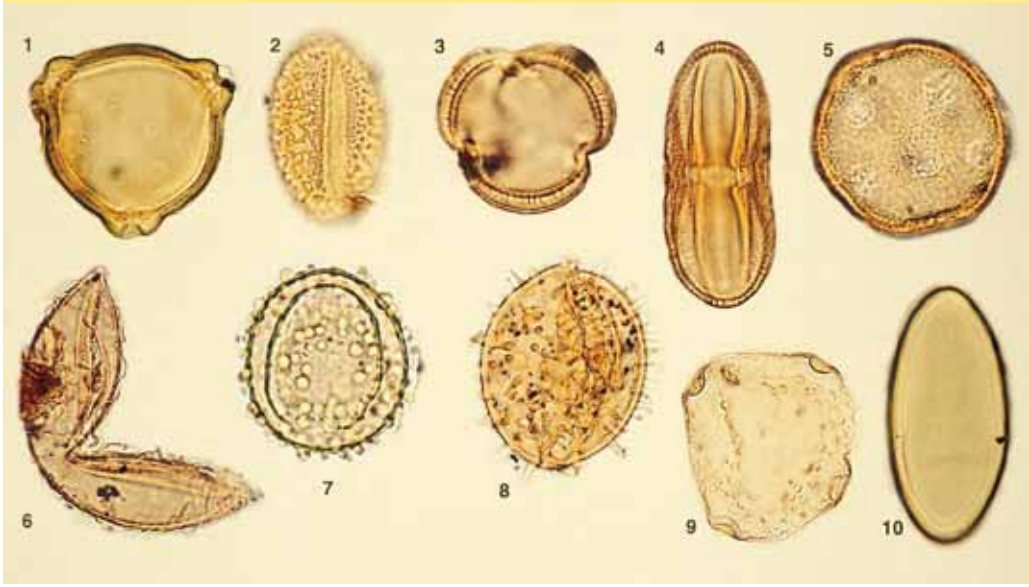
Peat (Hochmoor) studies

Taking samples in a raised bog (Hochmoor) deposit in eastern Netherlands



Peat profiles showing dry/wet shifts





We combine the analysis of microfossils and macroremains in natural archives of vegetation history and climate change


10 Ct
1984

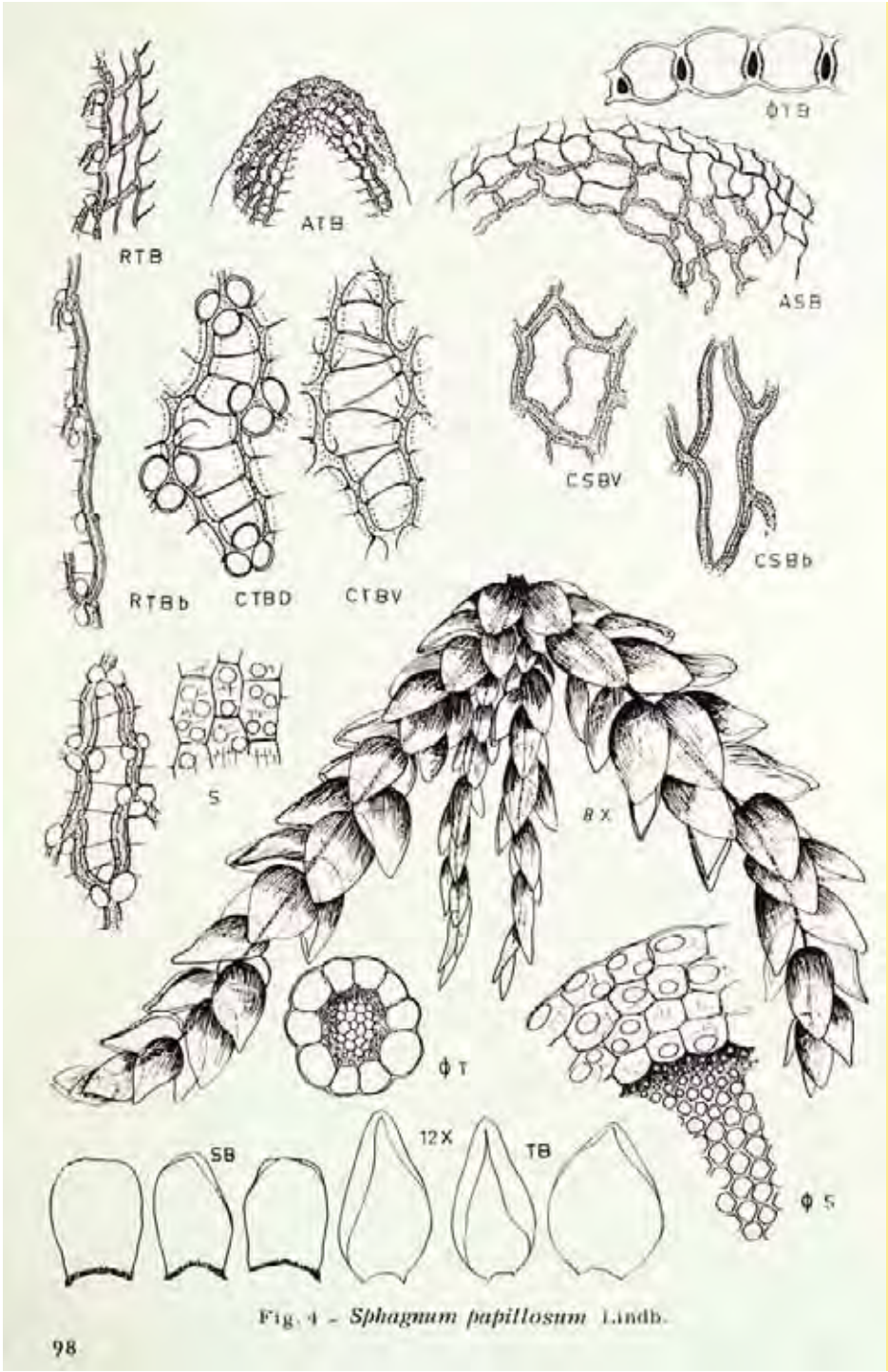
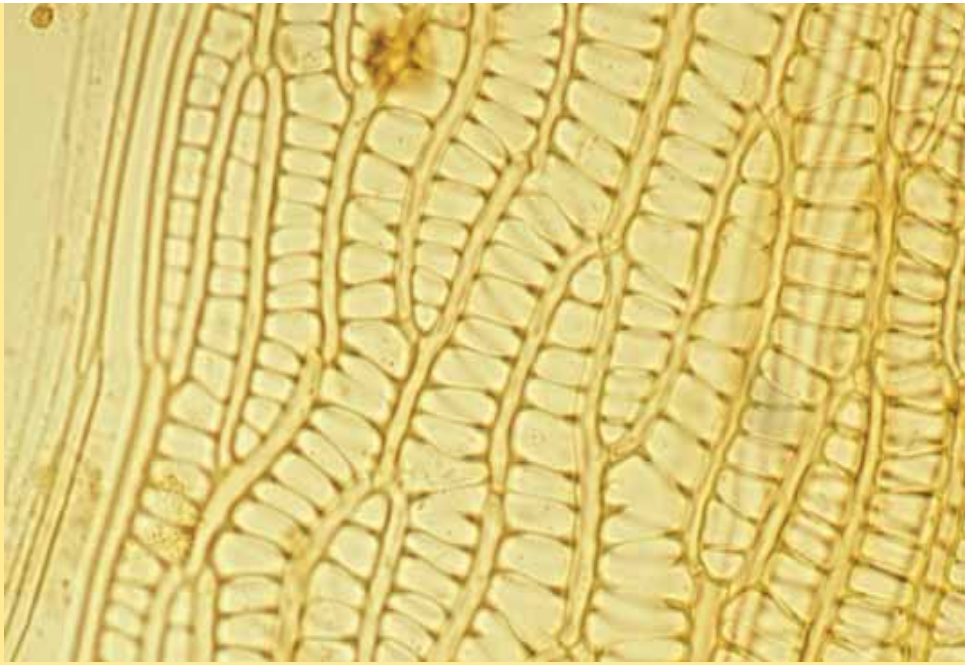
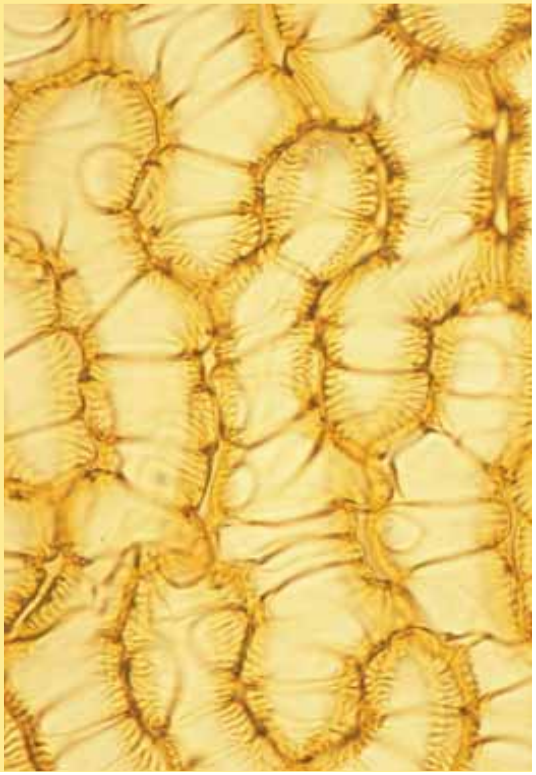


Fig. 4 – *Sphagnum papillosum* Lindb.

98

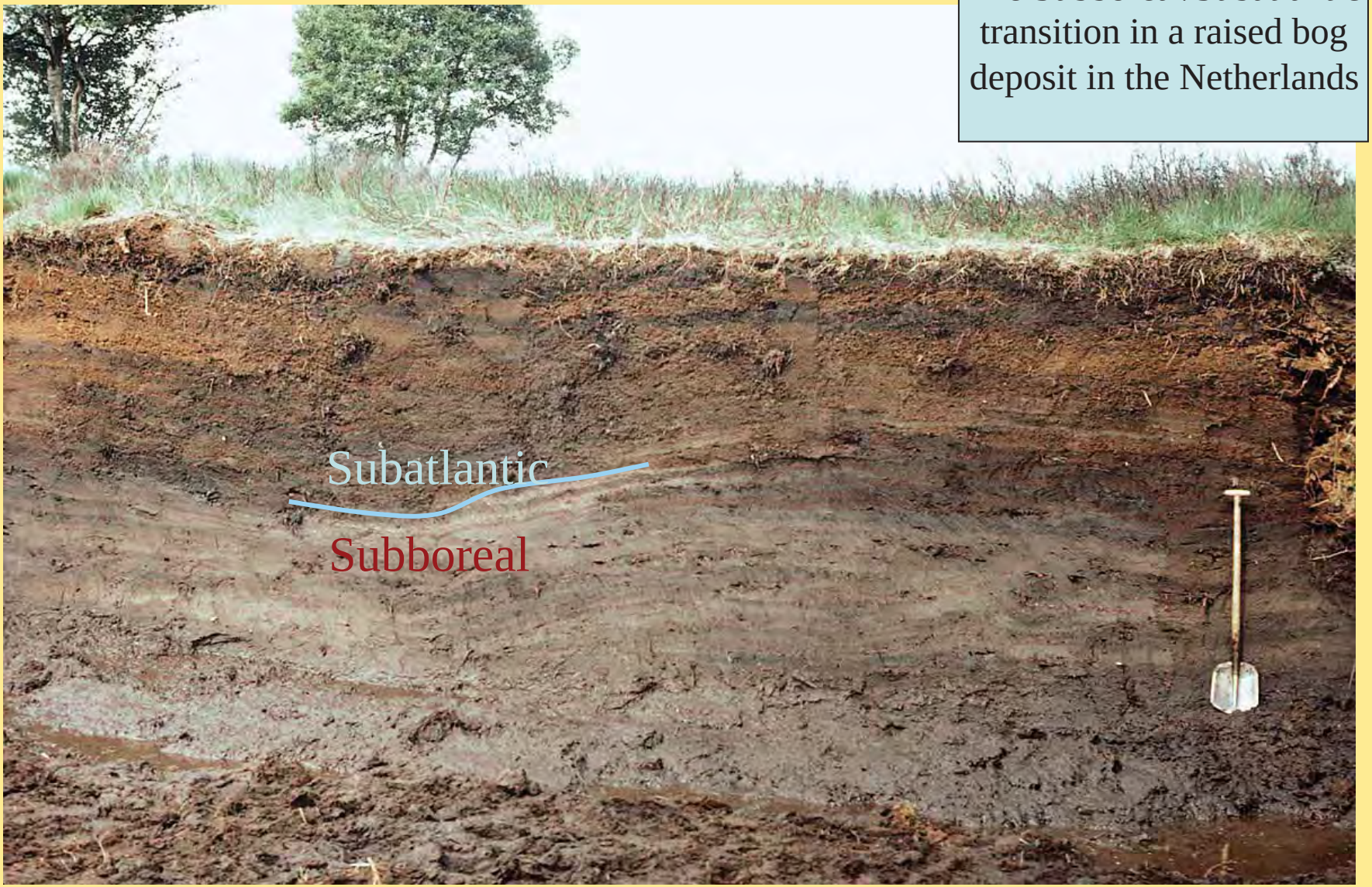




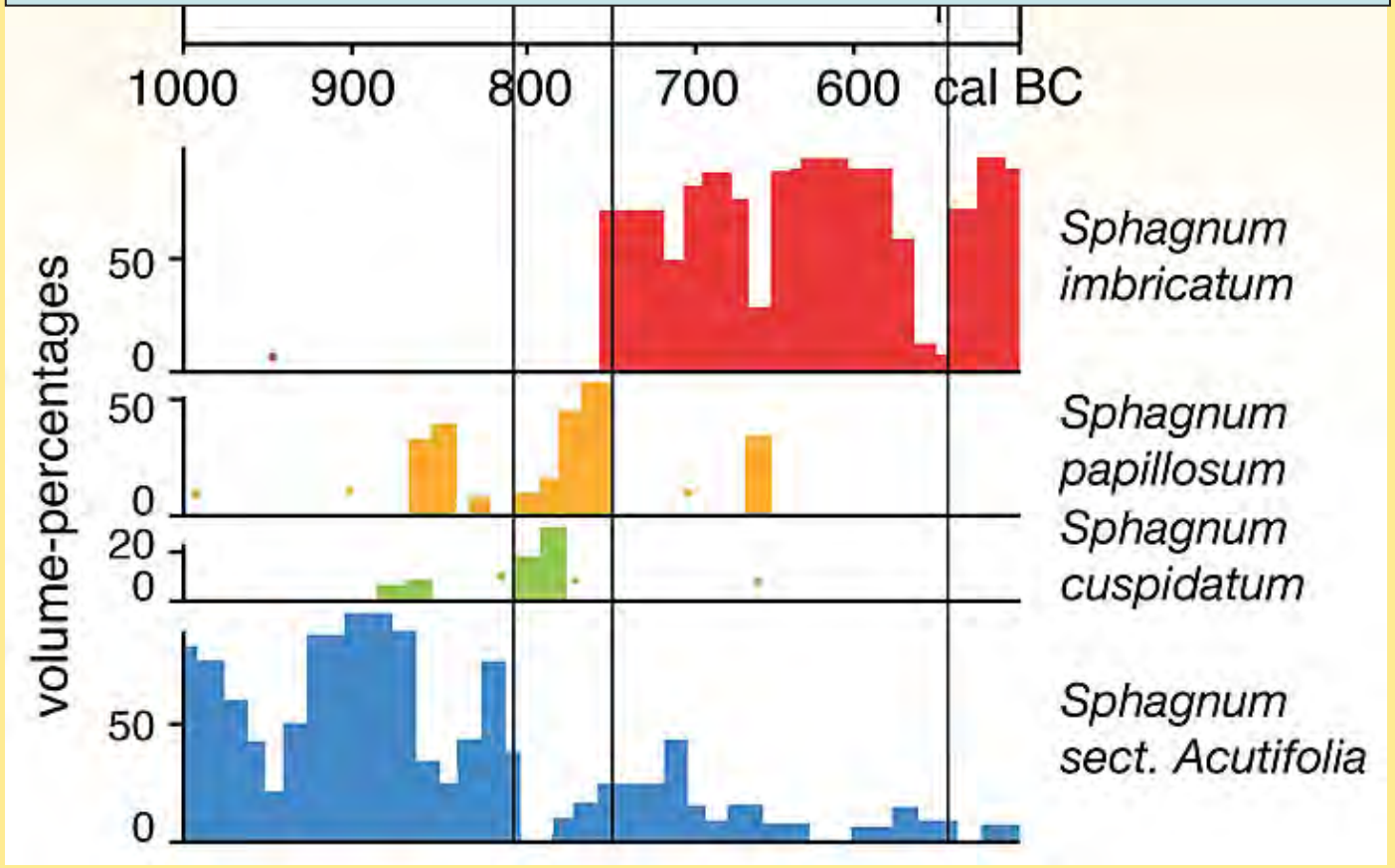
Different *Sphagnum* species can be identified:

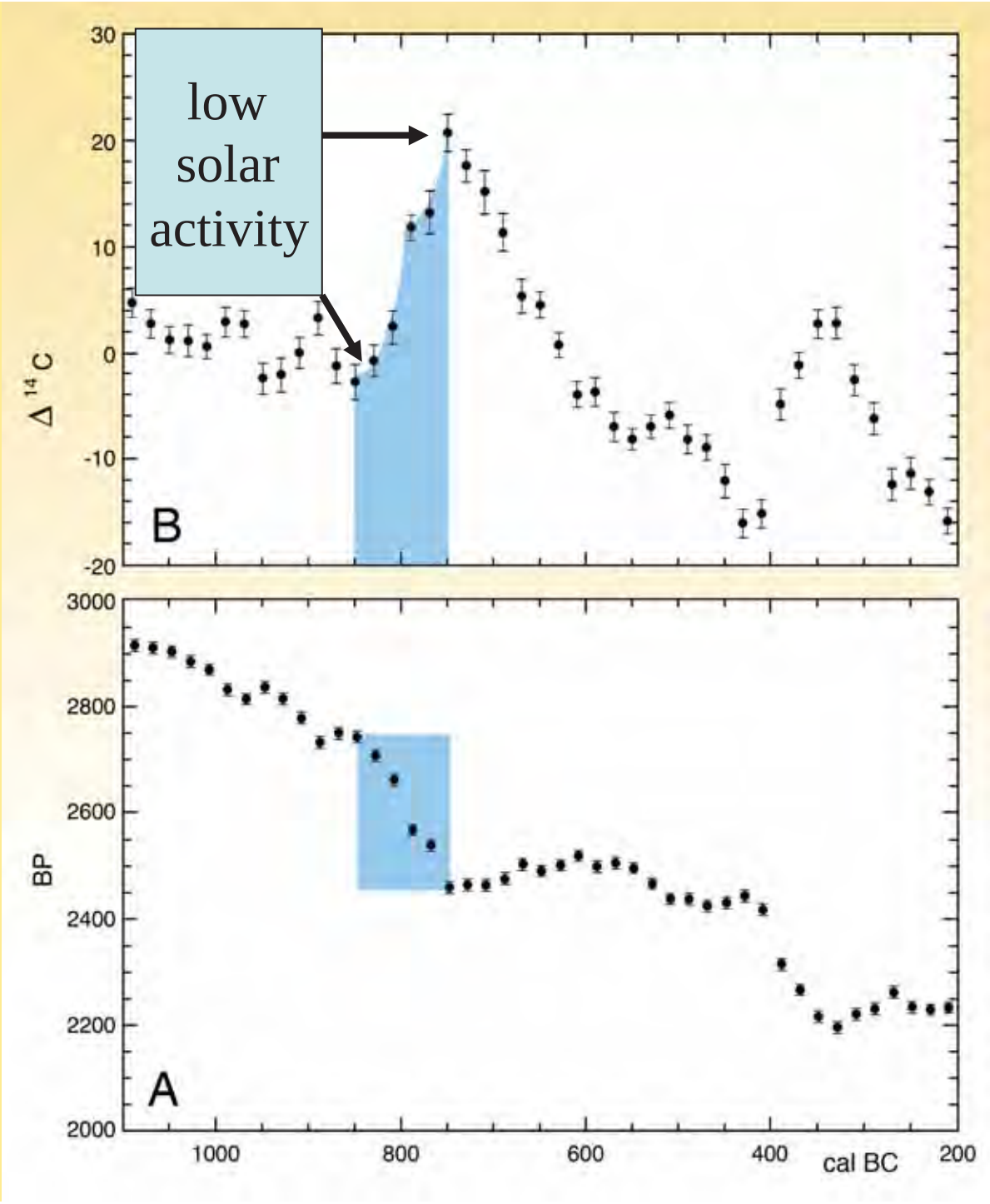
Information about changing hydrology!

The Subboreal/Subatlantic transition in a raised bog deposit in the Netherlands



Vegetation succession in raised bog
in eastern Netherlands:
The Subboreal-Subatlantic transition



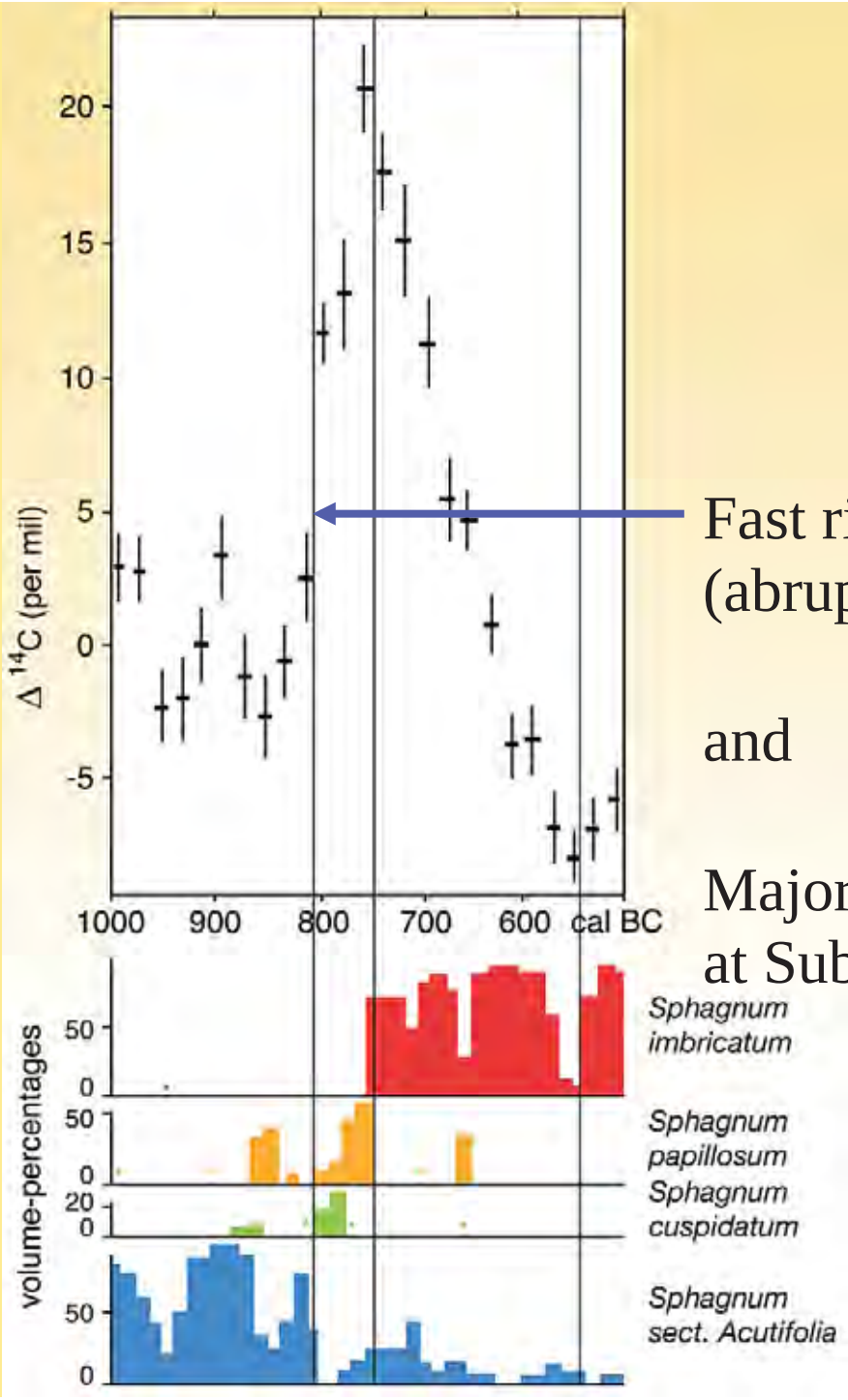


Delta ^{14}C

correction for radioactive decay

^{14}C calibration curve
1100 - 200 cal BC

ca 850 BC



Fast rise of delta ^{14}C
(abrupt decline solar activity)

and

Major change *Sphagnum* species
at Subboreal-Subatlantic transition

The 850 BC climate shift: any effects for people in marginal areas?

