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

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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.
Fluctuations of solar irradiance in W/m²? 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 $^{14}\text{C}$ and $^{10}\text{Be}$ 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
Cosmic ray intensity measured by the Univ. of Chicago Climax Neutron Monitor.
1947: Libby discovered $^{14}\text{C}$

6 protons: Carbon
6 neutrons: $^{12}\text{C}$ is stable
7 neutrons: $^{13}\text{C}$ is stable (1%)
8 neutrons: $^{14}\text{C}$ radioactive

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

$^{14}\text{C}$ decay: $^{14}\text{C} \rightarrow^{14}\text{N} + \text{elektron}$

(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
$^{14}\text{C} \text{ (BP)}$

U-series corals & marine varves

dendro-chronology

calBC/AD
Wiggles in the $^{14}$C calibration curve: changing cosmic ray intensity (changing solar activity)
Delta $^{14}$C calibration curve

1100 - 200 cal BC

correction for radioactive decay

low solar activity
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.
Fast Stalagmite Growth

δ¹⁸O measured in stalactites – indicator of rainfall on edge of inter-tropical convergence zone – compared with Δ¹⁴C observed globally in trees (Neff et al., Nature, 2001)

Stalagmite Growth in Oman
Ice-rafted debris abundance (%) vs. $^10$Be flux (10$^5$ atoms cm$^{-2}$)

$r = 0.56$

1000 years

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(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)
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.
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

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

and

Major change *Sphagnum* species at Subboreal-Subatlantic transition

c. 850 BC
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
Suddenly rising water table ca 850 cal BC
Bronze Age villages in West-Friesland

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

Archeological indications for fast rise of groundwater ca 850 BC.
$^{14}$C dates of a last, wet phase of archaeological sites in West-Friesland

- $2620 \pm 20$ BP
- $2650 \pm 30$ BP
- $2685 \pm 30$ BP
- $2690 \pm 25$ BP
- $2710 \pm 35$ BP
- $2740 \pm 40$ BP
- $2745 \pm 30$ BP
- $2745 \pm 30$ BP
- $2760 \pm 35$ 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)
low solar activity

Wet phase settlements West-Friesland
Abrupt rise of water table around 850 BC
Subboreal-Subatlantic transition

Magny; lake data from SE France and Switzerland
ca. 850 cal BC: starting peat growth on top of mineral soil with charcoal

Fochtelooër Veen

Raised bog deposit near Assen (northern Netherlands)
“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?
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!
Tree-ring curves of beech logs from an Iron Age fishing weir at Federsee showing a strong reduction of growth between 850 and 750 BC.

André Billamboz, 2001. Federsee (southern Germany)
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
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

More intense westerly winds bringing rain....

Haigh 1994, 1996 in Science and Nature
850 BC: problems and advantages

Problems: too wet

Advantage: less dry

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

More intense westerly winds bringing rain....

What about the tropics?
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)

Arid crisis 2700 BP

Lac Ossa, Cameroon
selection of taxa

Red line: cosmic ray intensity
Blue line: cloud anomalies

Blue line: low cloud amount
NORTHERN HEMISPHERE TEMPERATURE RECONSTRUCTIONS

Spaghetti Graph

Temperature anomaly (°C wrt 1961-1990)
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?
### Radiative Forcing Components

<table>
<thead>
<tr>
<th>HF Terms</th>
<th>HF Values (W m(^{-2}))</th>
<th>Spatial Scale</th>
<th>LCOU</th>
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<tbody>
<tr>
<td>Long-lived greenhouse gases</td>
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<td>Ozone</td>
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<td>Stratospheric water vapour from CH(_3)</td>
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<td>Surface albedo</td>
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<tr>
<td>Total Aerosol</td>
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<td></td>
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<tr>
<td>Linear albedo contribution</td>
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<td></td>
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<tr>
<td>Solar irradiance</td>
<td>0.12 (0.06 to 0.30)</td>
<td>Global</td>
<td>Low</td>
</tr>
<tr>
<td>Total net anthropogenic radiative forcing</td>
<td>1.8 (0.6 to 2.4)</td>
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</table>

**Notes:**
- Solar irradiance impact
- Total net anthropogenic forcing

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**IPCC 4th Assessment Report**
**Summary for Policymakers**
**2007**

**Steinhilber et al.**
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
El Niño warming
Past, present, future ....

The present unusual solar conditions
Instead of global warming the Earth soon will be facing a temperature decrease ....

Past solar cycles with a projection of solar cycles 24 and 25
C. de Jager and S. Duhau predict a major decline of solar activity between 2011 and 2017
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.

Predictions for maximum cycle 24: lower and later .....
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."
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.
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.
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 inconvenient 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.
A quiet sun in the near future and therefore a cool climate?

Better not ignore information from the past

I thank you for your attention!

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Your questions and critical remarks are welcome.