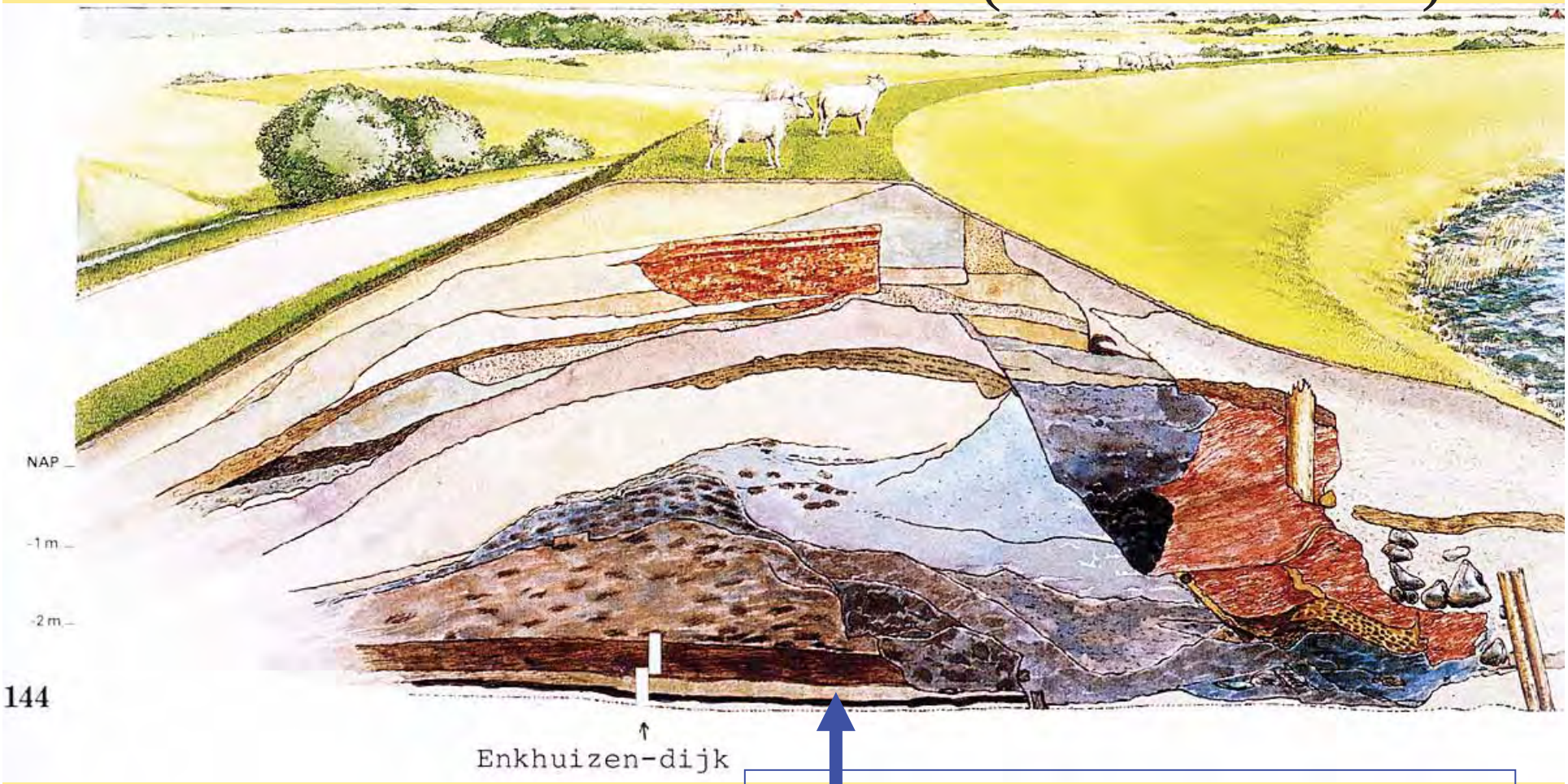
This is about a rapid neo-glacial transition

Many Bronze Age settlements in W-Friesland, but **not** during the Iron Age.

Aerial photograph after ploughing showing Bronze Age ditches


West-Friesland
DEN HELDER
Balgzand
Wieringermeer
IJssel
Oude Zeug
Medemblik
Enkhuizen
Hoorn
ALKMAAR
Schermer
Beemster
Purmer
Volendam
Marken
Zaandijk
ZAANDAM
Koog a.d. Zaan
Purmerend
Wormer
Wormerveer
Castricum
Egmond aan Zee
Egmond-Binnen
Bergen
Heiloo
Heerhugowaard
Warmenhuizen
Oudkarspel
Schoorl
Petten
Julianadorp
Breezand
Den Oever
Wieringerwerf
Andijk
Wervershoof
Venhuizen
Zwaag
Oosterblokker
Berkhout
Spierdijk
Obdam
Wognum
Oosthuizen
Midden-Beemster
Z.O.-Beemster
Heemskerk
Beverwijk
Wijk aan Zee
Krommenie
Assendelft
Velsen
IJmuiden (Velsen)
Santpoort
Bloemendaal
Overveen
HAARLEM
Zwanenburg
Halfweg
AMSTERDAM
Diemen
Amsterdam-Noord
Pampus
Almere
Weesp
Muiden
Naarden
Huizen
AMSTELVEEN
Bijlmermeer (A'dam)
Badhoevedorp
Heemstede
Aerdenhout
Vijfhuizen
Hillegom
Haarlemmermeer
Landsmeer
Monnickendam
Ilpendam
Broek in Waterland
Zuidelijk Flevoland

Cross section through a dike in W-Friesland (near Enkhuizen)



Suddenly rising water table ca 850 cal BC

Bronze Age villages in West-Friesland

Early period	Late period (short!)
Houses directly on soils	Houses on artificial mounts
Deep wells	Shallow wells
Food for cattle: Hey and straw	Hay, straw and cereals
Good harvest	Bad harvest
Moist meadows	Inundated meadows
Landsnails	Freshwater snails
Fishing not important	Fishing important
Rodents far from houses	Rodents near houses

Archeological indications for fast rise of groundwater ca 850 BC.

^{14}C dates of a last, wet phase of archaeological sites in West-Friesland

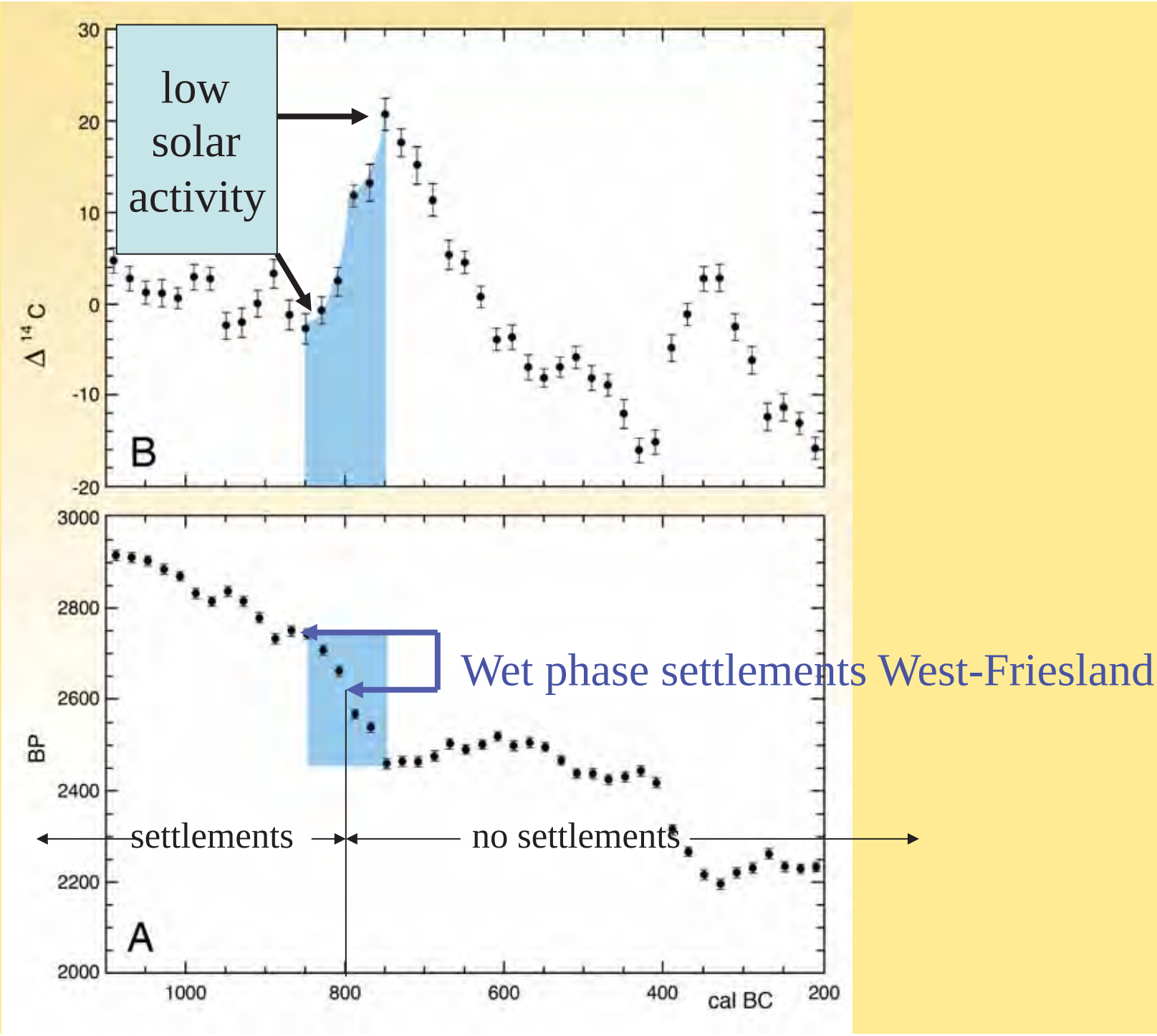
2620 ± 20 BP
2650 ± 30 BP
2685 ± 30 BP
2690 ± 25 BP
2710 ± 35 BP
2740 ± 40 BP
2745 ± 30 BP
2745 ± 30 BP
2760 ± 35 BP

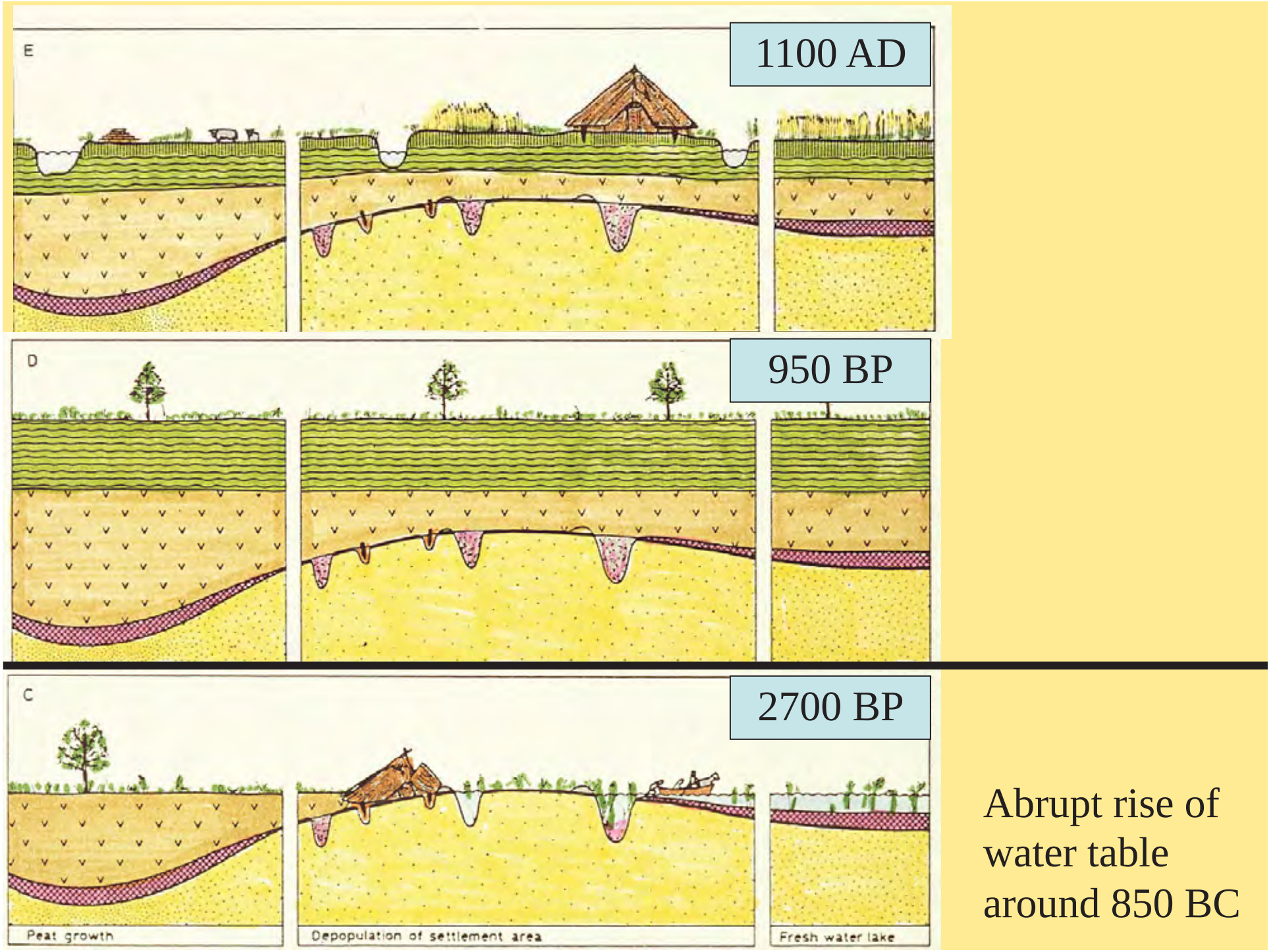
ca. 140 radiocarbon ‘years’, but only ca. 60 calendar yrs

This is a period of:

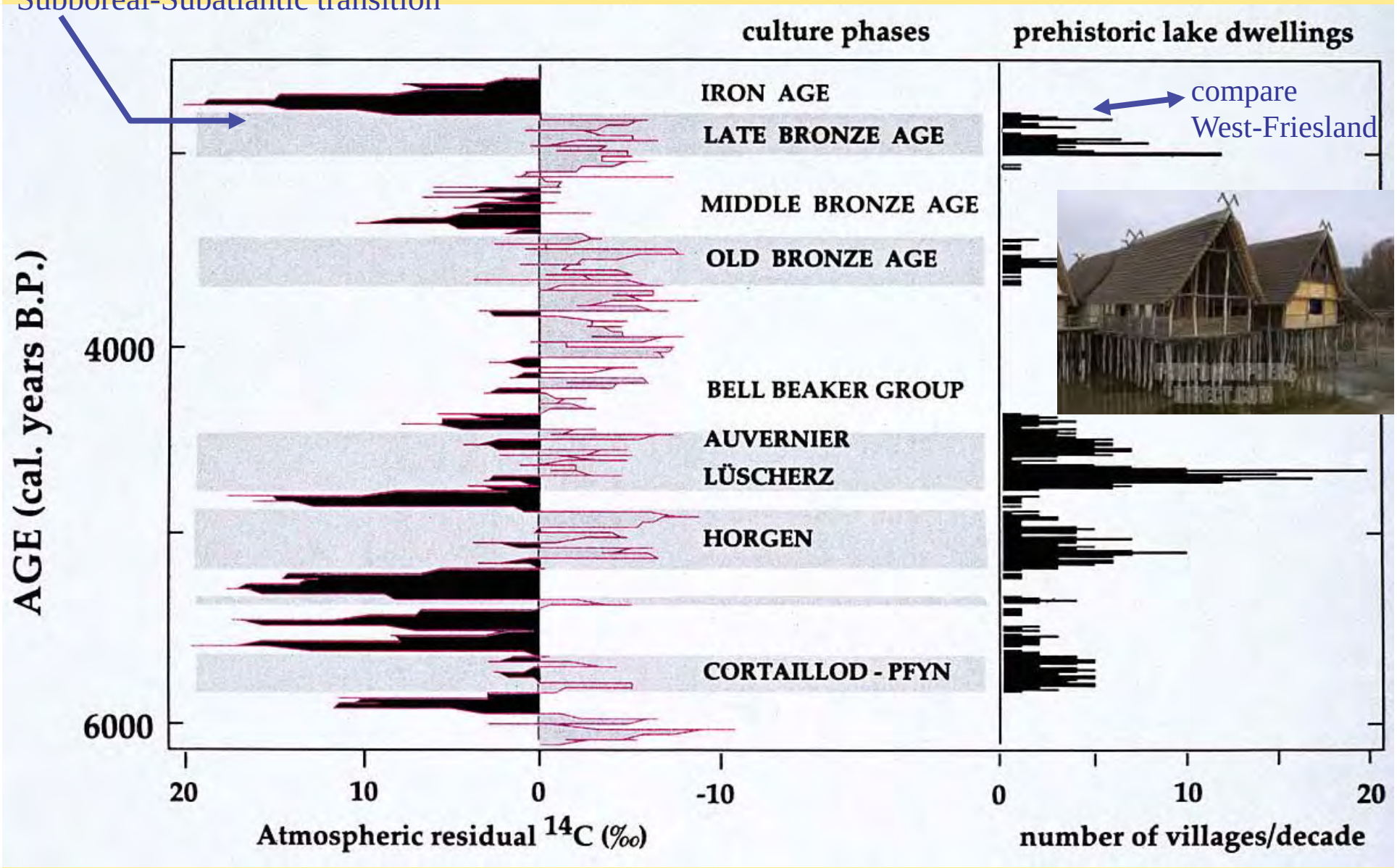
- A fast rise of ^{14}C in the atmosphere:
- Rising ground water tables
- Changing species composition in raised bogs
- Climate change (cooler, wetter)


B
3100 BP
Fresh water lake
Bronze age settlement area on sandy ridge


low
solar
activity
B
Δ 14 C
30
20
10
0
-10
-20
A
BP
3000
2800
2600
2400
2200
2000
1000
800
600
400
200
cal BC
Wet phase settlements West-Friesland
settlements
no settlements



Abrupt rise of water table around 850 BC



Magny; lake data from SE France and Switzerland

Fochtelooër Veen

Raised bog deposit
near Assen
(northern Netherlands)

ca. 850 cal BC:
starting peat growth
on top of mineral soil
with charcoal

“Ruinen-Wommels pottery” around Subboreal-Subatlantic transition
--> information about migrations

Migration: from inundated arable to newly exposed salt marshes

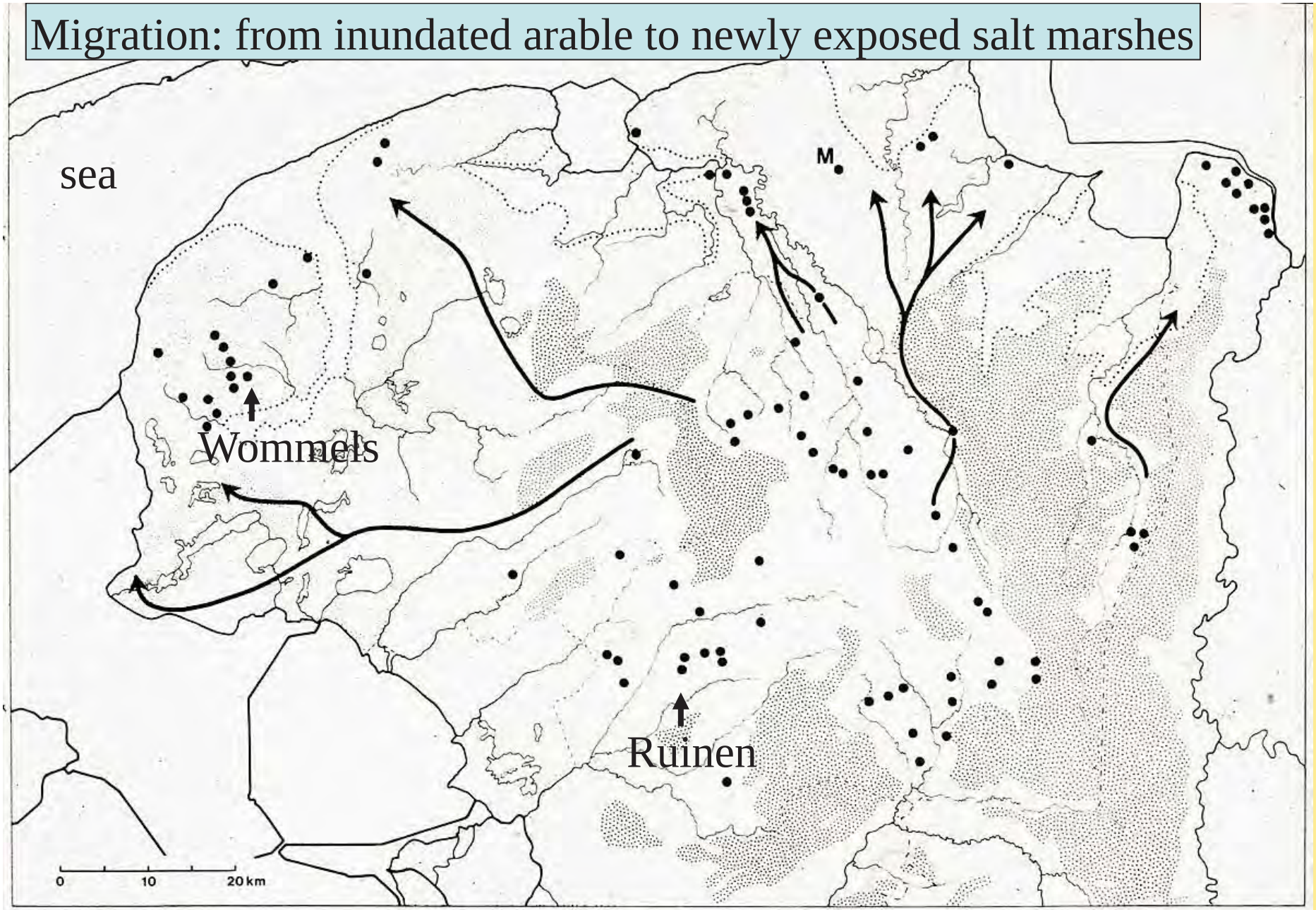
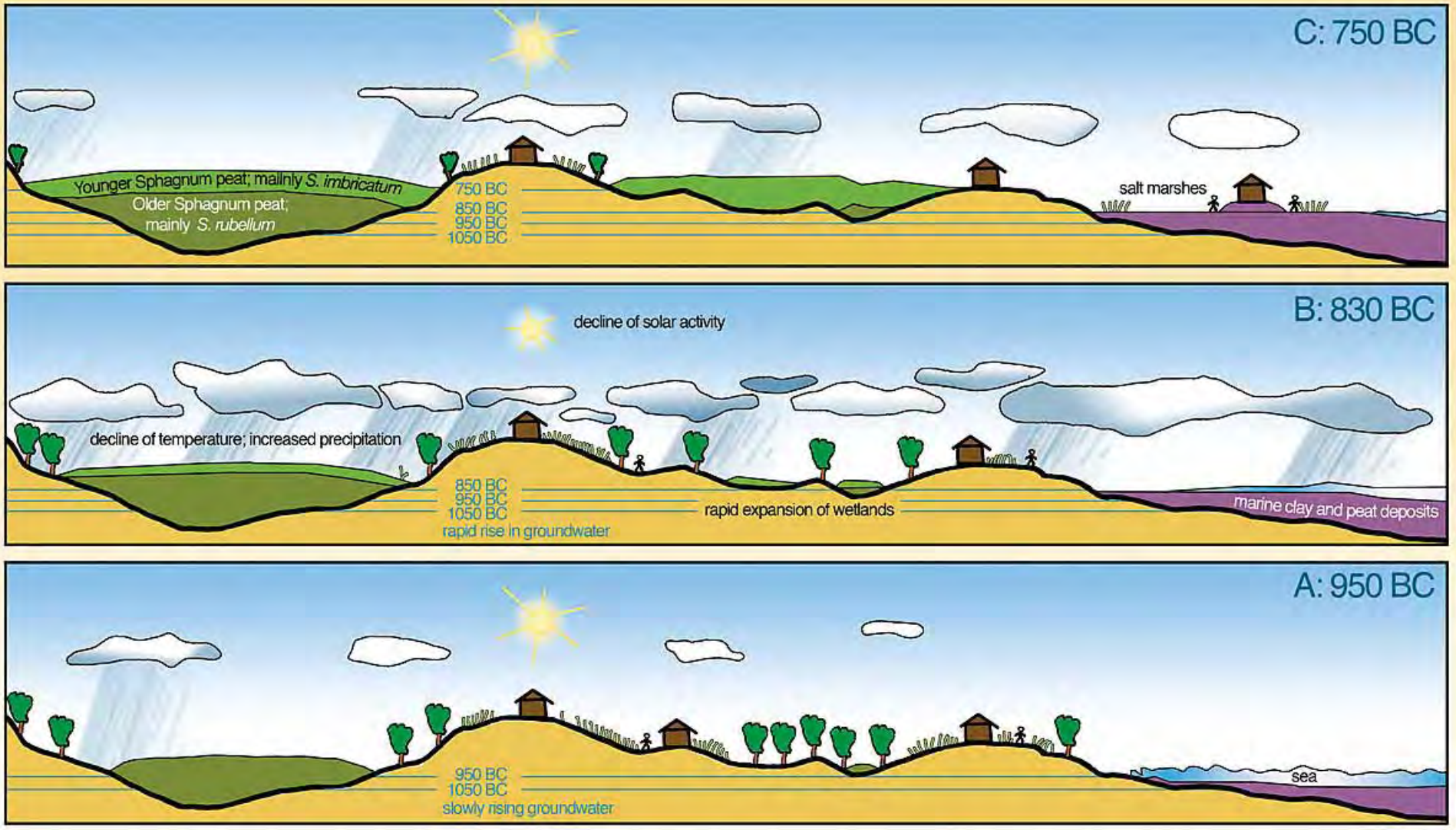


Fig. 10. Distribution of Middle Iron Age pottery (types RWI and RWII) in the northern Netherlands. Arrows suggest possible routes for transhumance and colonization.

Newly exposed salt marshes around 850 BC
Thermal contraction of ocean water?

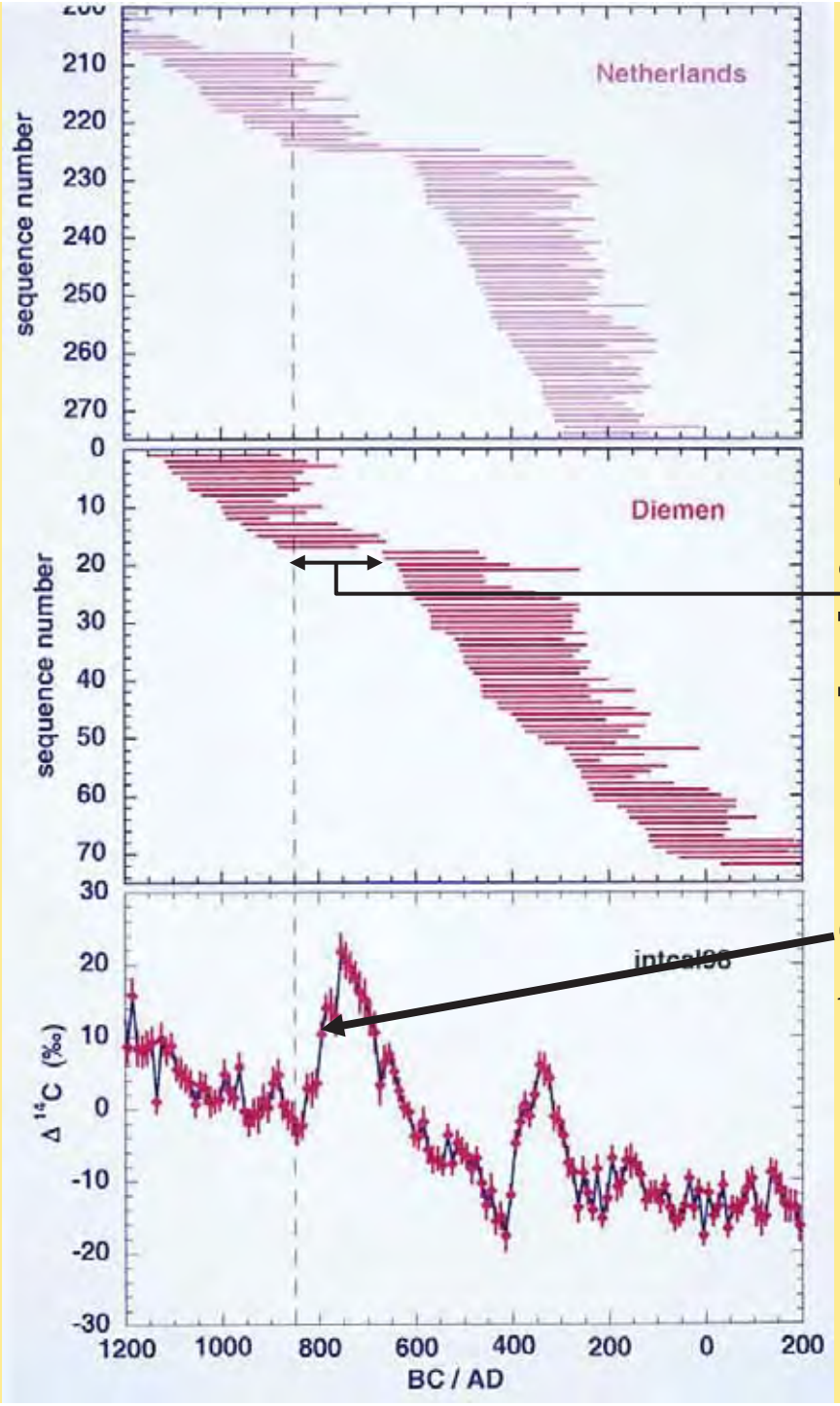



DEN HELDER
Noorderhaaks
Zuiderhaaks
Huisduinen
Balgzand
Breehorn
Den Oever
Wieringen
Hippolytushoef
Oude Zeug
Staverenhoek
Rode Klif
Breezand
Anna Paulowna
Anna Paulowna-polder
Kleine Sluis (Anna Paulowna)
Wieringerwerf
Oude Zeug
Kreileroord
Zeughoek
Slootdorp
Wieringerwaard
Wieringermeer
Middenmeer
Ussel
Medemblik
Opperdoes
Andijk
Onderdijk
Wervershoof
Bovenkarspel
Enkhuizen
Lutjebroek
Hoogkarspel
Grootebroek
Venhuizen
Nibbixwoud
Wognum
Zwaag
Oosterblokker
Hem
Hoorn
Spierdijk
Berkhout
Wijdenes
Scharwoude
Noordse Hop
Zijpe
Schagen
Callantsoog
Petten
Dirkshorn
Nieuwe Niedorp
Hoogwoud
Oudkarspel
Warmenhuizen
N.-Scharwoude
Z.-Scharwoude
Spanbroek
Schoorl
Bergen
Bergen aan Zee
Koedijk
St. Pancras
Heerhugowaard
Obdam
Broek op Langedijk
Oudorp
Egmond aan Zee
Egmond a.d. Hoef
Egmond-Binnen
ALKMAAR
Heiloo
Schermer
Schermerhorn
Ursem
Limmen
Akersloot
Castricum
Castricum a. Zee
Uitgeest
Heemskerk
Beverwijk
Wijk aan Zee
Krommenie
Wormer
Wormerveer
Zaandijk
Assendelft
Velsen
IJmuiden (Velsen)
Santpoort
Kennemer Duinen
Bloemendaal
Spaarndam
Overveen
HAARLEM
Zwanenburg
Halfweg
Heemstede
Aerdenhout
Vijfhuizen
Badhoevedorp
Vogelenzang
Bennebroek
Hoofddorp
De Zilk
Hillegom
Haarlemmermeer
Beemster
De Rijp
Midden-Beemster
Z.O.-Beemster
Purmerend
Purmer
Volendam
Edam
Katwoude
Ilpendam
Monnickendam
Marken
Kerkbuurt
Koog a.d. Zaan
Den Ilp
ZAANDAM
Oostzaan
Landsmeer
Watergang
Zunderdorp
A'DAM-NOORD
Oude IJ
AMSTERDAM
Diemen
Pampus
Durgerdam
Muiden
Muiderberg
Almere
Weesp
Bijlmermeer (A'dam)
AMSTELVEEN
Ouderkerk
Bovenkerk
Nieuwerbrug
Naarden
Huizen
TAFELBERG
Zuidelijk Flevoland

Site Diemen
near Amsterdam

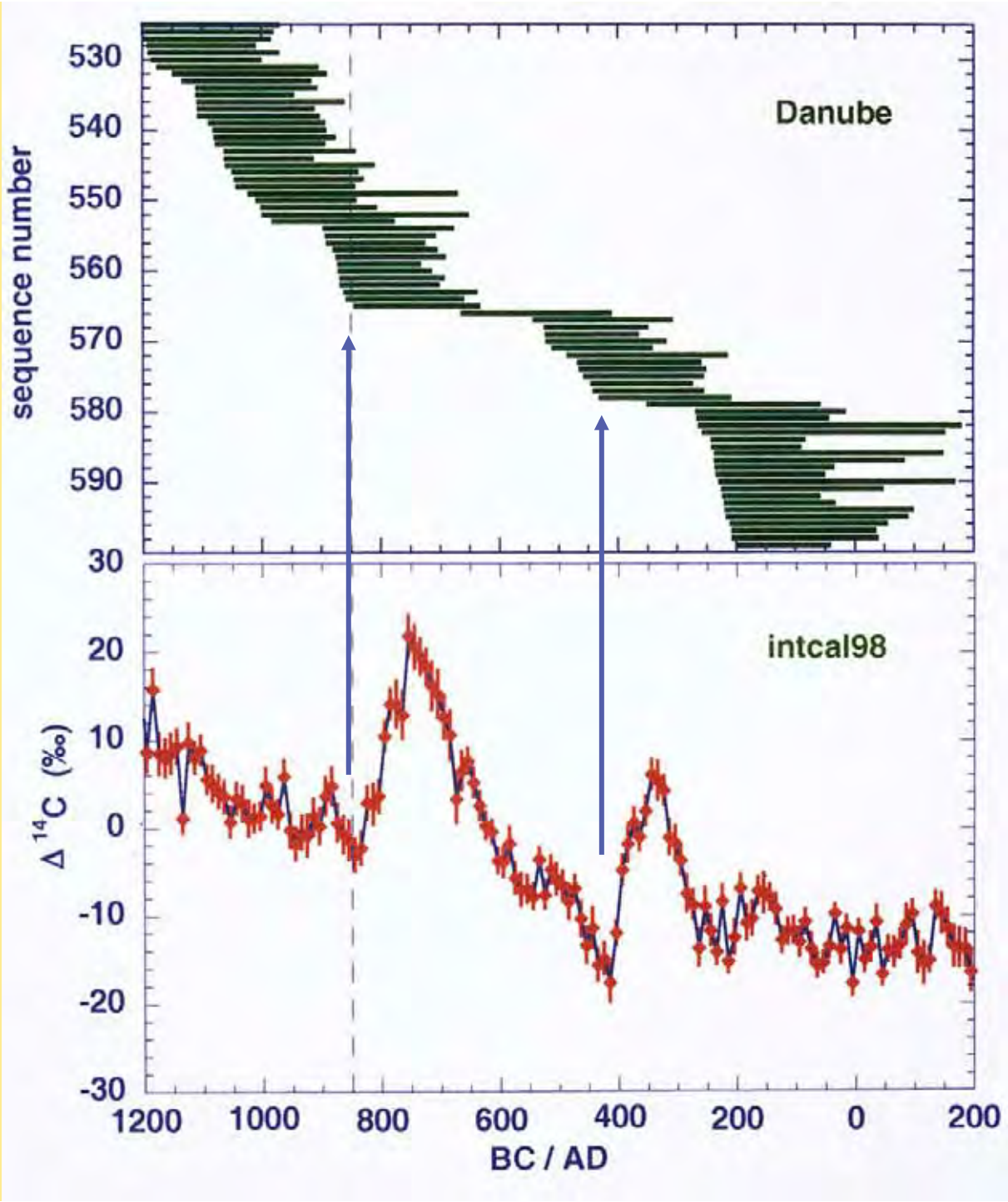
Many oak trunks were found when new ditches were made.

All the trees were dated with dendro-chronology



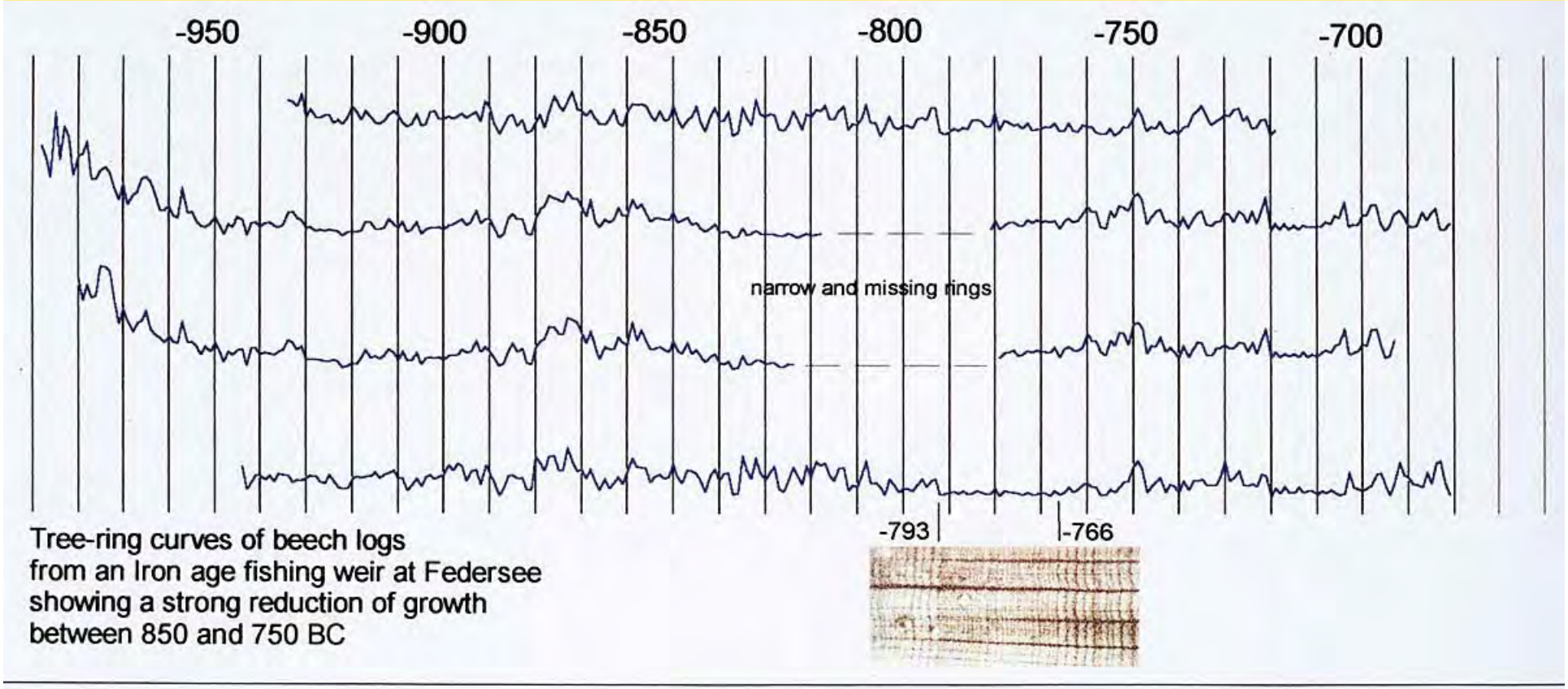
Oaks had a recruitment problem after 850 BC.
Too short growing season?
Too wet? Too cold?

Caused by climate change during temporary decline of solar activity.

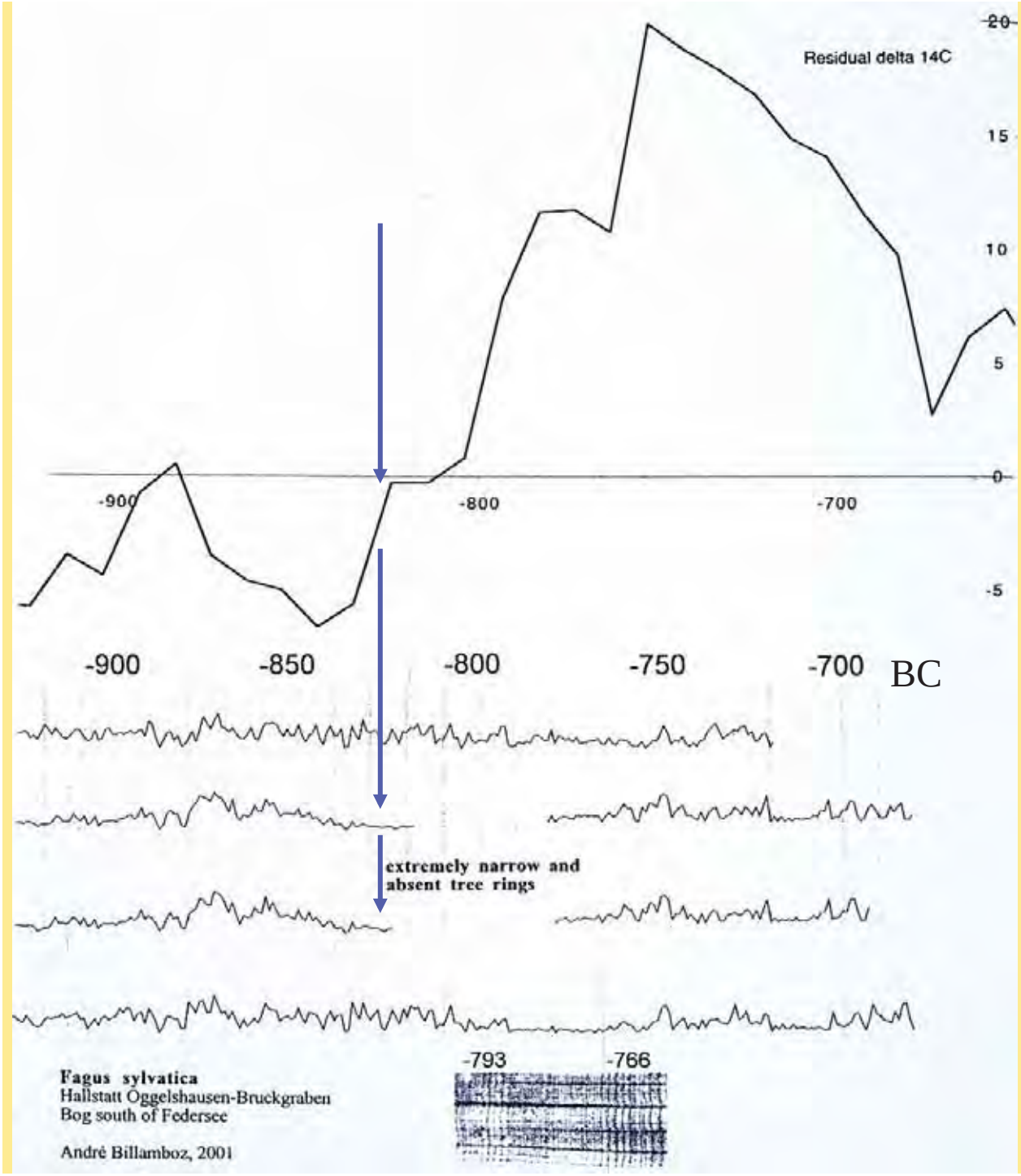


van Geel et al.,
in prep.

The start of the Subatlantic period was a hazard for Bronze Age farming communities in the northern Netherlands, but also for oak trees in Europe!



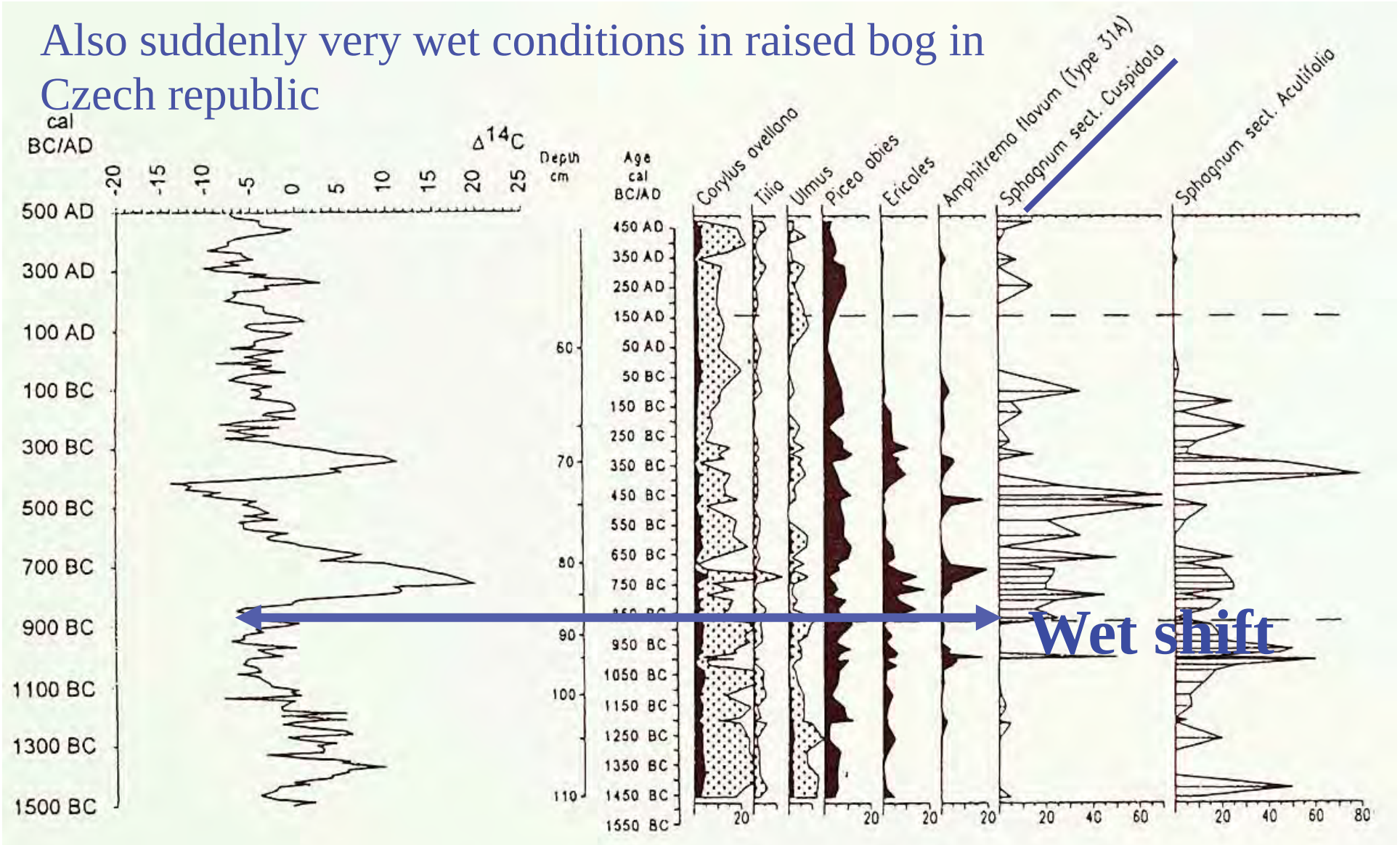
André Billamboz, 2001. Federsee (southern Germany)



delta ^{14}C

Tree rings in beech wood
Billamboz, 2001

Also suddenly very wet conditions in raised bog in Czech republic



Delta ^{14}C and vegetation succession in a Czech raised bog

Speranza et al., 2002 in Global and Planetary Change 35: 51-65

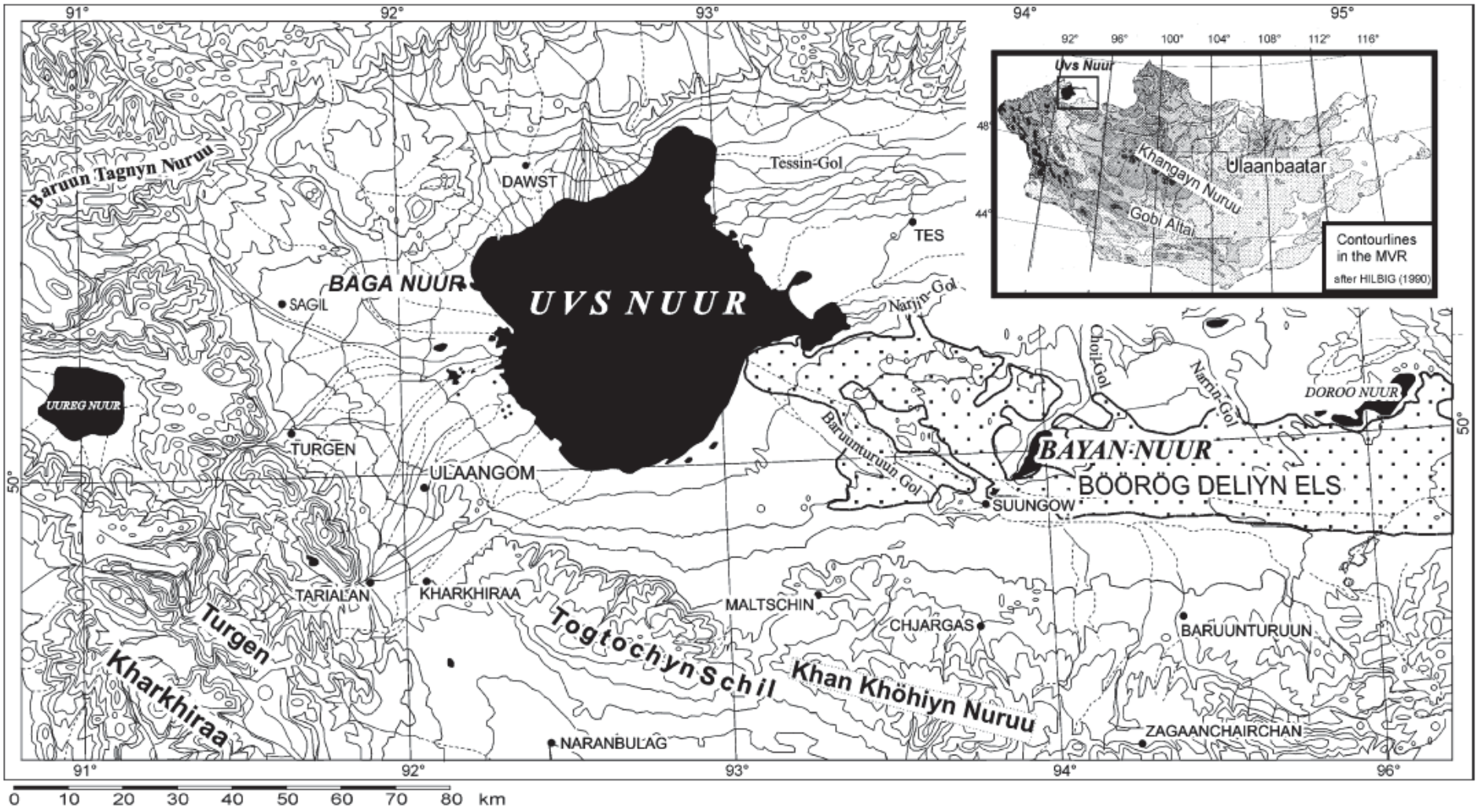


Fig. 1. Map of the study area.

Lake deposits in NW Mongolia

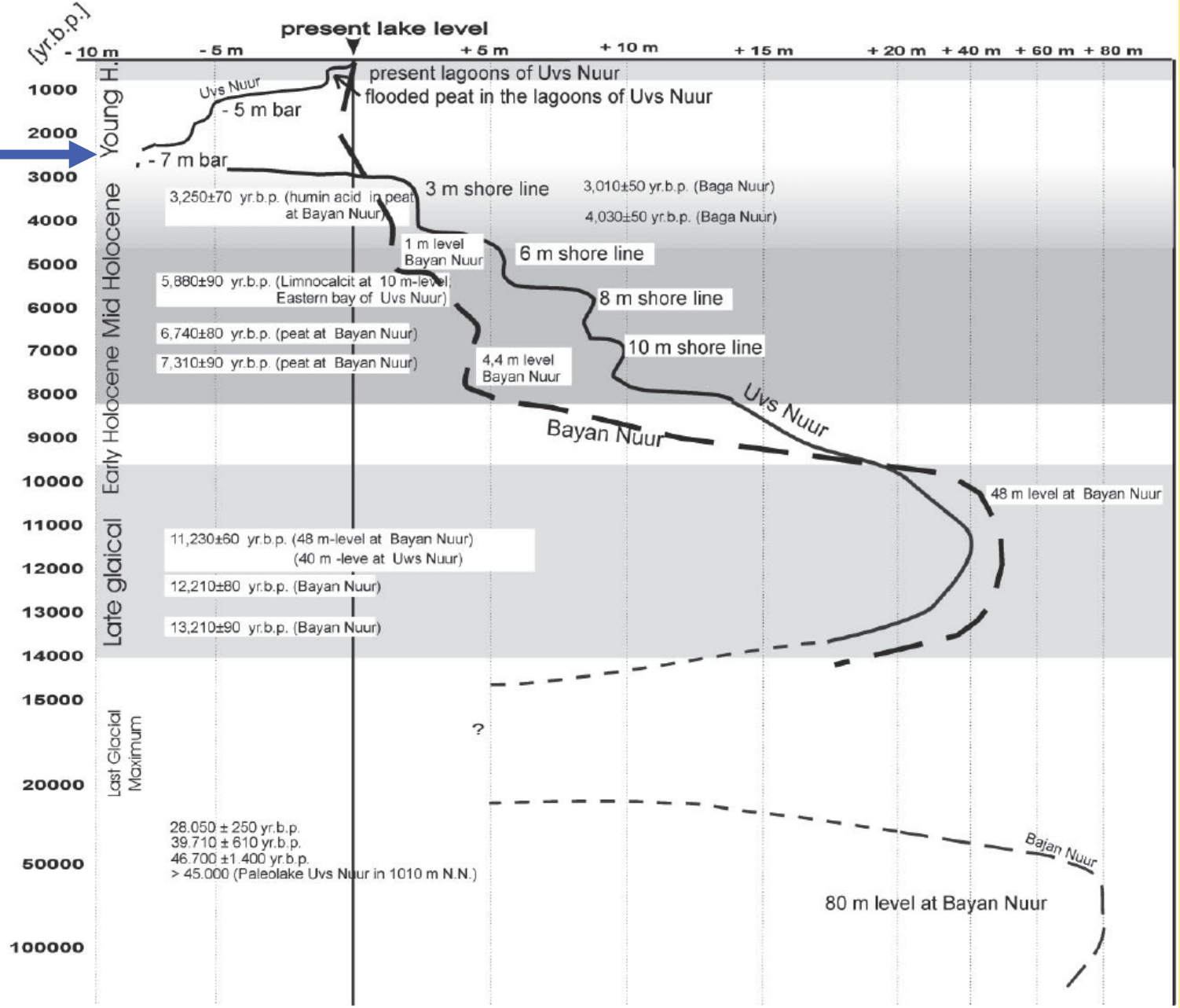
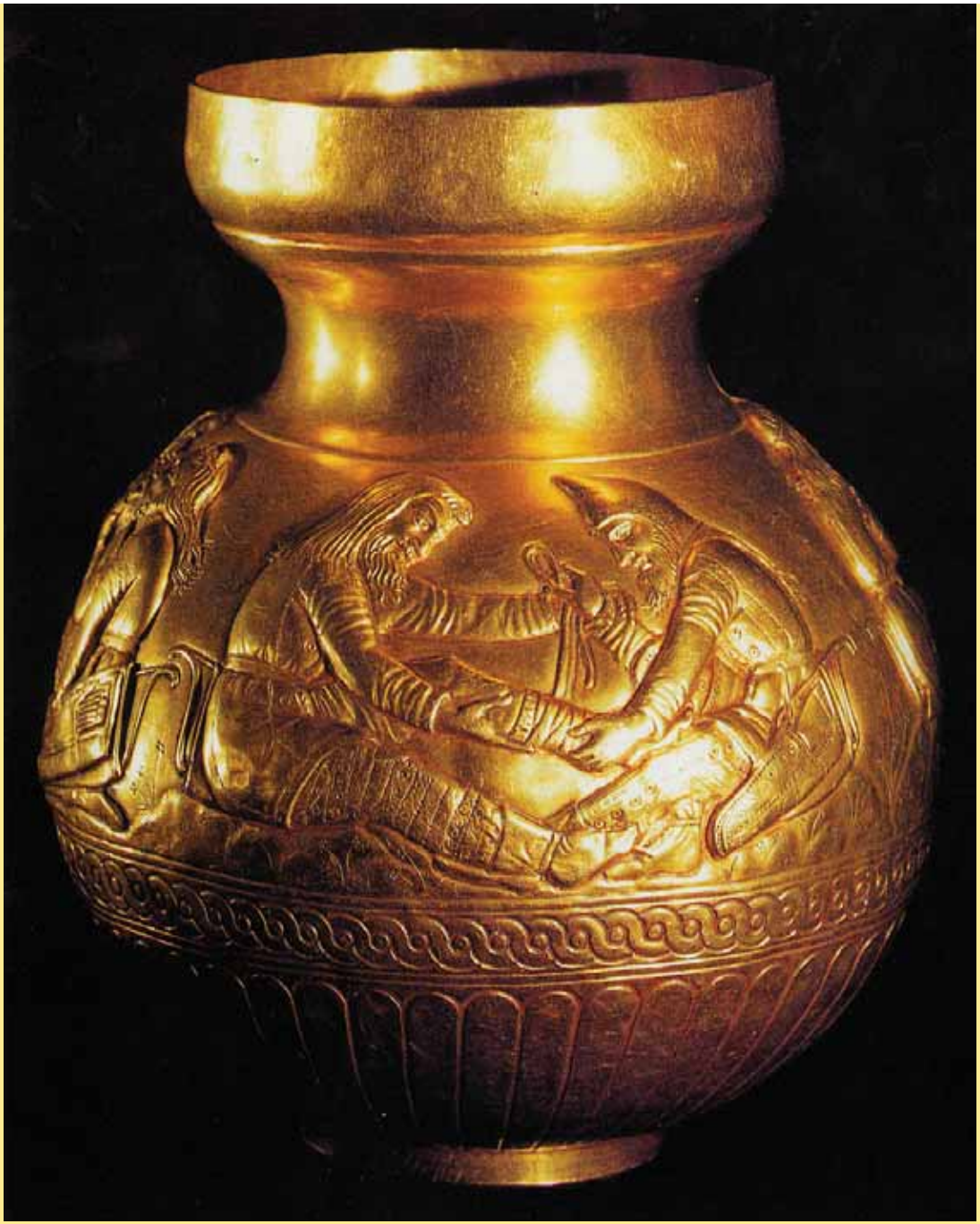
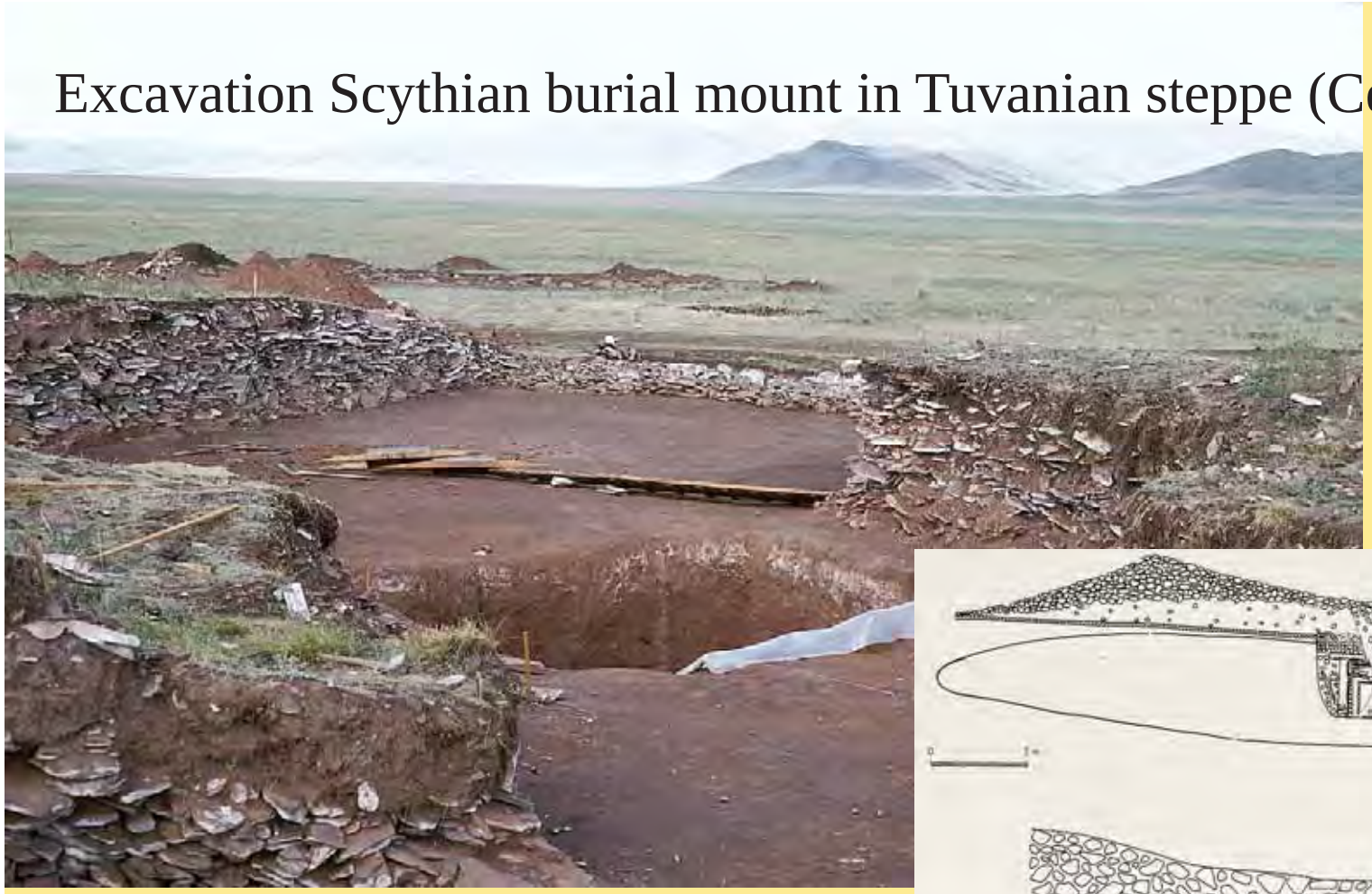


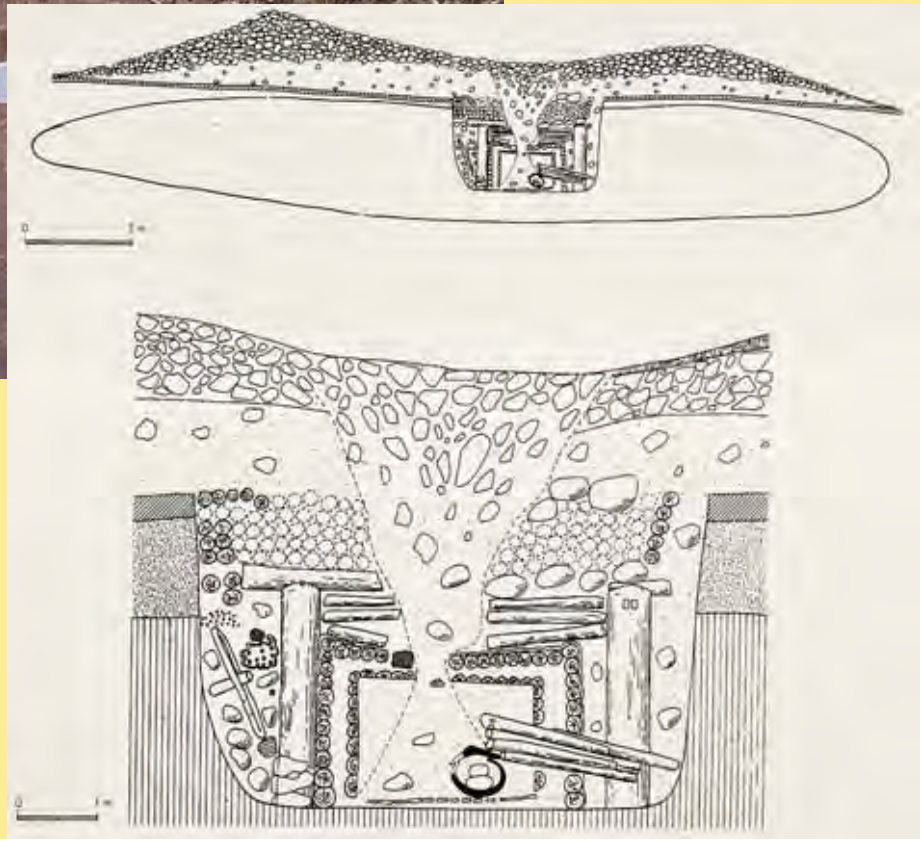
Fig. 6. Preliminary young Quaternary lake level fluctuations of Bayan Nuur and Uvs Nuur.



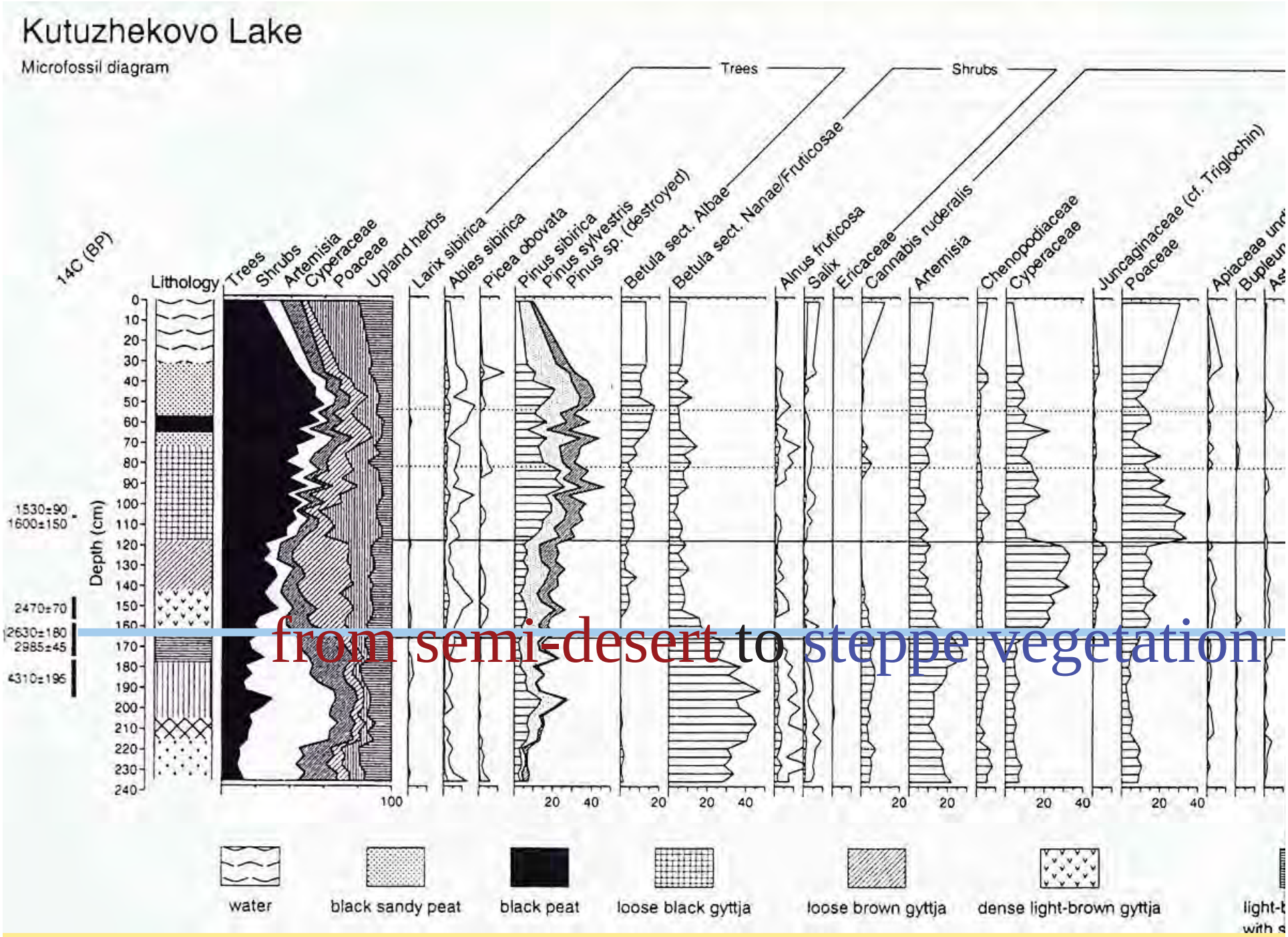
Scythians as depicted by themselves on a golden bowl

Excavation Scythian burial mount in Tuvanian steppe (Central Asia)



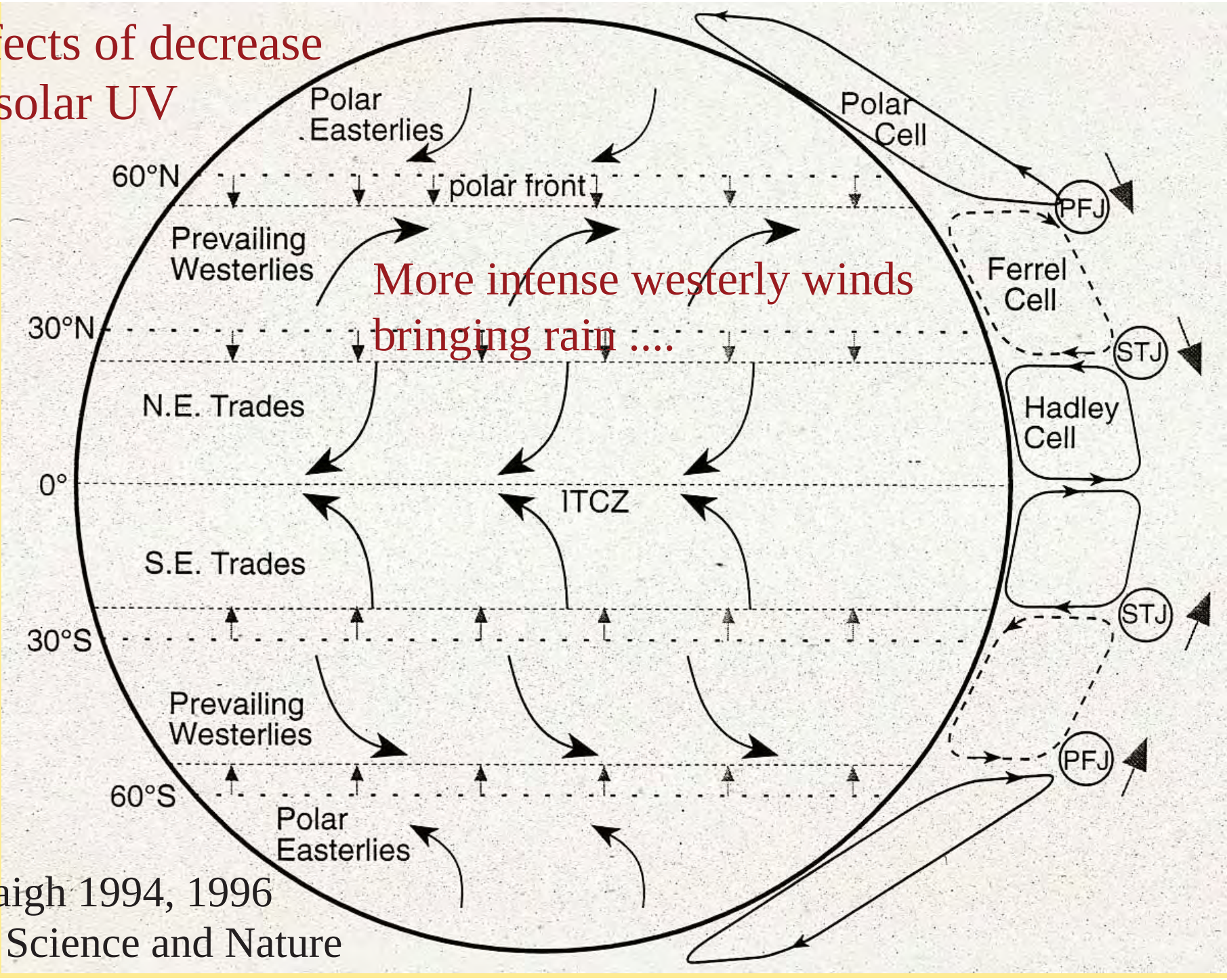


Small lake near excavation of large Scythian barrow



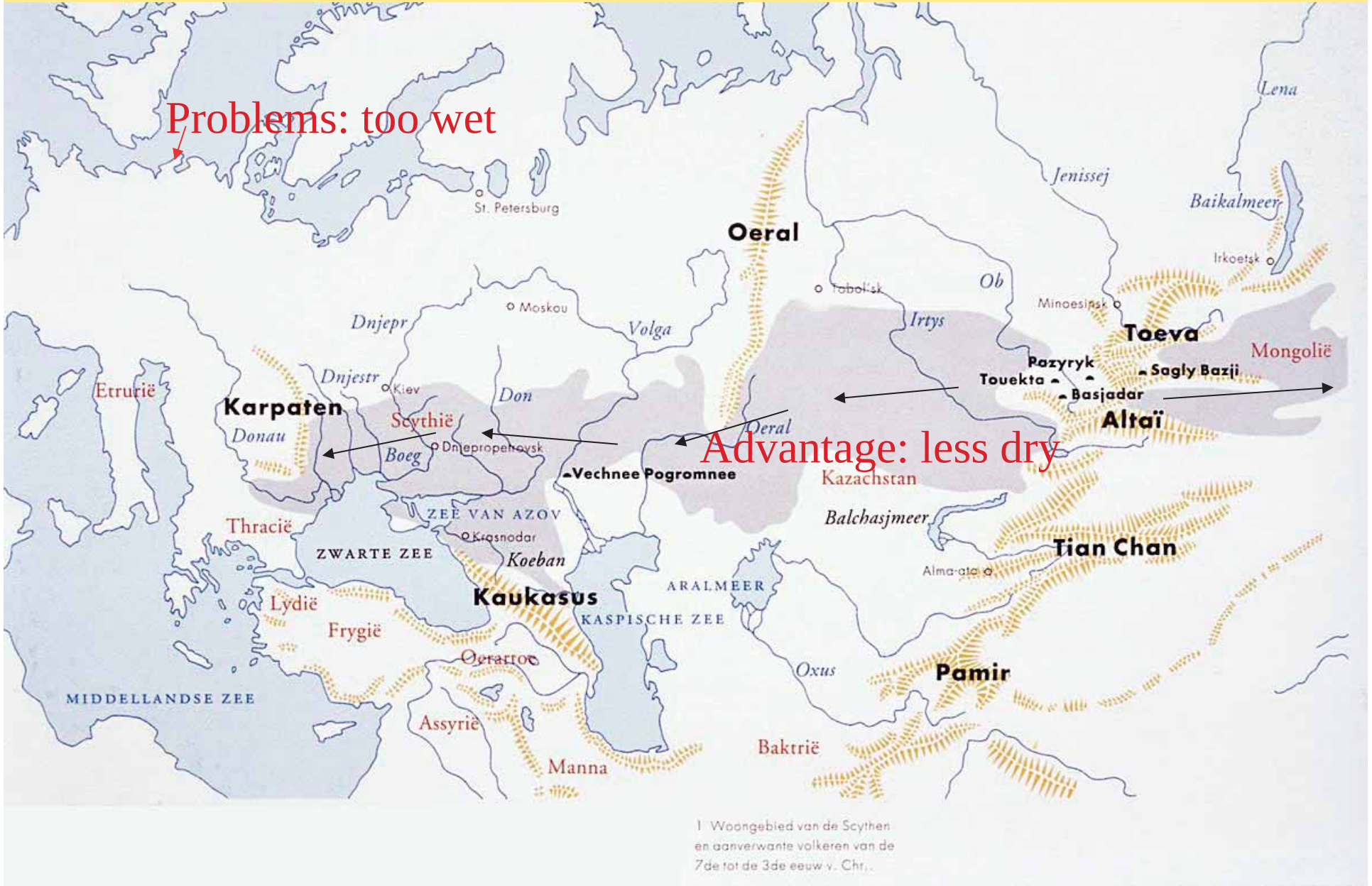
from semi-desert to steppe vegetation

Effects of decrease of solar UV

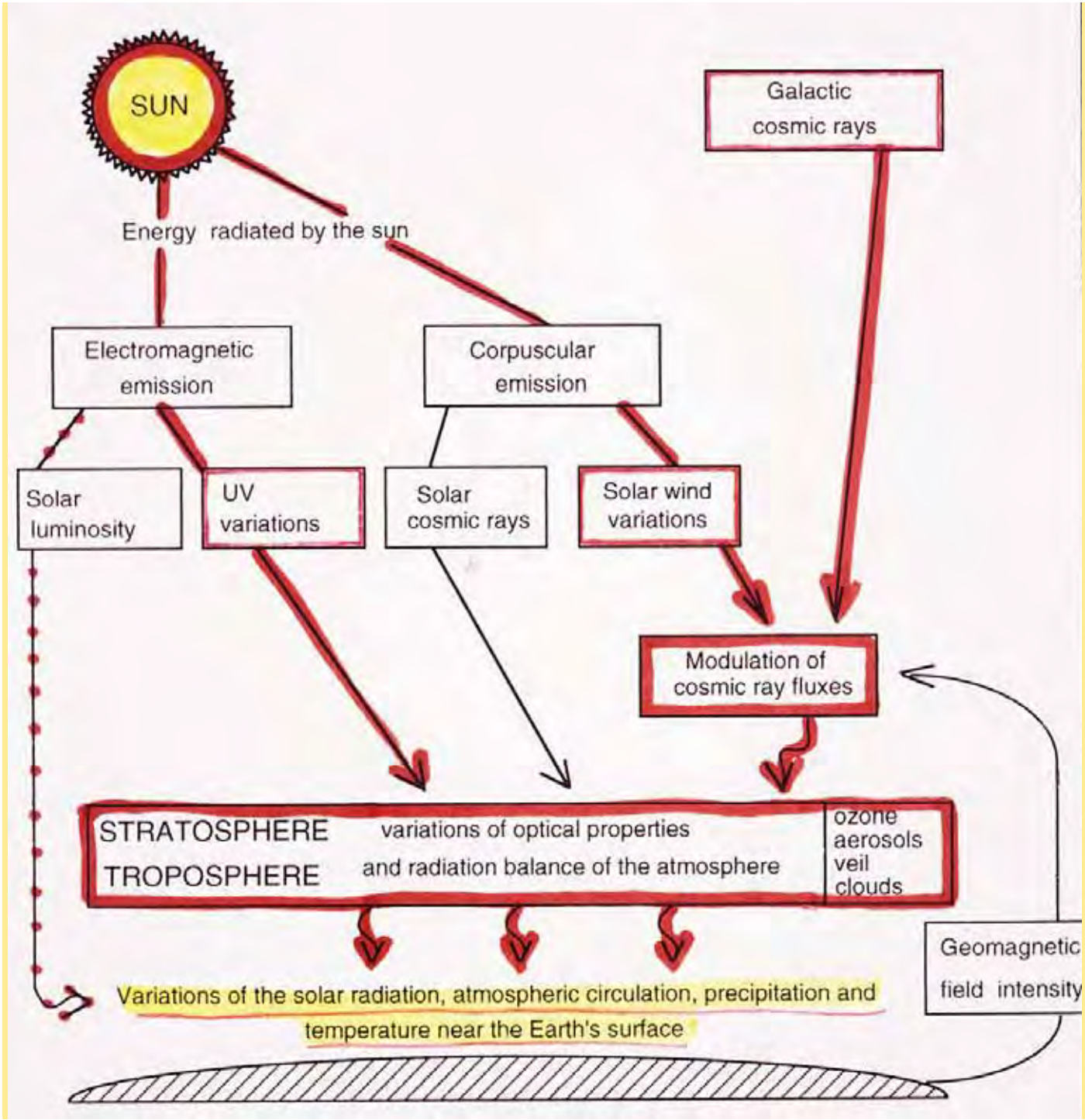


Haigh 1994, 1996
in Science and Nature

850 BC: problems and advantages

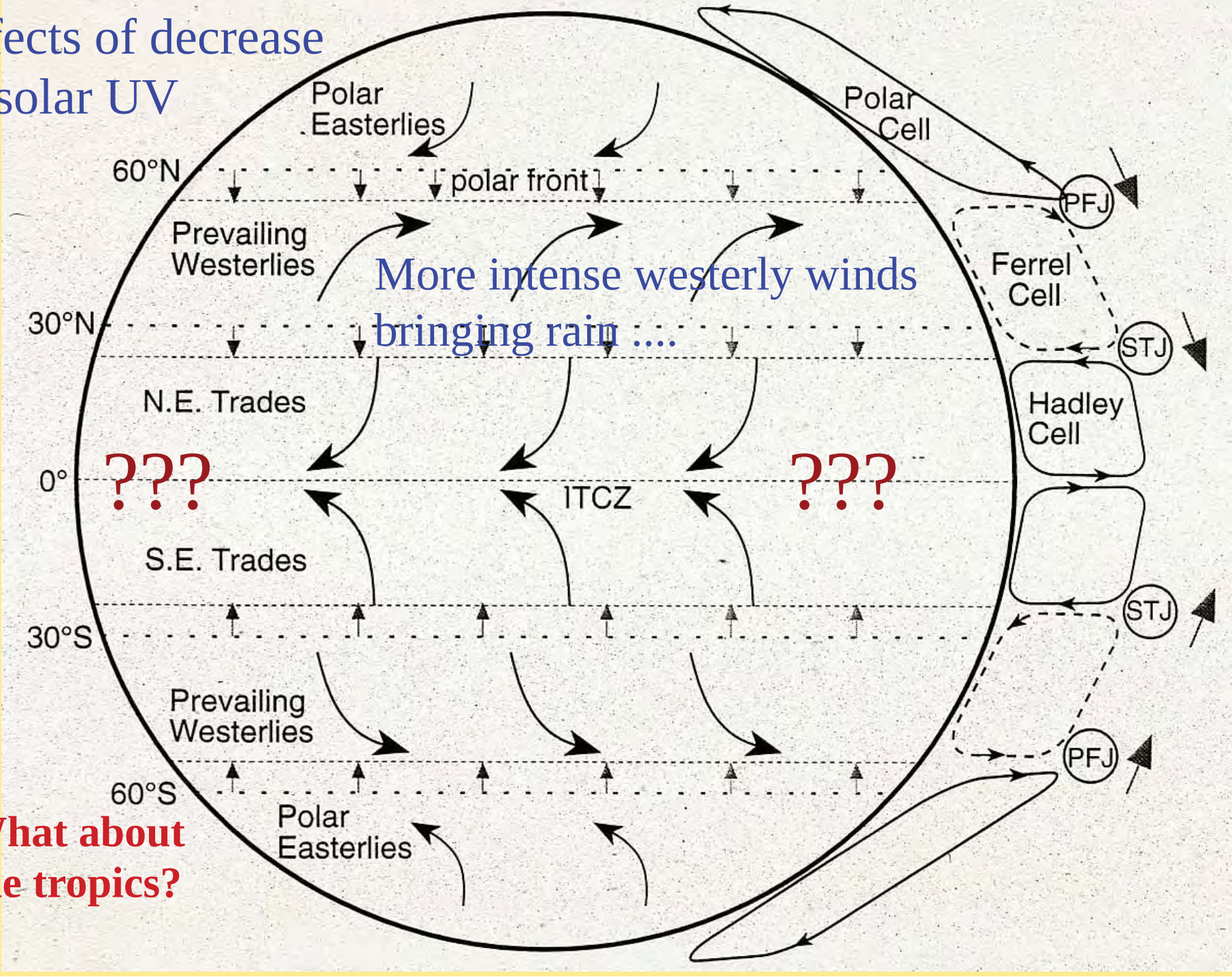


Blooming and expansion of Scythian culture when semi-desert changed into steppe



Two possible amplification mechanisms for relatively small changes of solar activity

Effects of decrease of solar UV



What about the tropics?

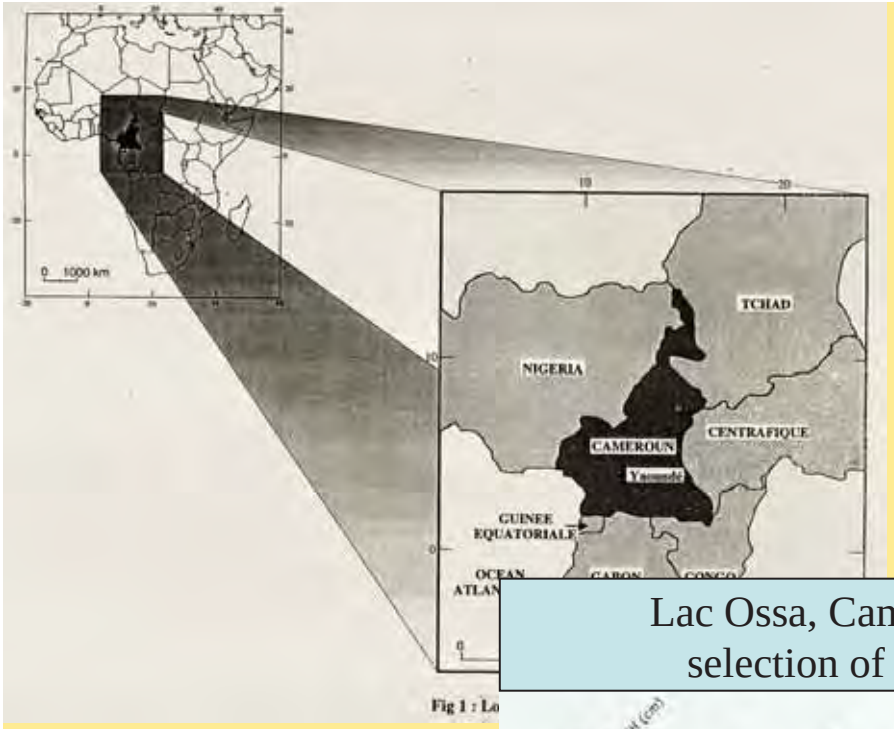
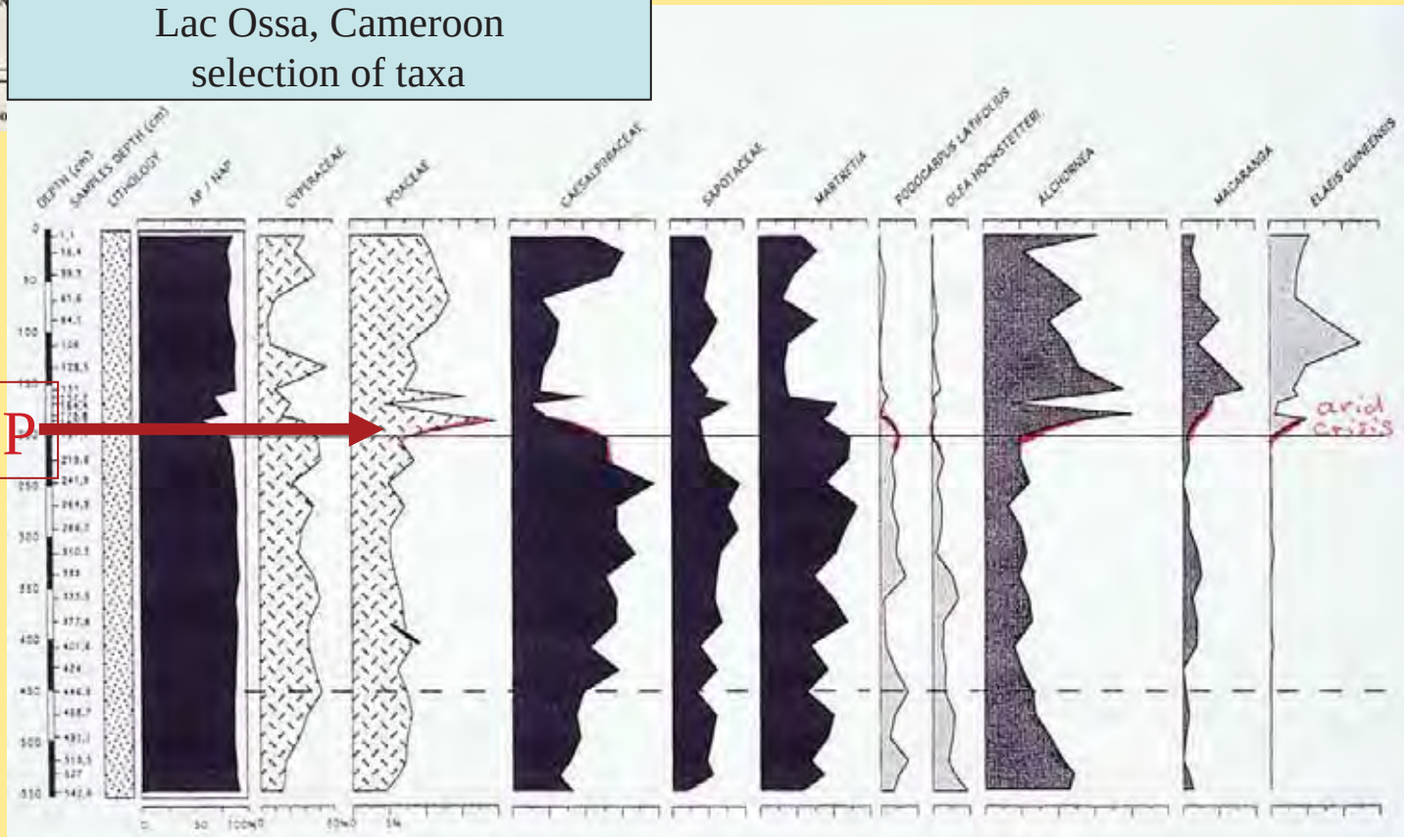


Fig 1 : Lo

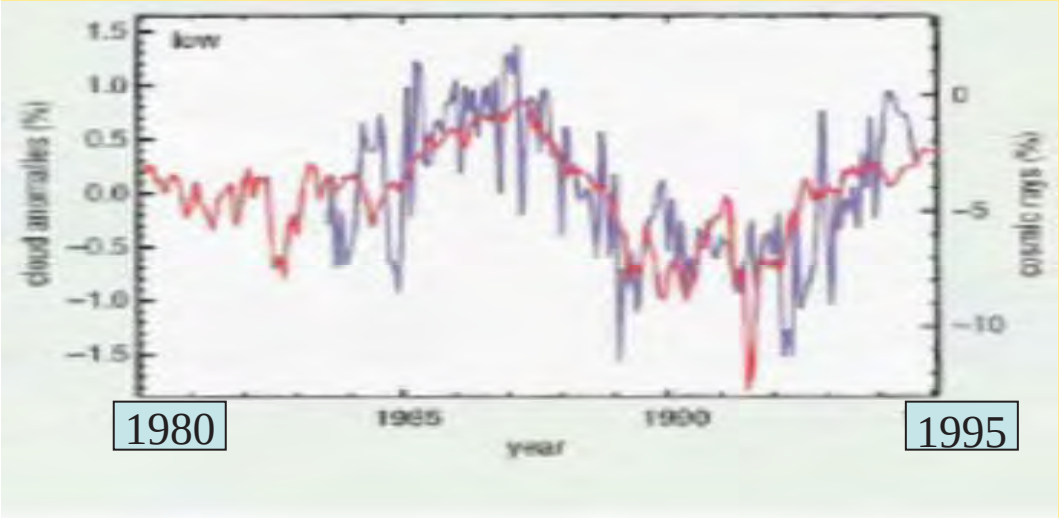
Cool, wet conditions in temperate zones and dryness in the tropics: This is evidence pointing to a role of UV in the amplification of small changes in solar activity (compare Haigh 1994, 1996)

Lac Ossa, Cameroon
selection of taxa

Arid crisis 2700 BP

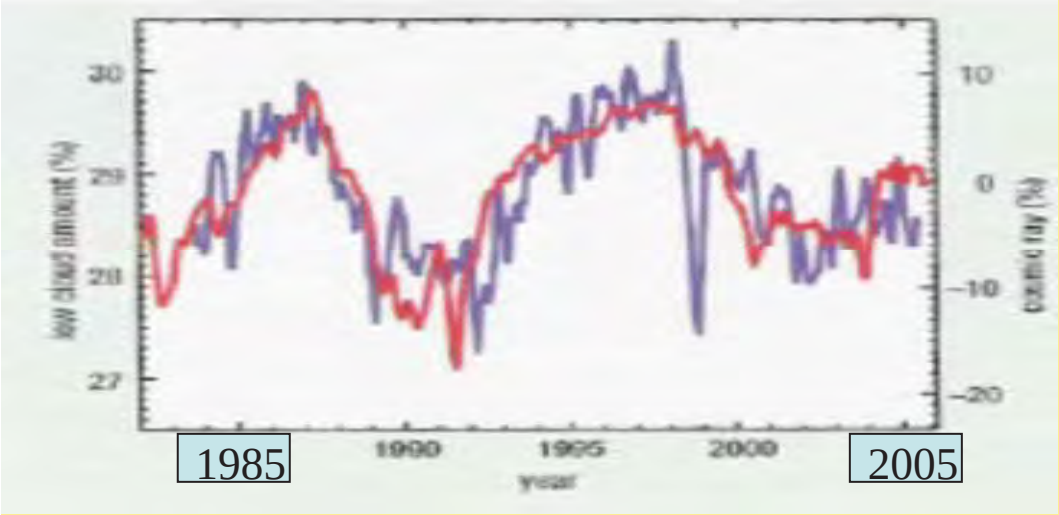


Svensmark (2007) in Astronomy and Geophysics 48: 1.18-1.24

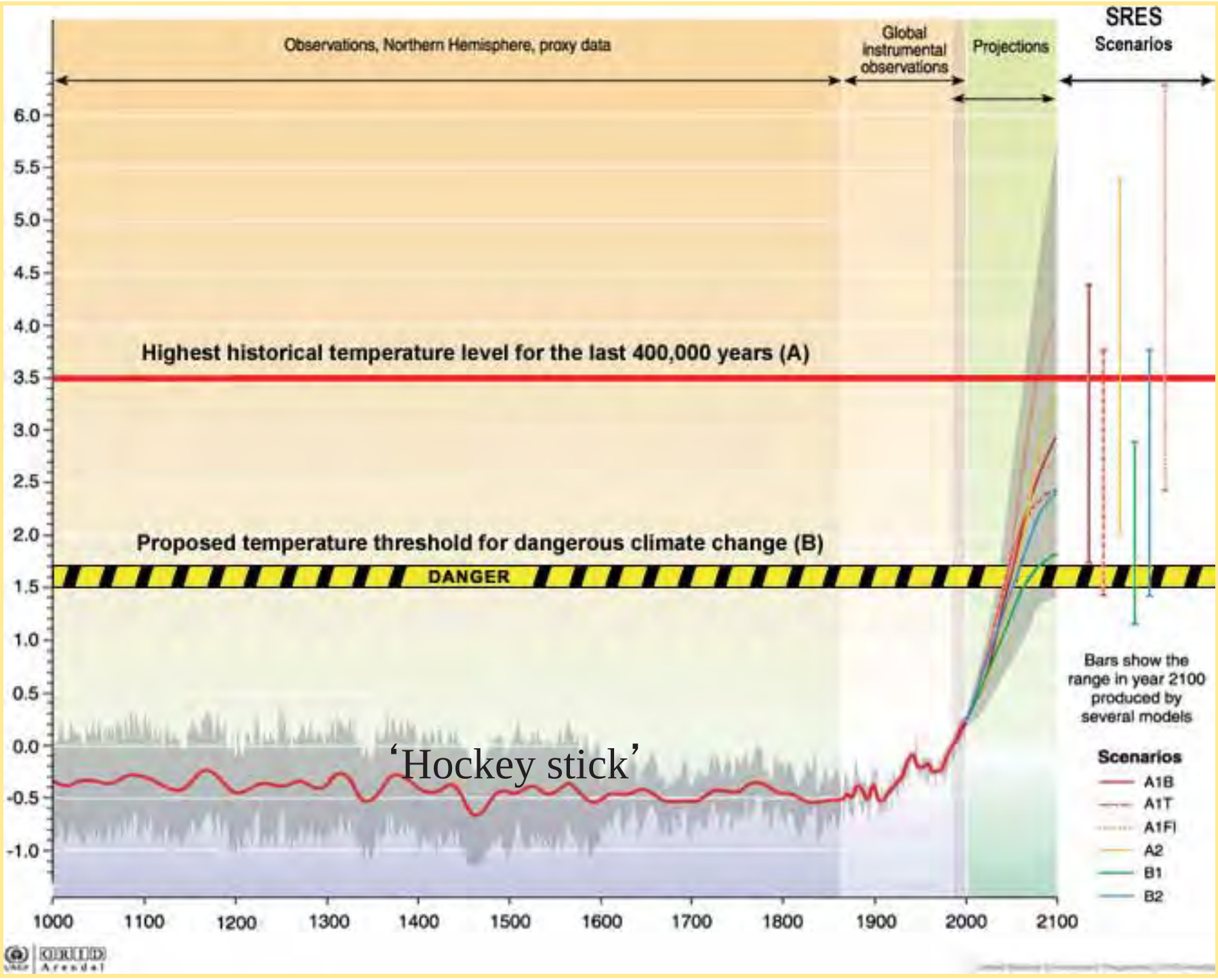


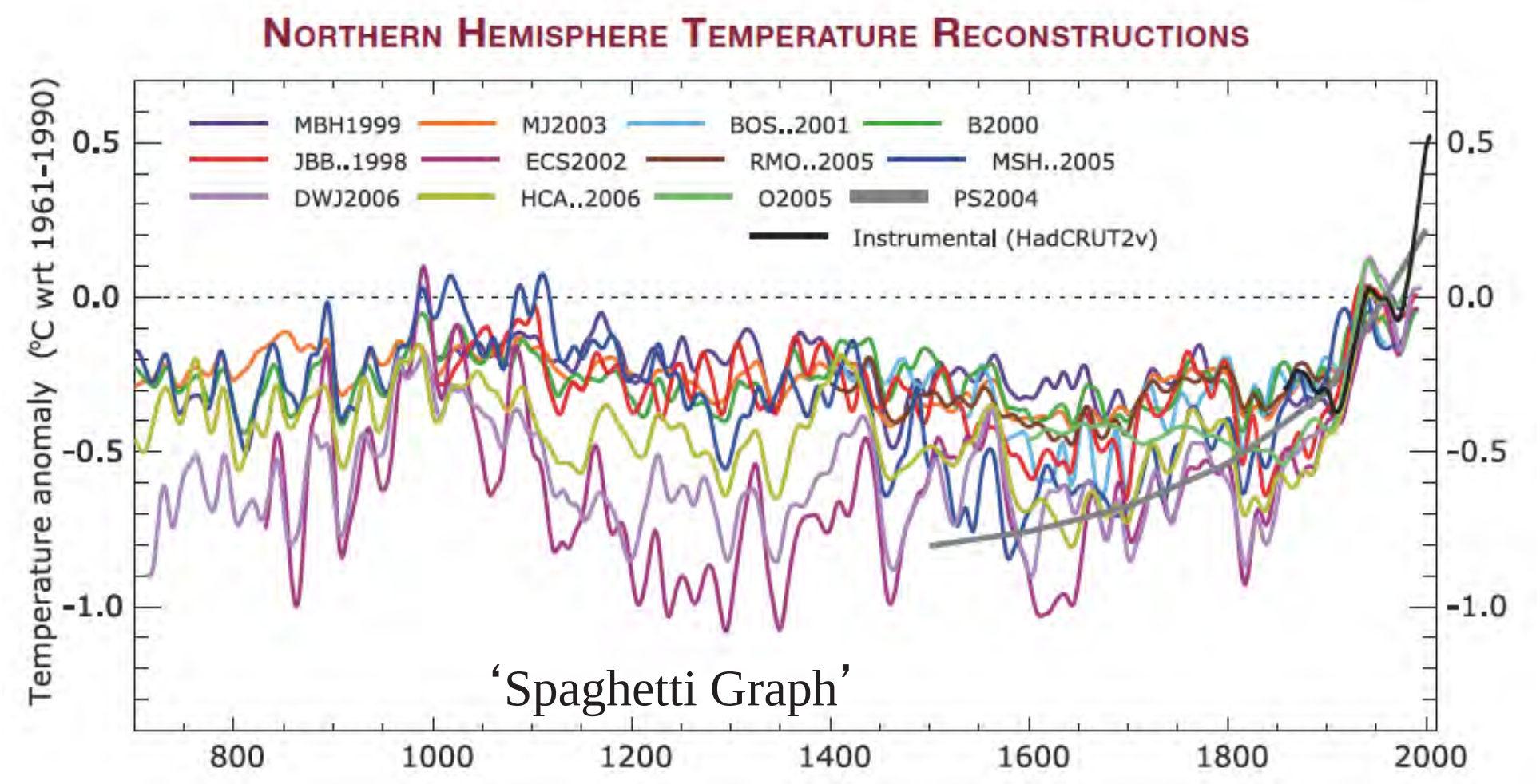
Red line: cosmic ray intensity

Blue line: cloud anomalies



Blue line: low cloud amount


Observations, Northern Hemisphere, proxy data
Global instrumental observations
Projections
SRES Scenarios
Highest historical temperature level for the last 400,000 years (A)
Proposed temperature threshold for dangerous climate change (B)
DANGER
'Hockey stick'
Bars show the range in year 2100 produced by several models
Scenarios
A1B
A1T
A1FI
A2
B1
B2
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100



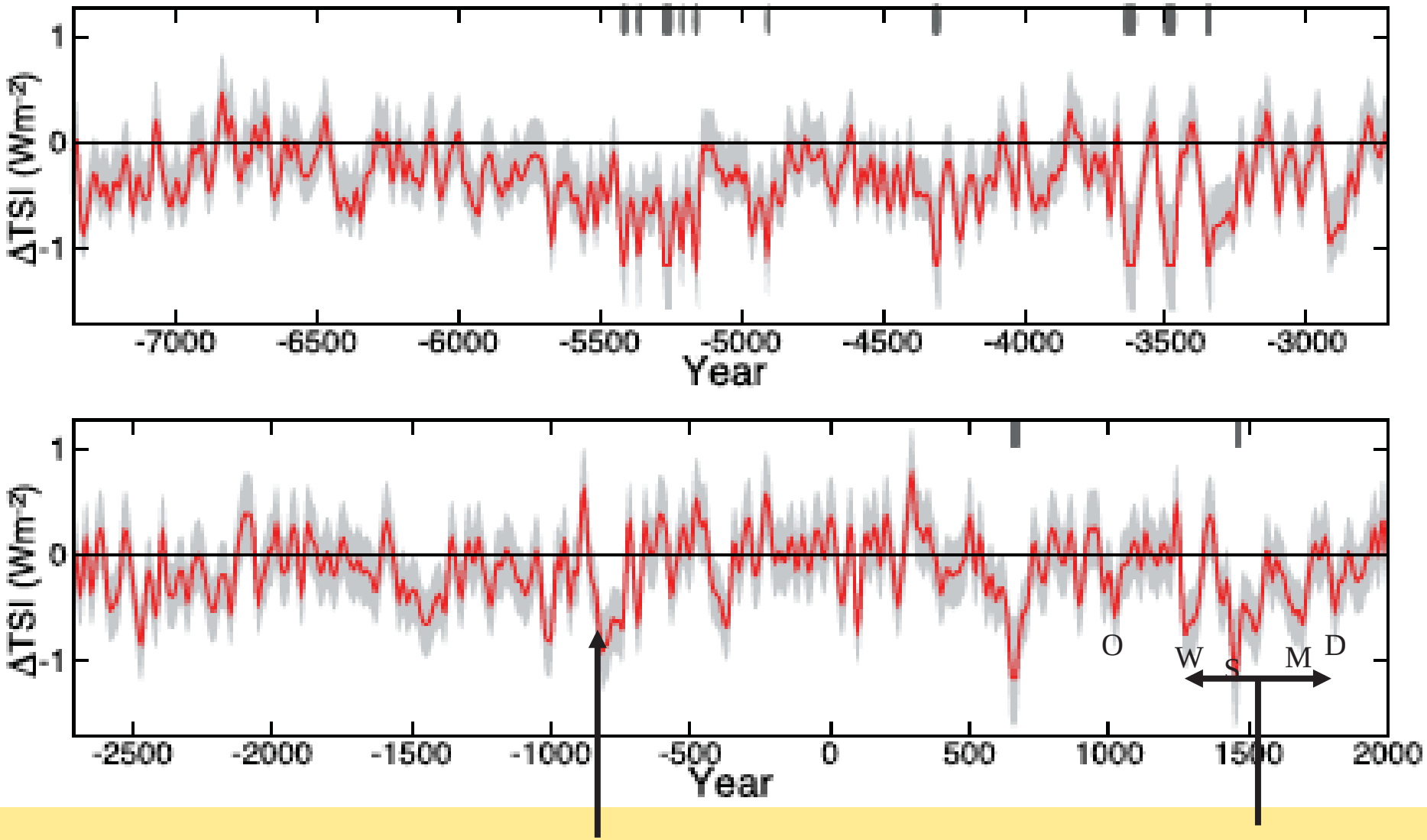
'Spaghetti Graph'

Are the present temperatures exceptional?

Are we responsible for climate change?

(probably we are; but for which part?)

What sort of risks and hazards in the near future?



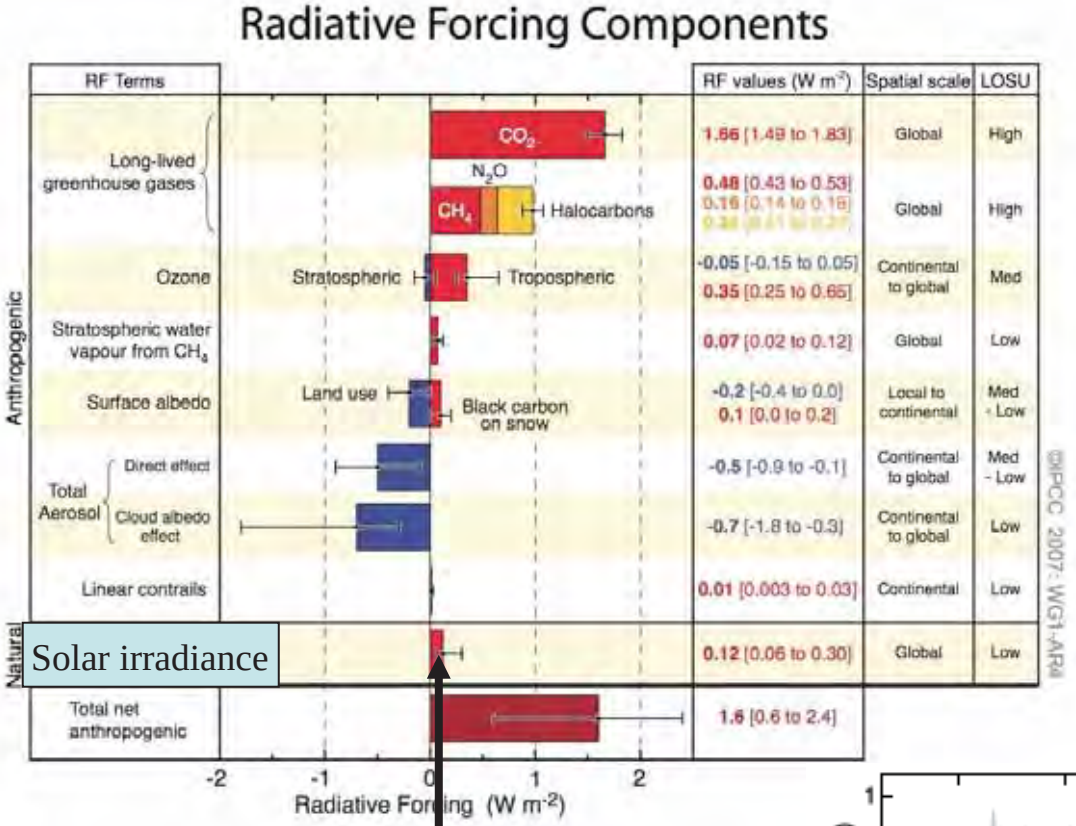
Subboreal-Subatlantic transition

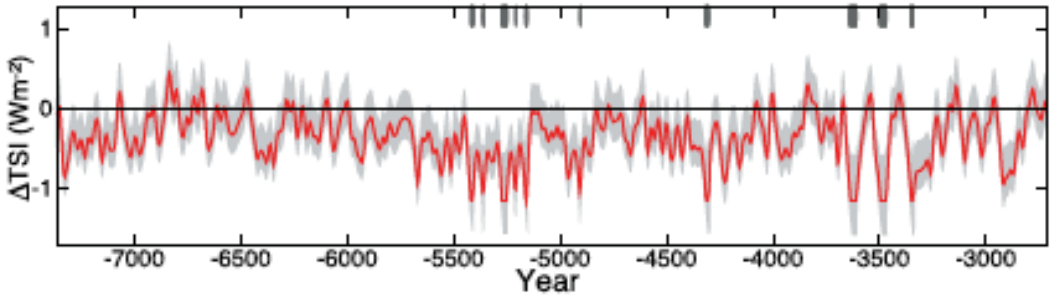
Little Ice Age

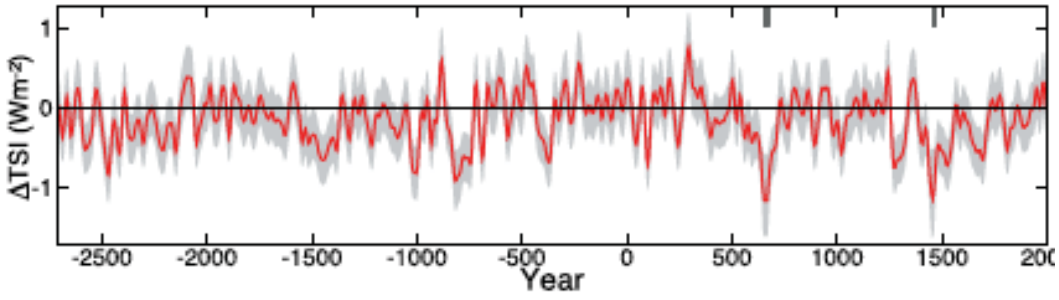
Steinhilber, F., Beer, J. & Fröhlich, C., 2009. Total solar irradiance during the Holocene. Geophysical Research Letters 36. L19704, doi: 10.1029/2009GL040142.

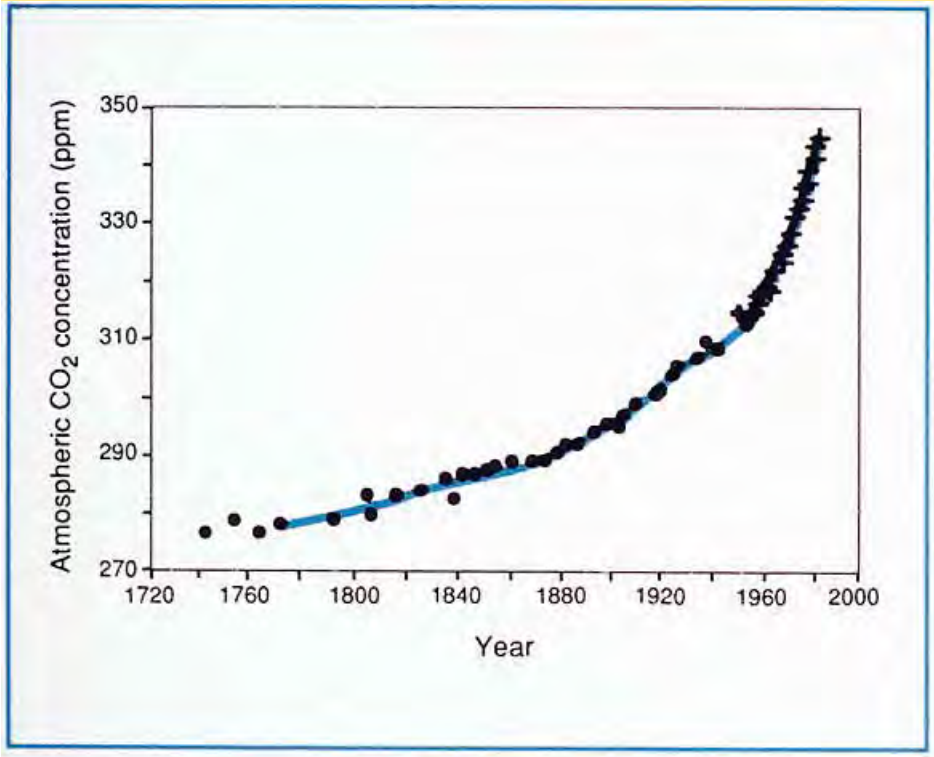
IPCC 4th Assessment Report
Summary for Policymakers
2007

Steinhilber et al.

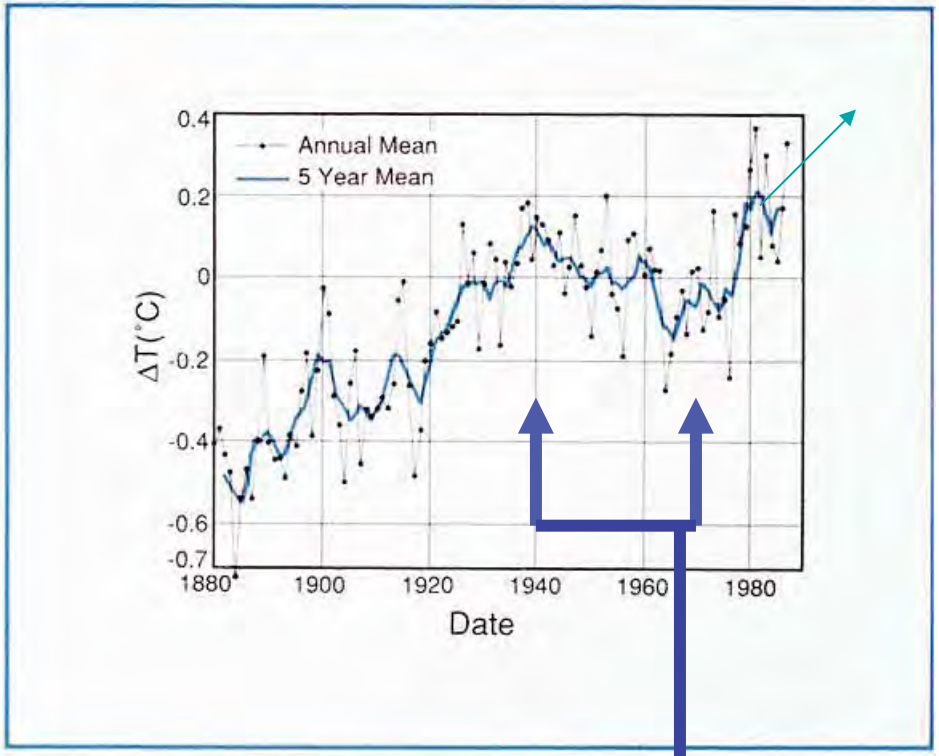




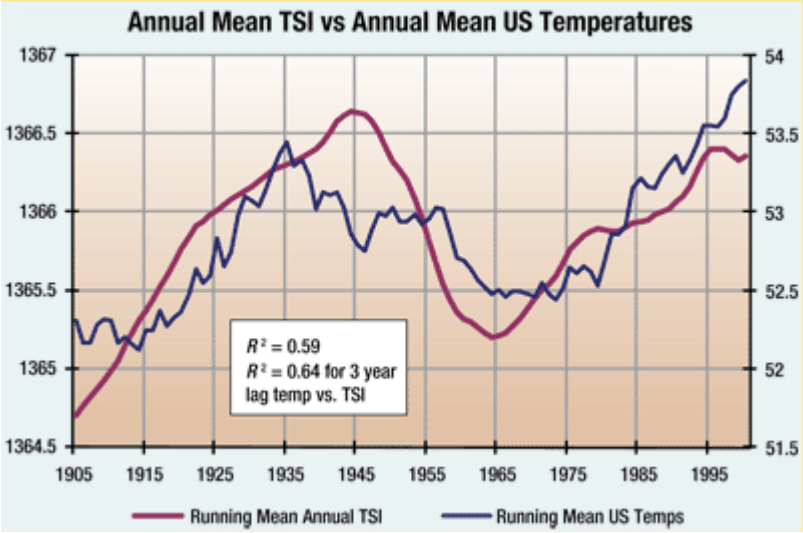




Rise of CO_2 concentration during the last 270 years



Temperature increase during the last century



Decline of solar activity **or** air pollution?

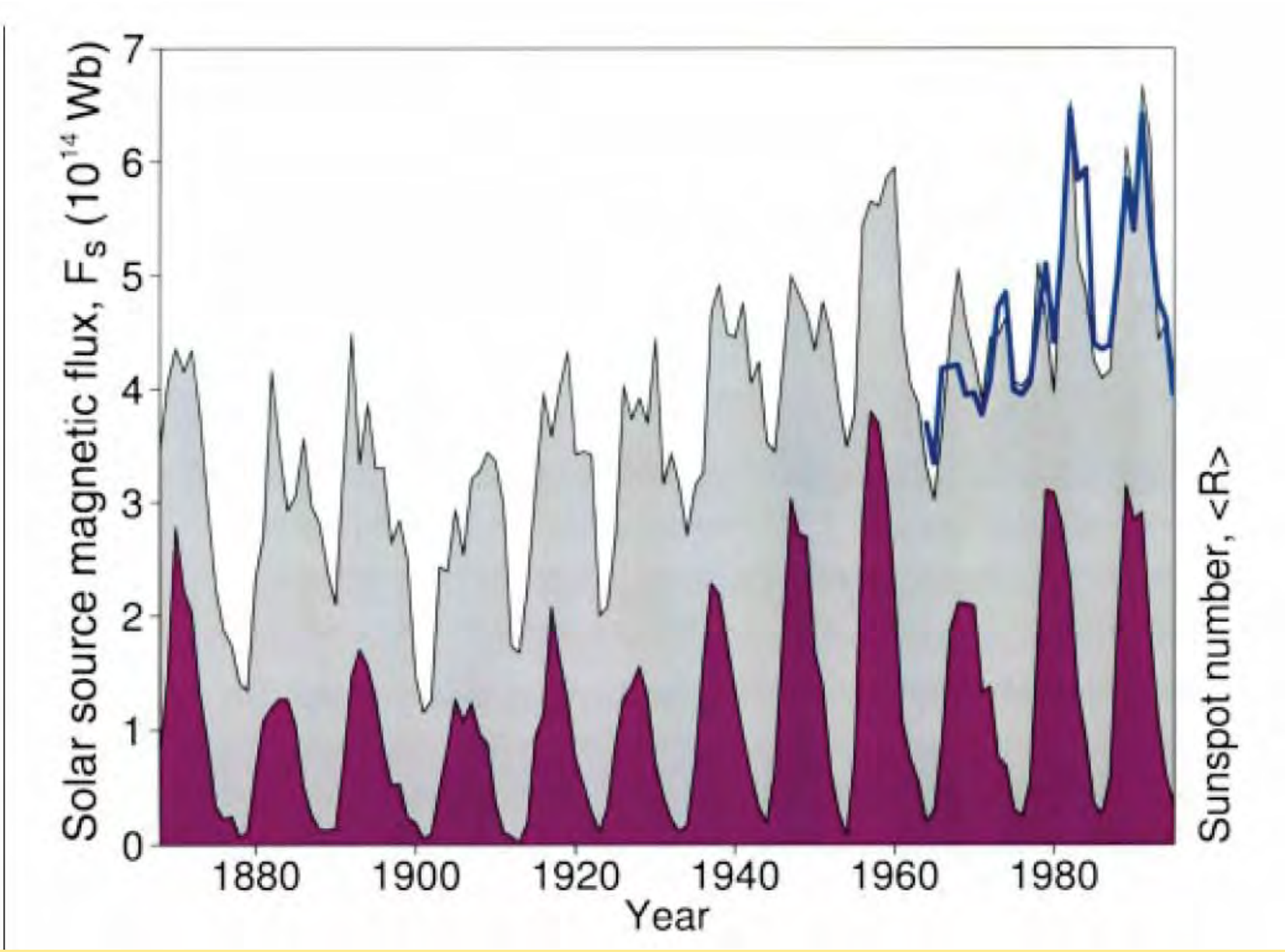
Do we know enough about solar forcing of climate change?

Probably not: we do not even know the amplification mechanisms.

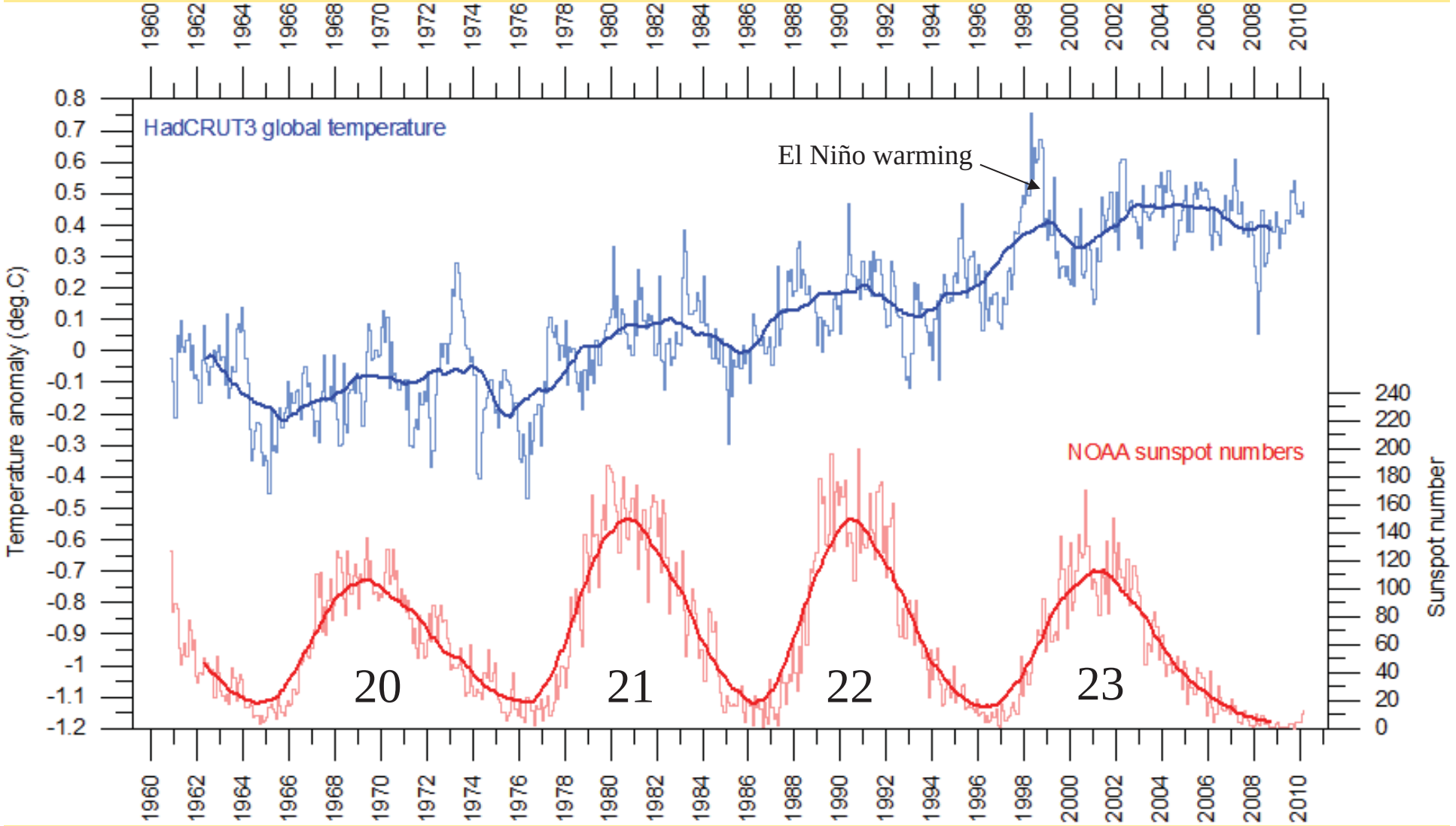
Role of the sun cannot be quantified in climate models.

My opinion: underestimation of solar forcing; overestimation of enhanced greenhouse effect and the role of humans.

ICLEA: separation natural/anthropogenic climate signatures

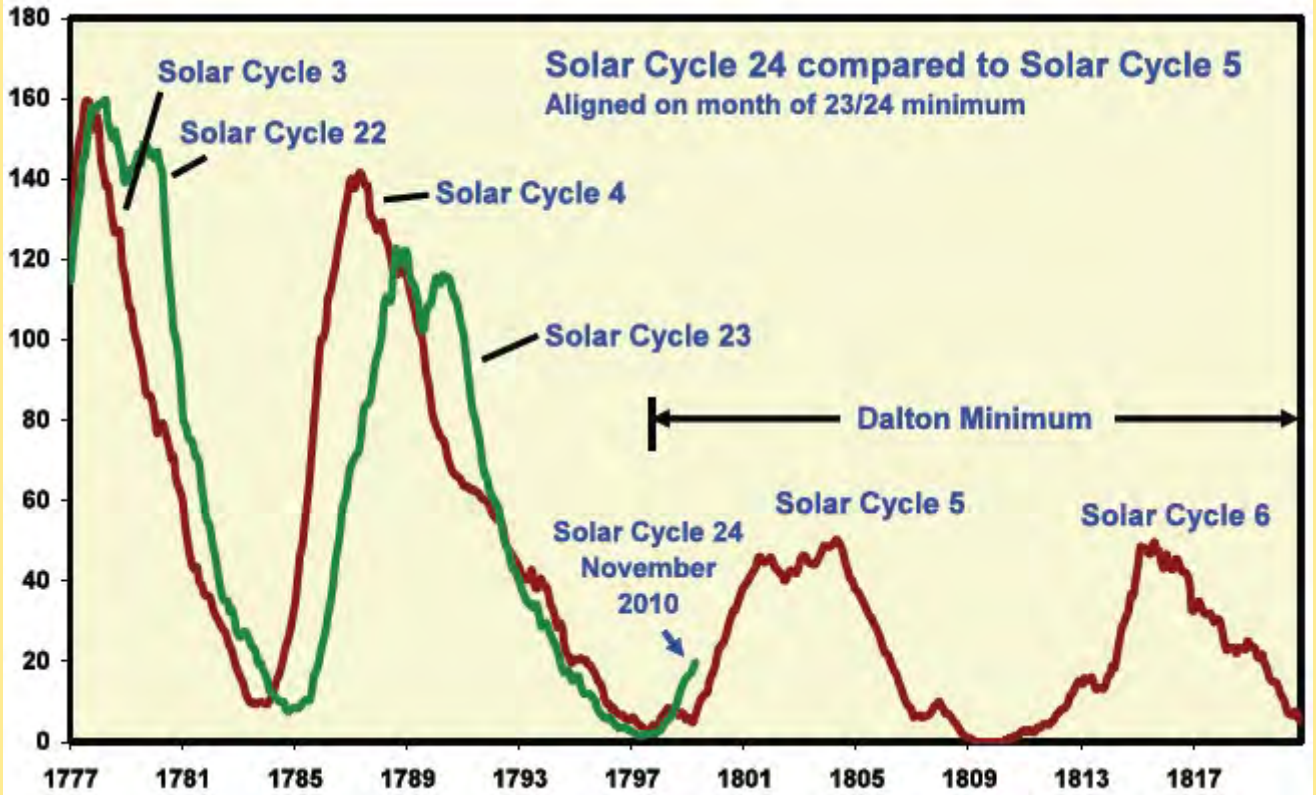


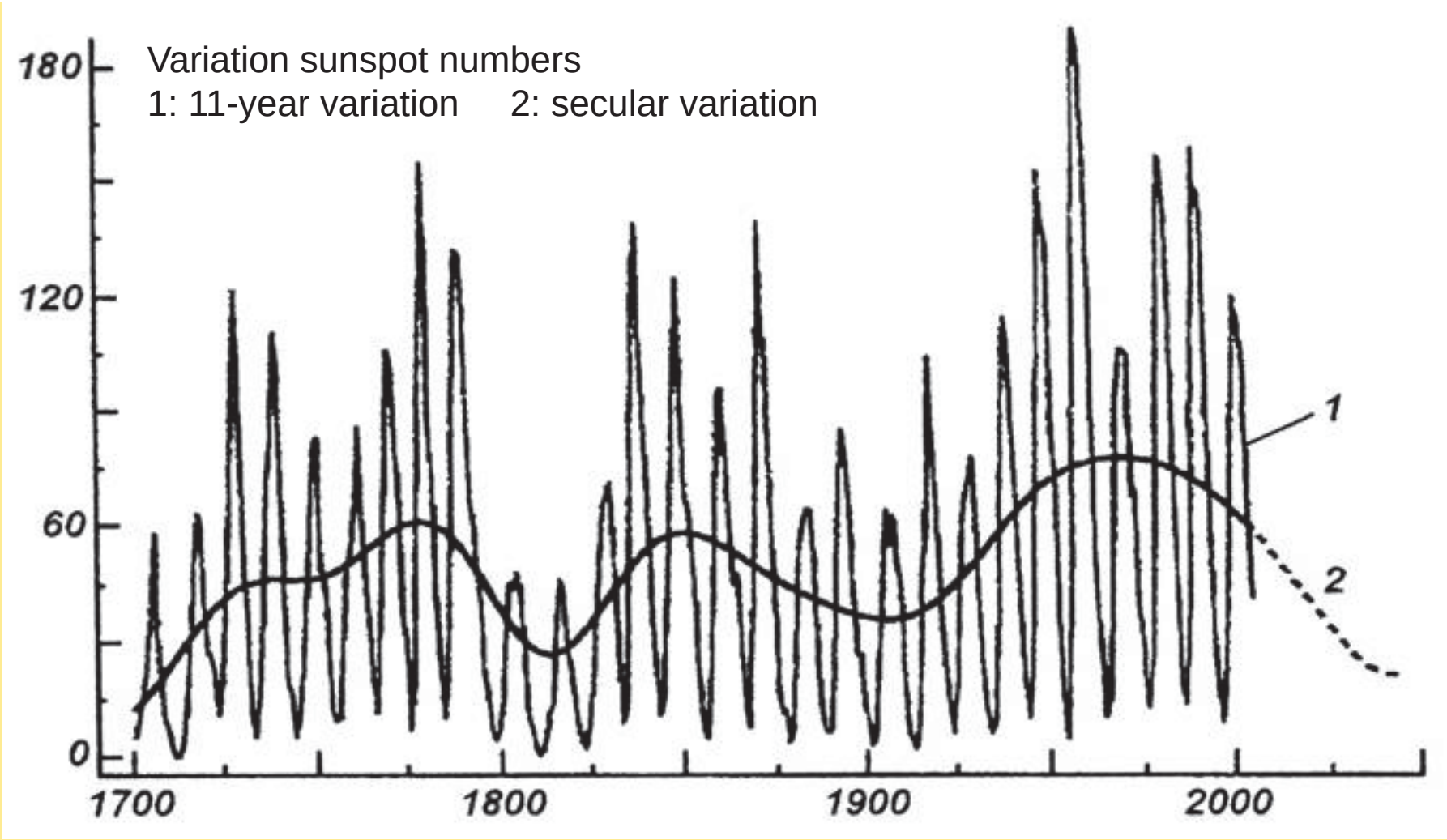
Lockwood et al., 1999. A doubling of the Sun's coronal magnetic field during the past 100 years. Nature 399: 437-439.


HadCRUT3 global temperature
El Niño warming
NOAA sunspot numbers
Temperature anomaly (deg.C)
Sunspot number
20
21
22
23
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
-1.2
240
220
200
180
160
140
120
100
80
60
40
20
0
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

Past, present, future ....

The present unusual solar conditions

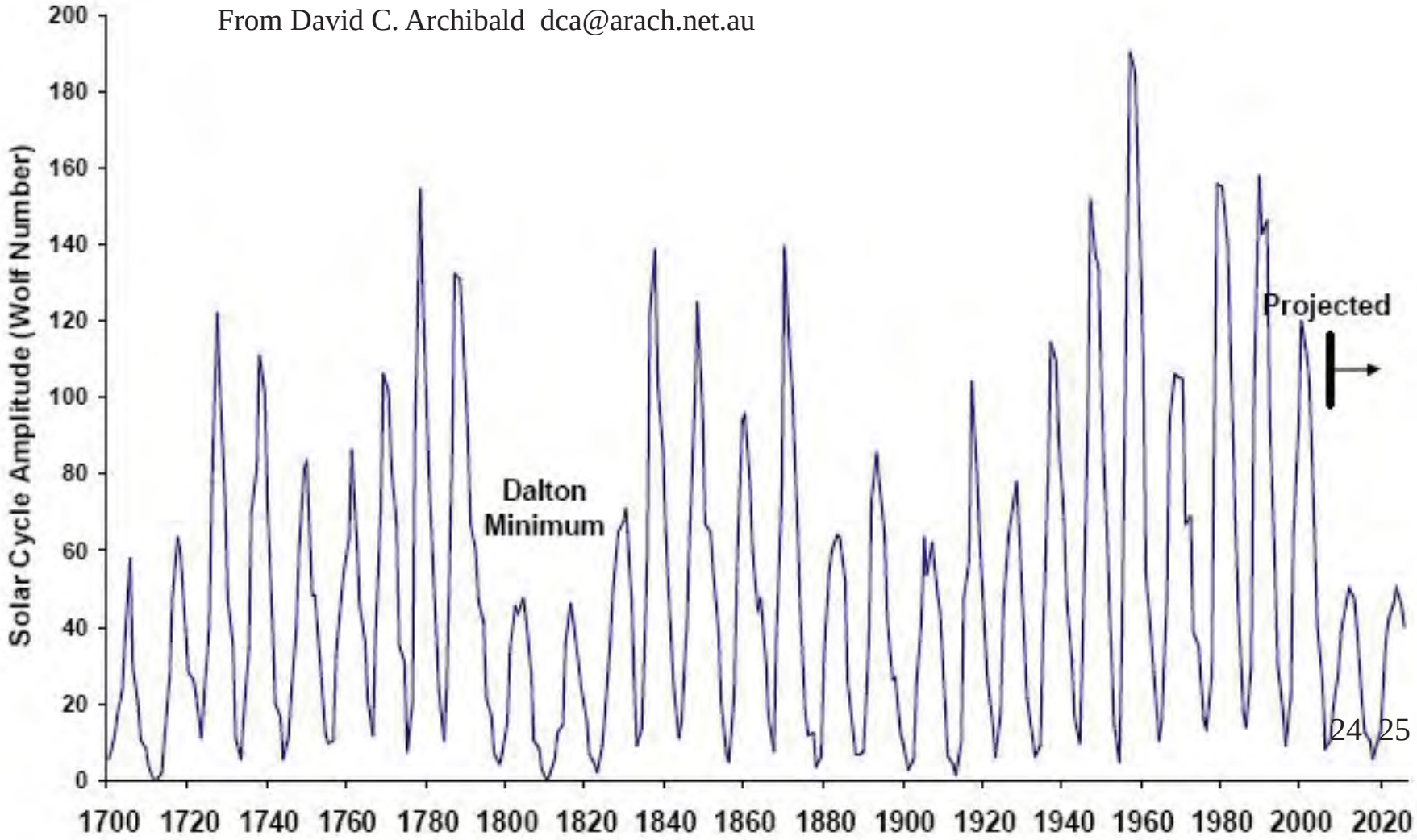




Instead of global warming the Earth soon will be facing a temperature decrease ....

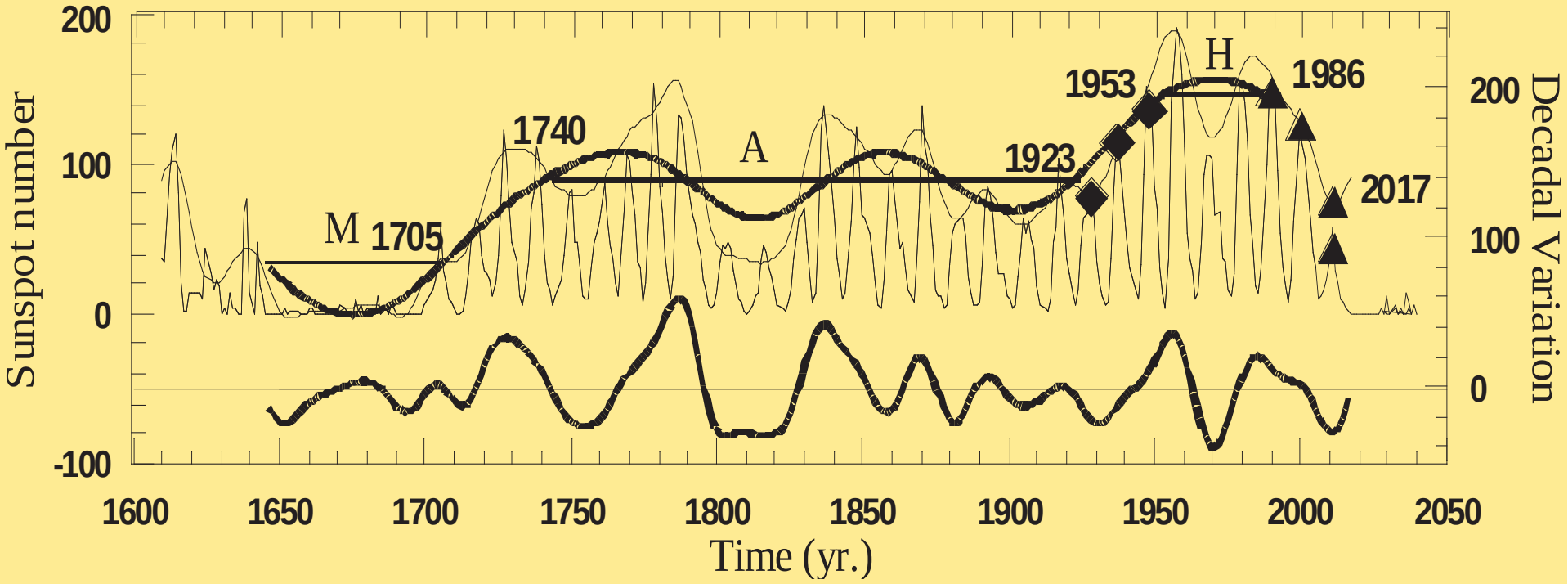
Abdussamatov, H.I., 2005. On long-term variations of the total irradiance and on probable changes of temperature in the Sun's core. Kinematics and Physics of Celestial Bodies 21 (6): 471-477.

From David C. Archibald dca@arach.net.au

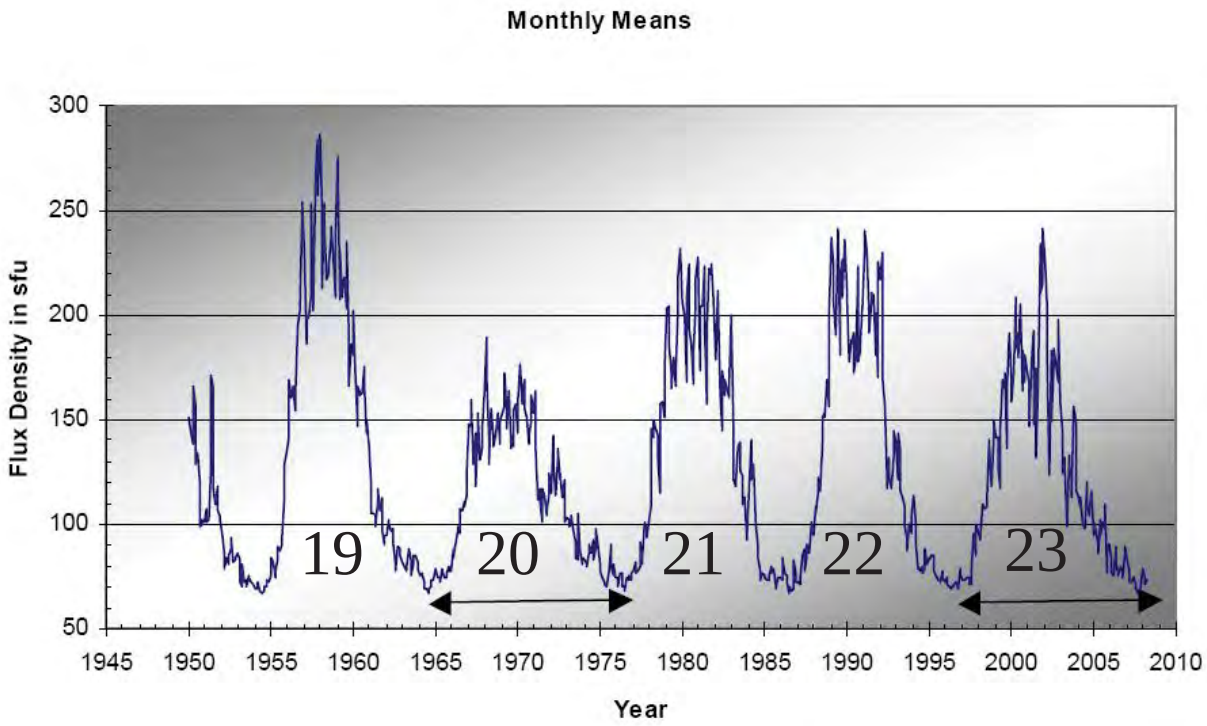


Past solar cycles with a projection of solar cycles 24 and 25

Duhau & de Jager: Solar activity at a turning point



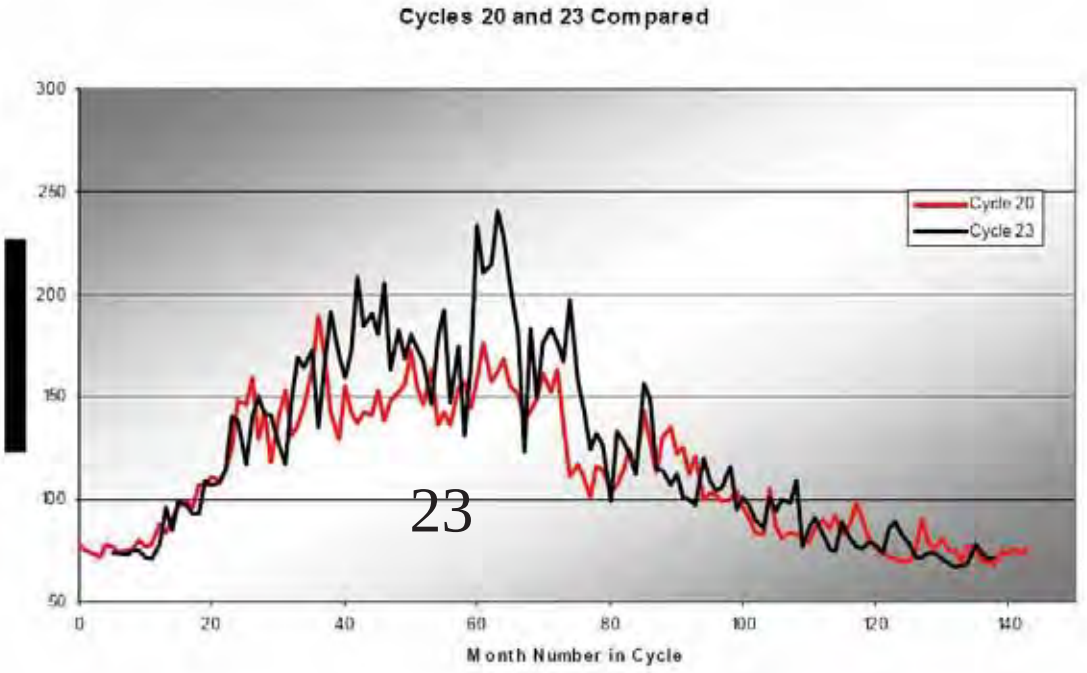
C. de Jager and S. Duhau predict a major decline of solar activity between 2011 and 2017

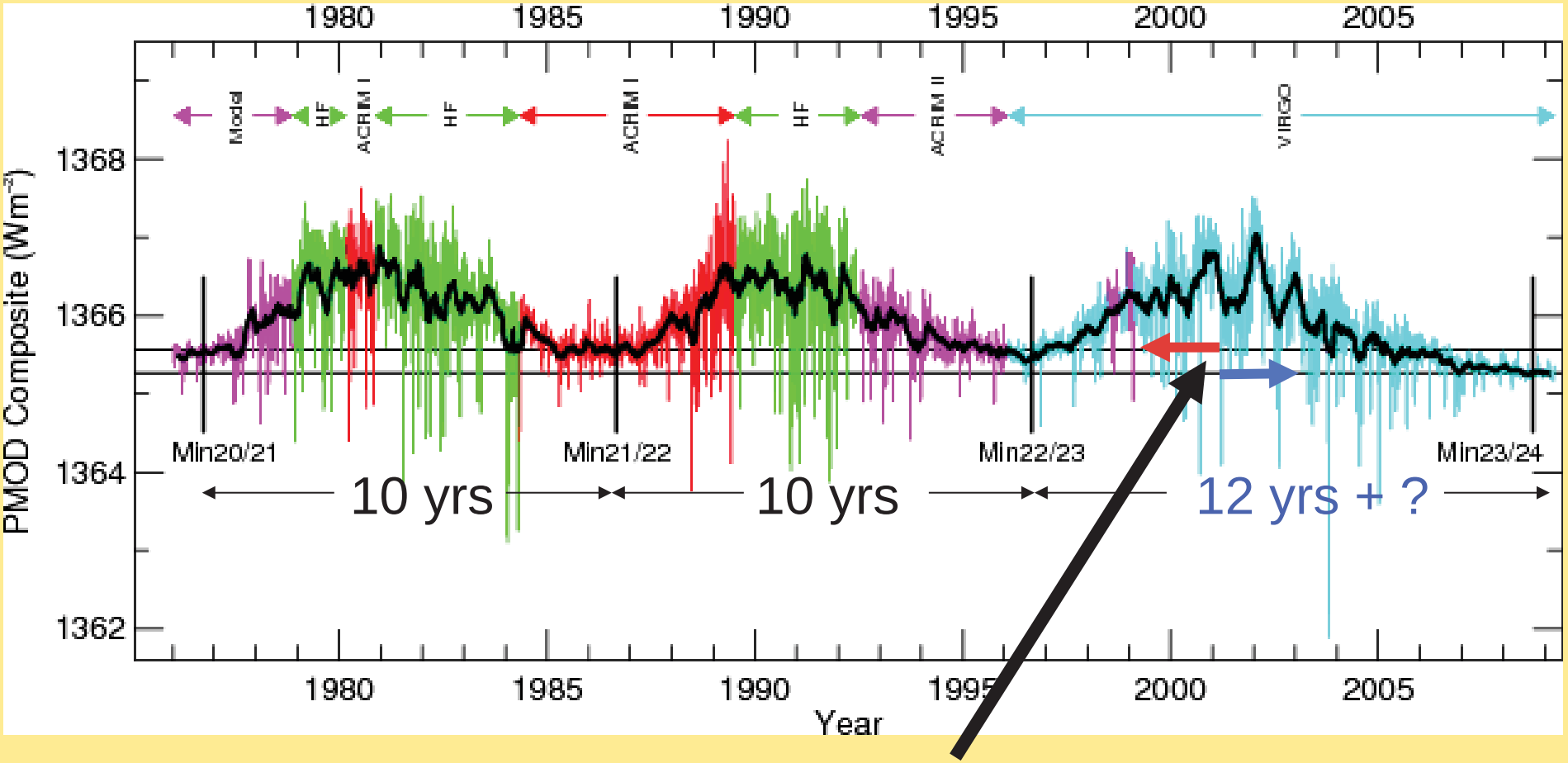


2008:

AT THE MOMENT IT IS UNJUSTIFIED TO ASSUME THE SUN IS UNDERGOING A SIGNIFICANT CHANGE IN BEHAVIOUR.

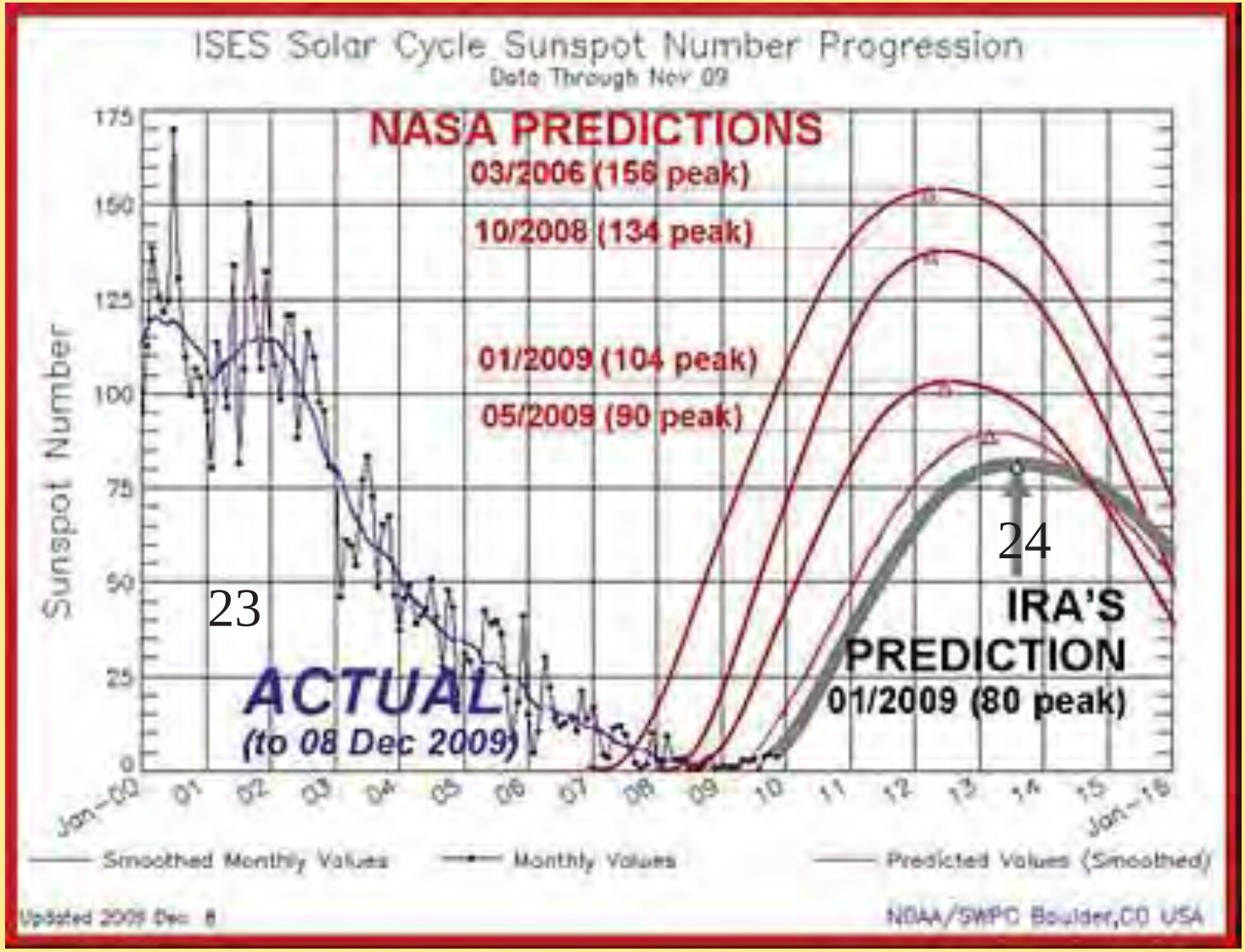
ON THE BASIS OF SUNSPOT NUMBER DATA, WE CANNOT ASSUME ANYTHING ODD IS HAPPENING UNLESS THE NEXT CYCLE DELAYS ITS START INTO 2009 OR 2010.



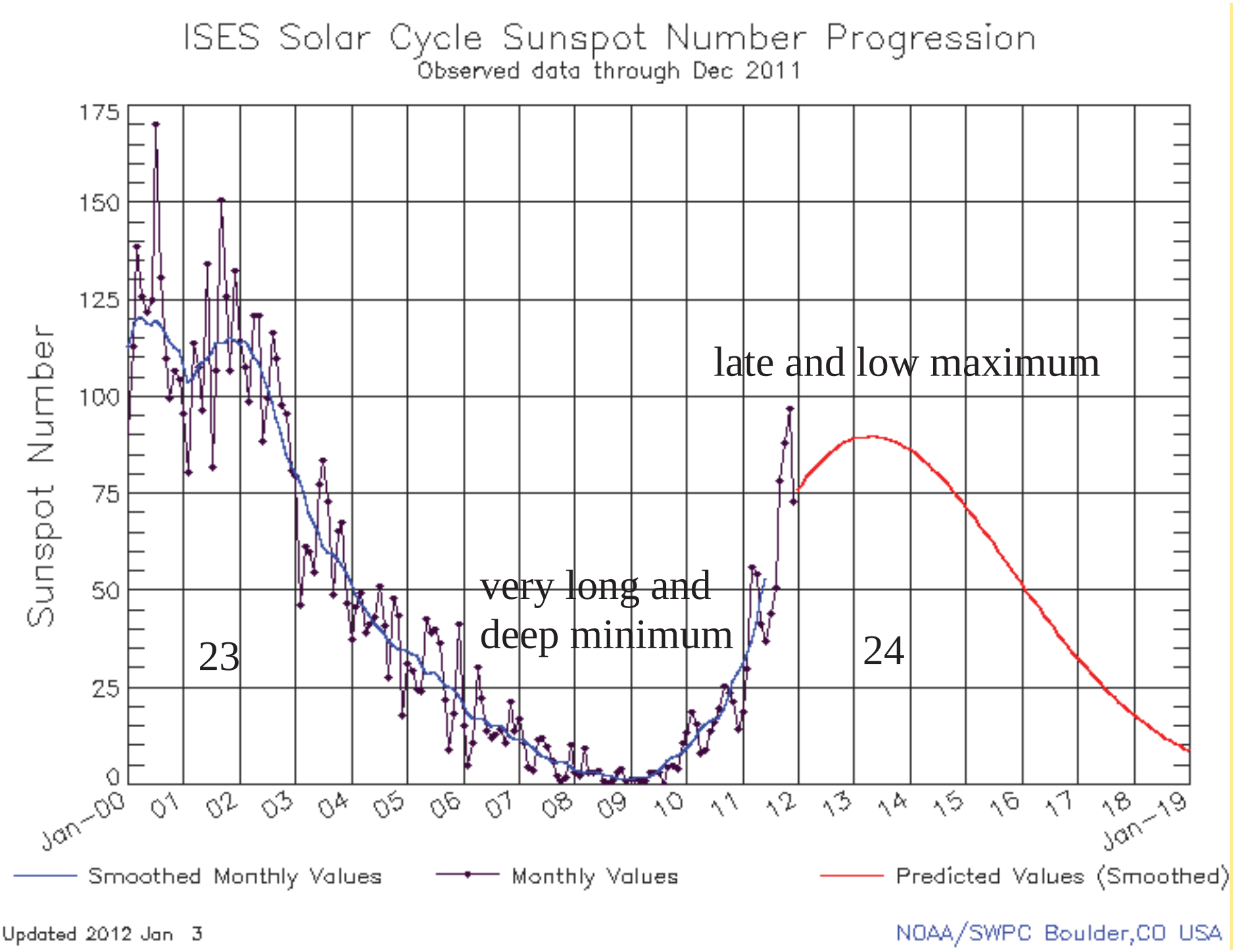


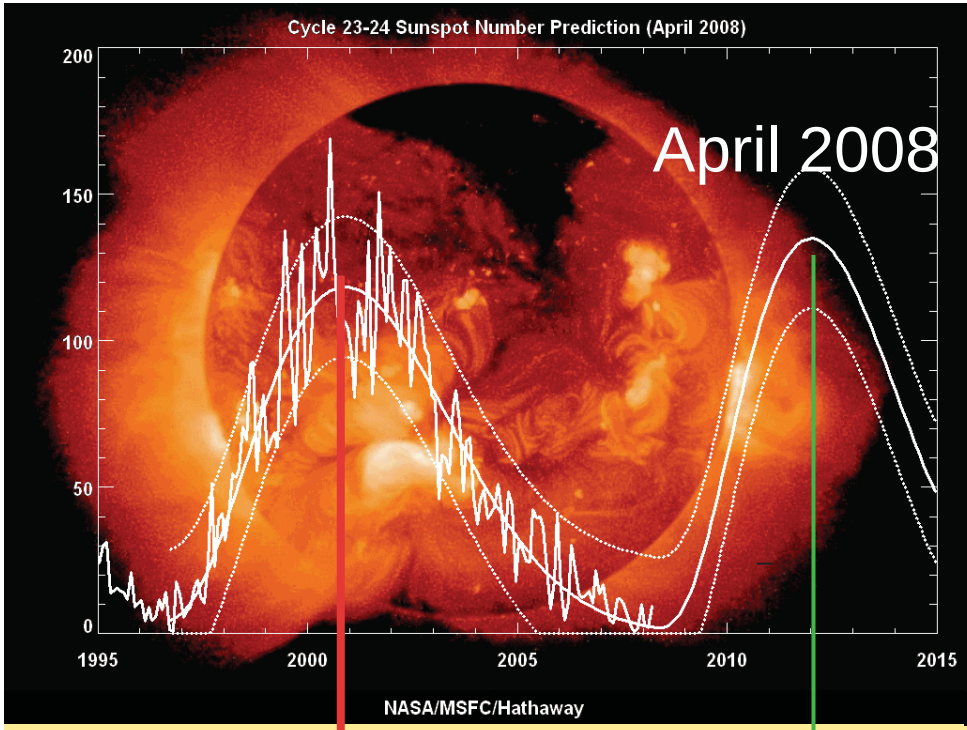
The most complete current estimate of the TSI variation between the current and prior solar minima: a decrease in the current minimum of 140 ± 92 ppm.

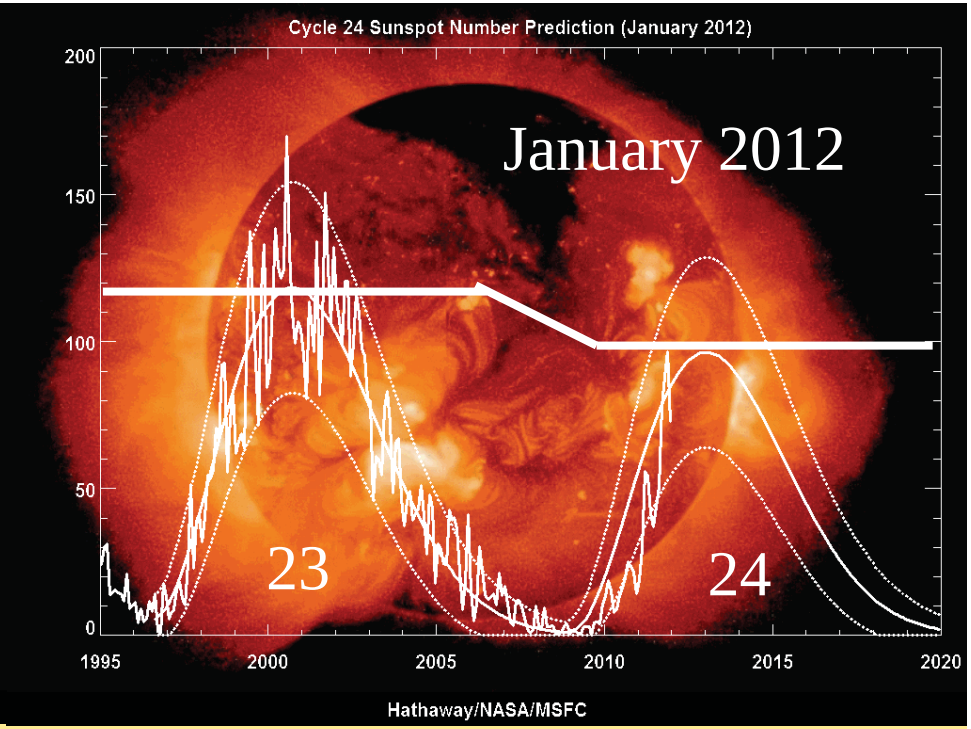
Fröhlich, C., 2009. Observational evidence of a long-term trend in total solar irradiance. Astronomy and Astrophysics 501(3): L27-L30.

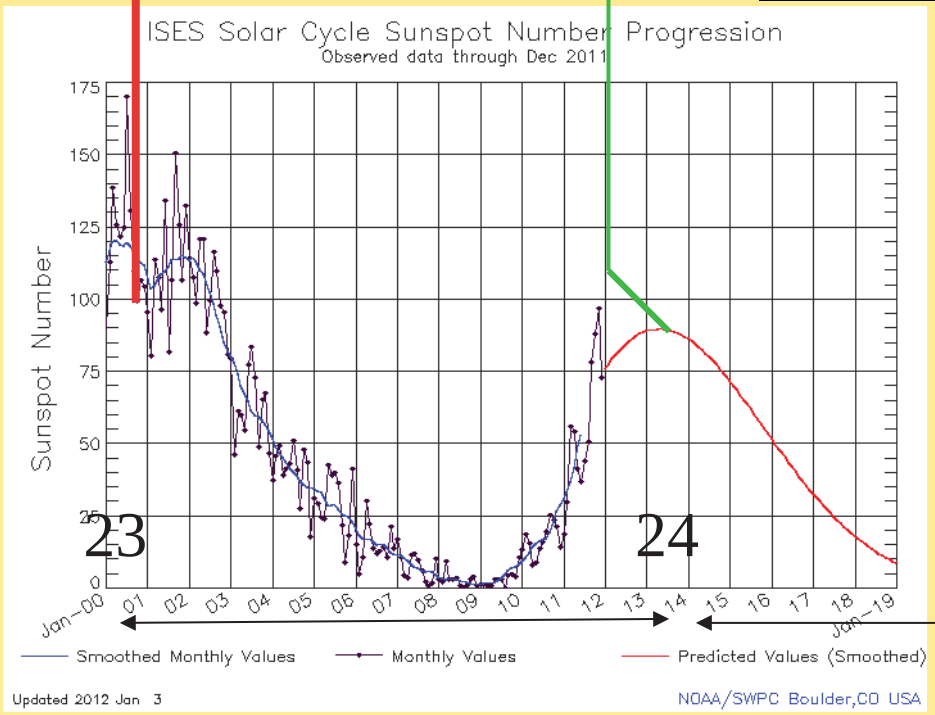


Predictions for maximum cycle 24: lower and later .....


ISES Solar Cycle Sunspot Number Progression
Observed data through Dec 2011
Sunspot Number
175
150
125
100
75
50
25
0
Jan-00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
Jan-19
late and low maximum
very long and
deep minimum
23
24
Smoothed Monthly Values
Monthly Values
Predicted Values (Smoothed)
Updated 2012 Jan 3
NOAA/SWPC Boulder,CO USA







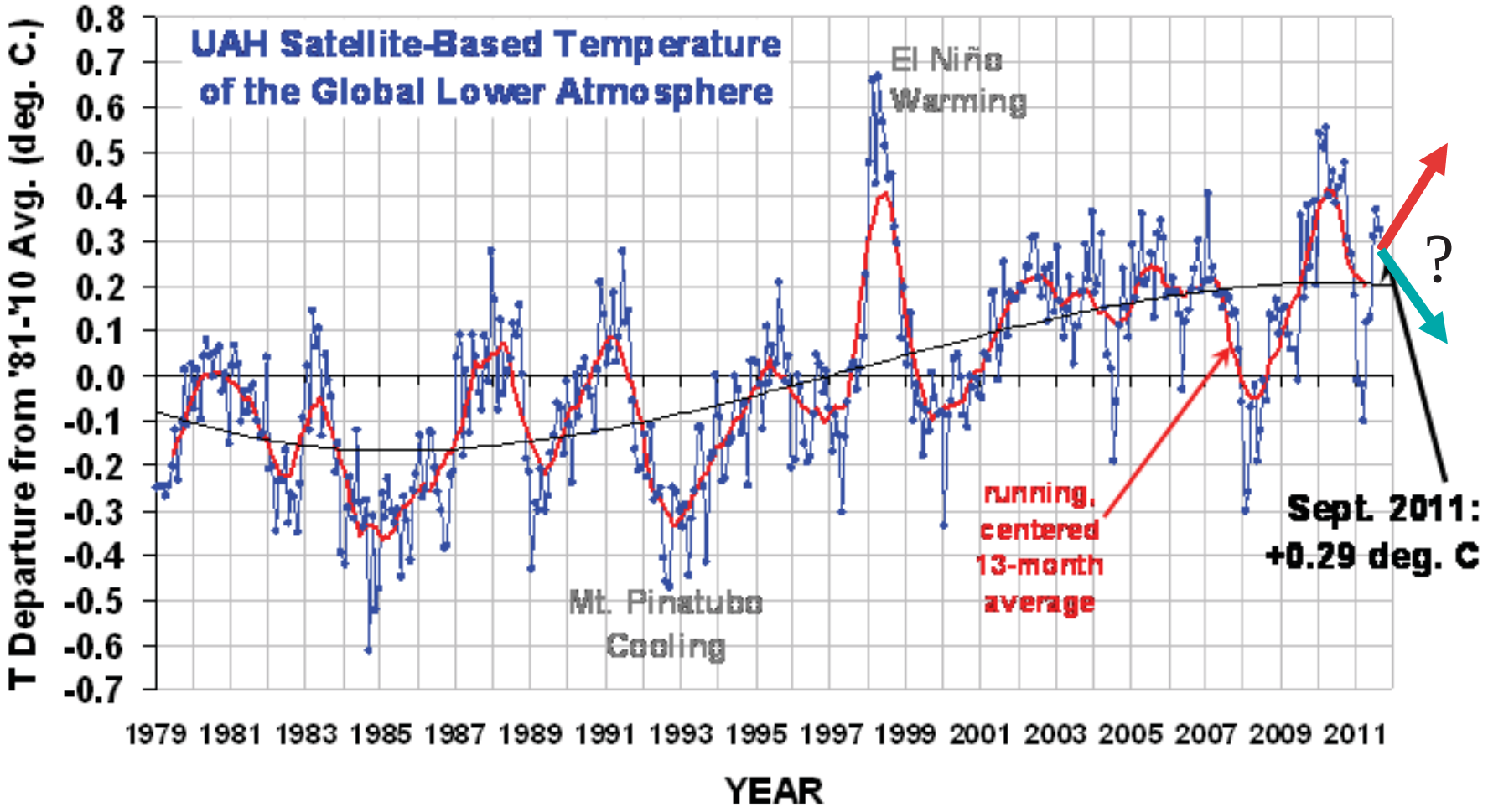
about 13 yrs from maximum to maximum

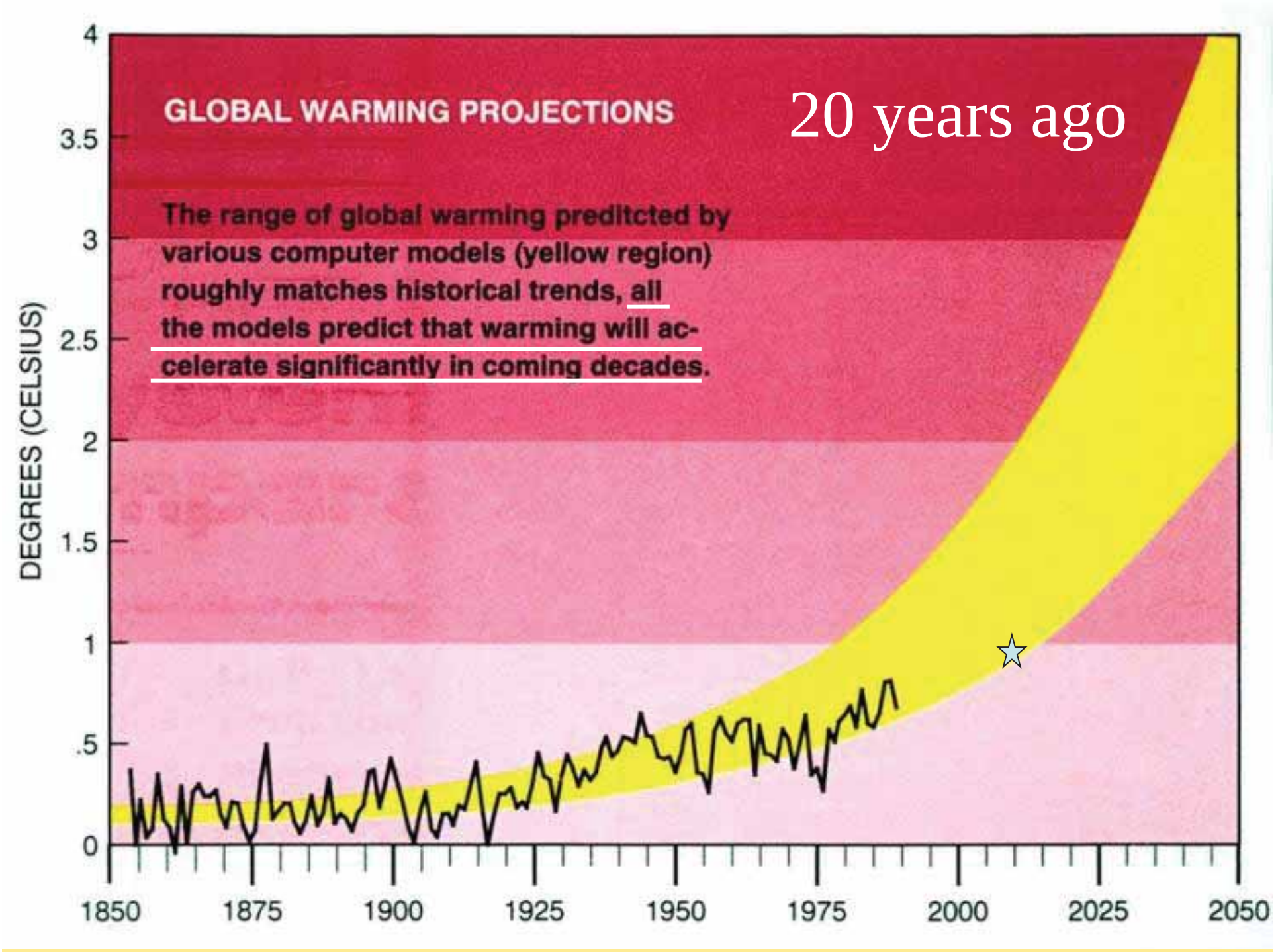
New Scientist d.d. 14th June 2010

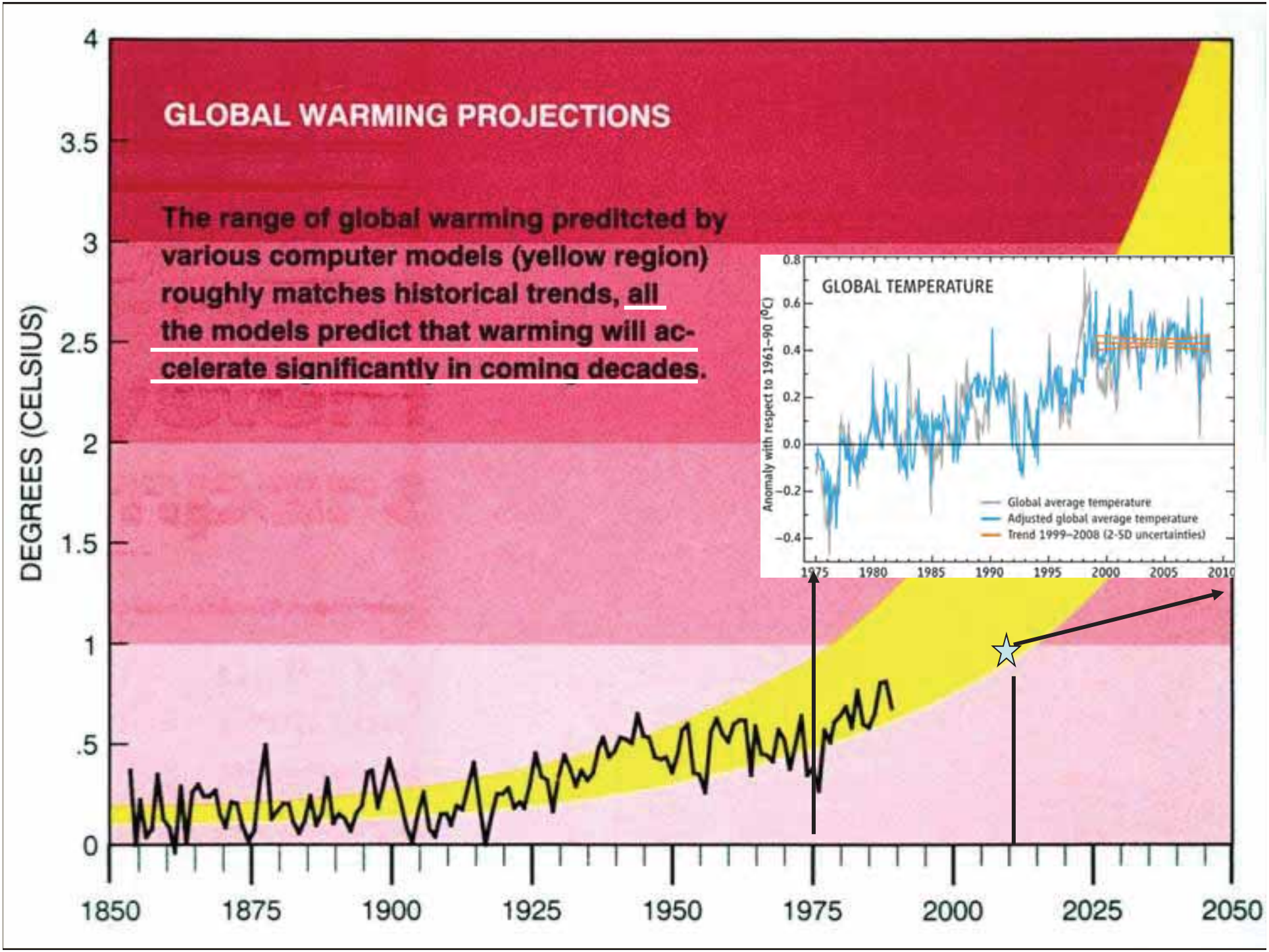
The extended collapse in solar activity during the past two years may be precisely the right sort of test, in that it has significantly changed the amount of solar radiation bombarding our planet.

Joanna Haigh (climatologist at Imperial College London):

"As a natural experiment, this is the very best thing to happen, now we have to see how the Earth responds."


UAH Satellite-Based Temperature
of the Global Lower Atmosphere
El Niño
Warming
Mt. Pinatubo
Cooling
running,
centered
13-month
average
Sept. 2011:
+0.29 deg. C
?
T Departure from '81-'10 Avg. (deg. C.)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011
YEAR


GLOBAL WARMING PROJECTIONS
20 years ago
The range of global warming predicted by various computer models (yellow region) roughly matches historical trends, all the models predict that warming will accelerate significantly in coming decades.
DEGREES (CELSIUS)
4
3.5
3
2.5
2
1.5
1
.5
0
1850
1875
1900
1925
1950
1975
2000
2025
2050


GLOBAL WARMING PROJECTIONS
The range of global warming predicted by various computer models (yellow region) roughly matches historical trends, all the models predict that warming will accelerate significantly in coming decades.
DEGREES (CELSIUS)
4
3.5
3
2.5
2
1.5
1
.5
0
1850
1875
1900
1925
1950
1975
2000
2025
2050
GLOBAL TEMPERATURE
Anomaly with respect to 1961–90 (°C)
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
1975
1980
1985
1990
1995
2000
2005
2010
Global average temperature
Adjusted global average temperature
Trend 1999–2008 (2-SD uncertainties)

Conclusions:

Solar forcing of climate change was a very important factor and probably still is very important factor.

We may experience a temperature decline in the near future.

IPCC may underestimate solar forcing of climate change.

The societal foundation for a serious energy policy will fall apart when it becomes evident that anthropogenic climate change is not very important.

The unconvenient truth is that climate is the most complex system we know.

A ‘stable climate’ is a *contradictio in terminis*.

Natural archives (lake sediments, peat deposits, etc.) are very important for understanding natural climate change.

The argumentation for the necessity to reduce the use of fossil fuels

Does that matter?

Good reasons to reduce the usage of energy based on fossil fuels:

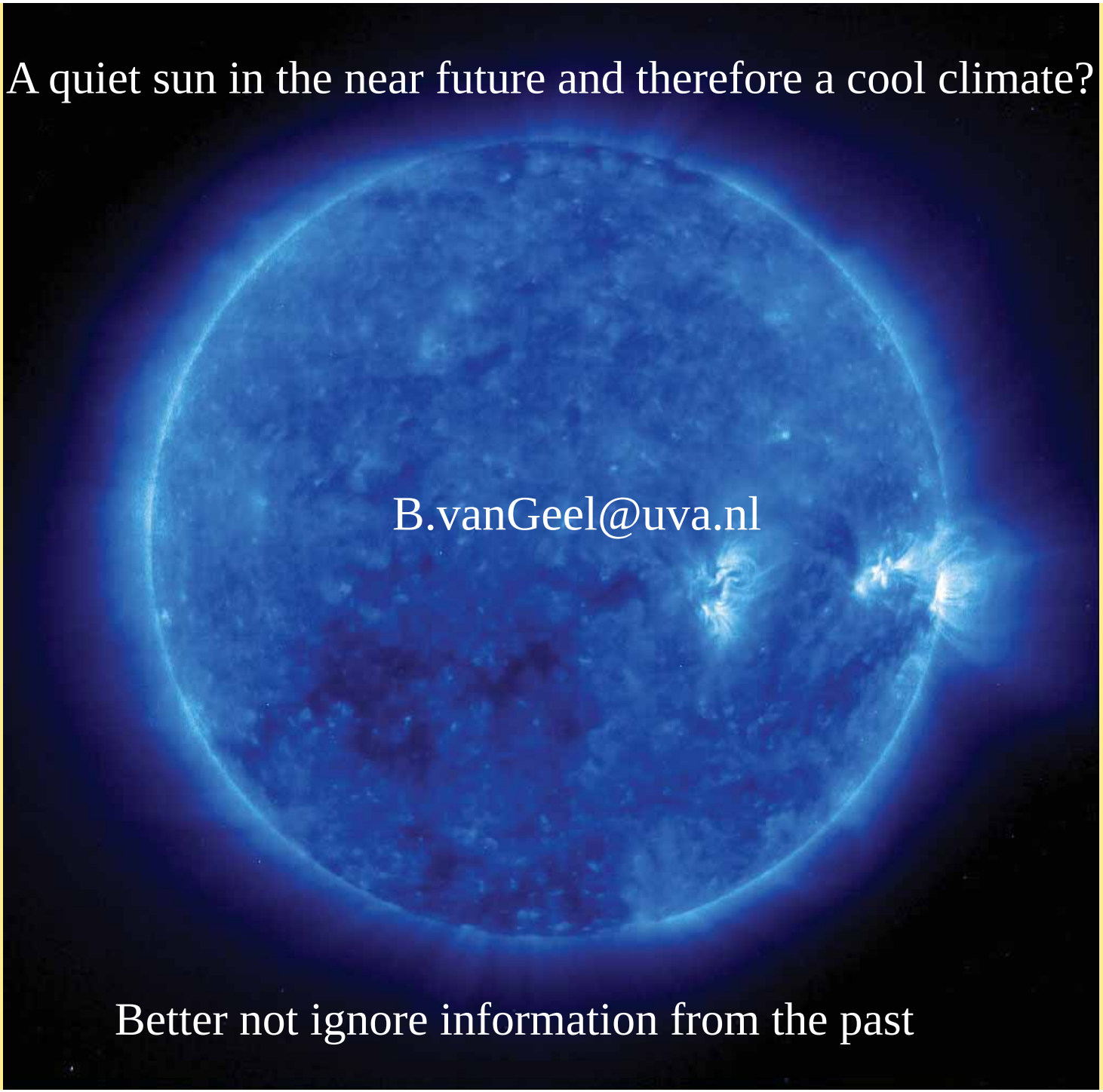
- geopolitical reasons
- avoid acidification of the oceans
- improvement air quality
- better use oil to make products instead of burning it
- (maybe we trigger climate change)

‘Energy policy’ is important and necessary!

Development of durable forms of energy supply is urgent.

Within a few years ***‘climate policy’*** probably will become a debacle for many scientists, governments, political parties and green organizations.

The debacle will be a triumph for conservative anti-green politicians.



I thank you for your attention!

Your questions and critical remarks are welcome.