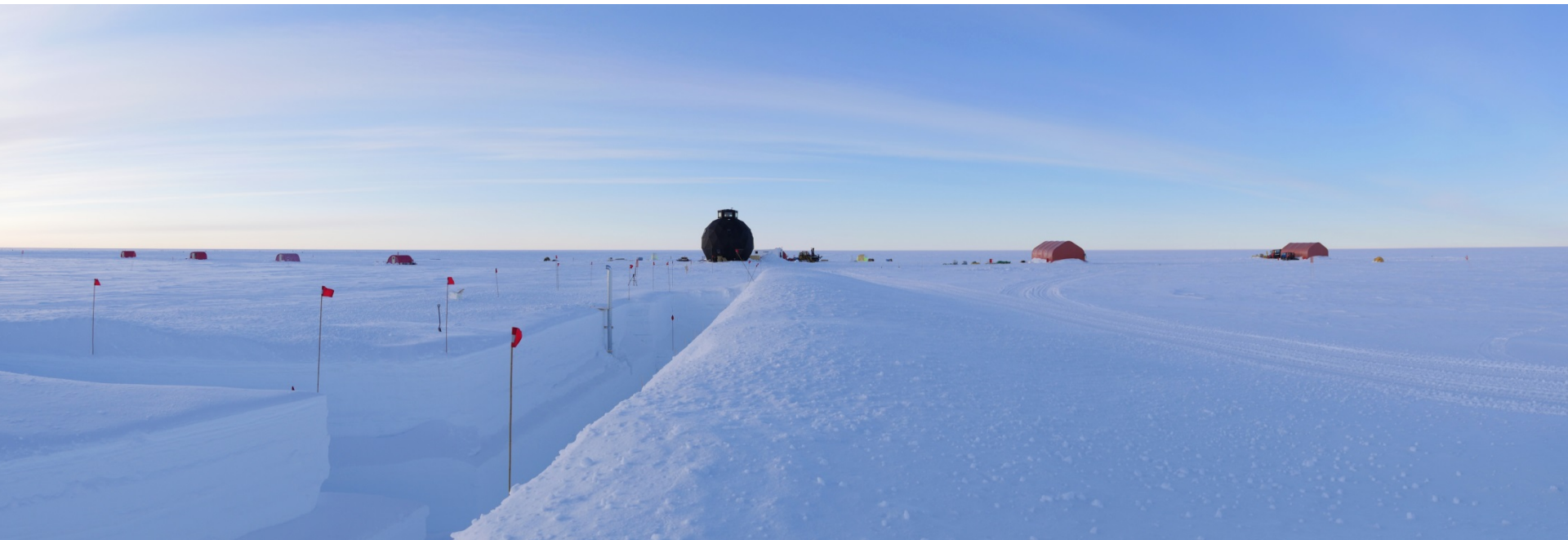
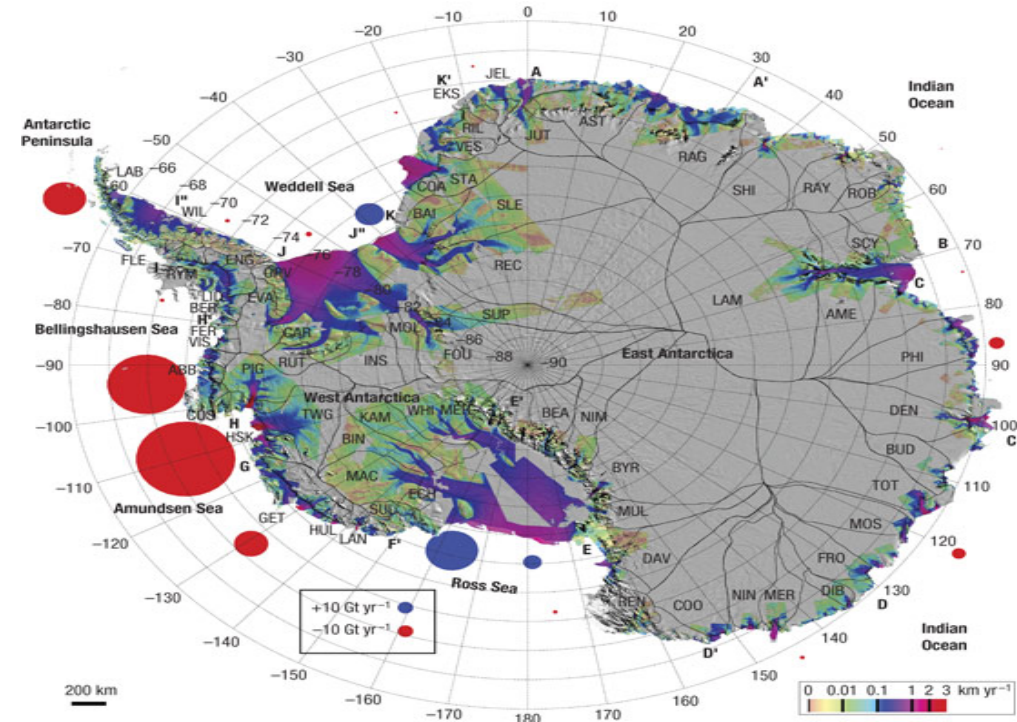


Iskerner og andre kilder fortæller om fortidens bratte klimaskift.

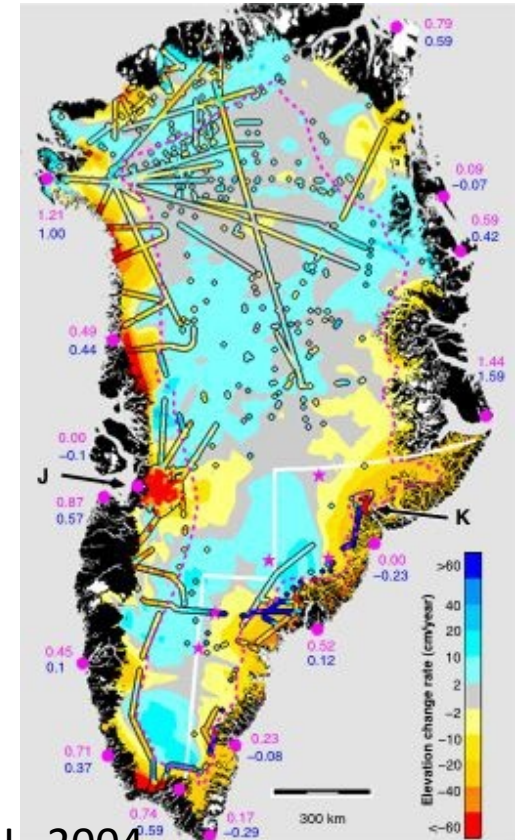


Præsenteret af Jørgen Peder Steffensen, Center for is og klima ved Niels Bohr Institutet.
Foredrag til "Big Bang", Aarhus og København 25. januar 2019.

Skrumper isen?



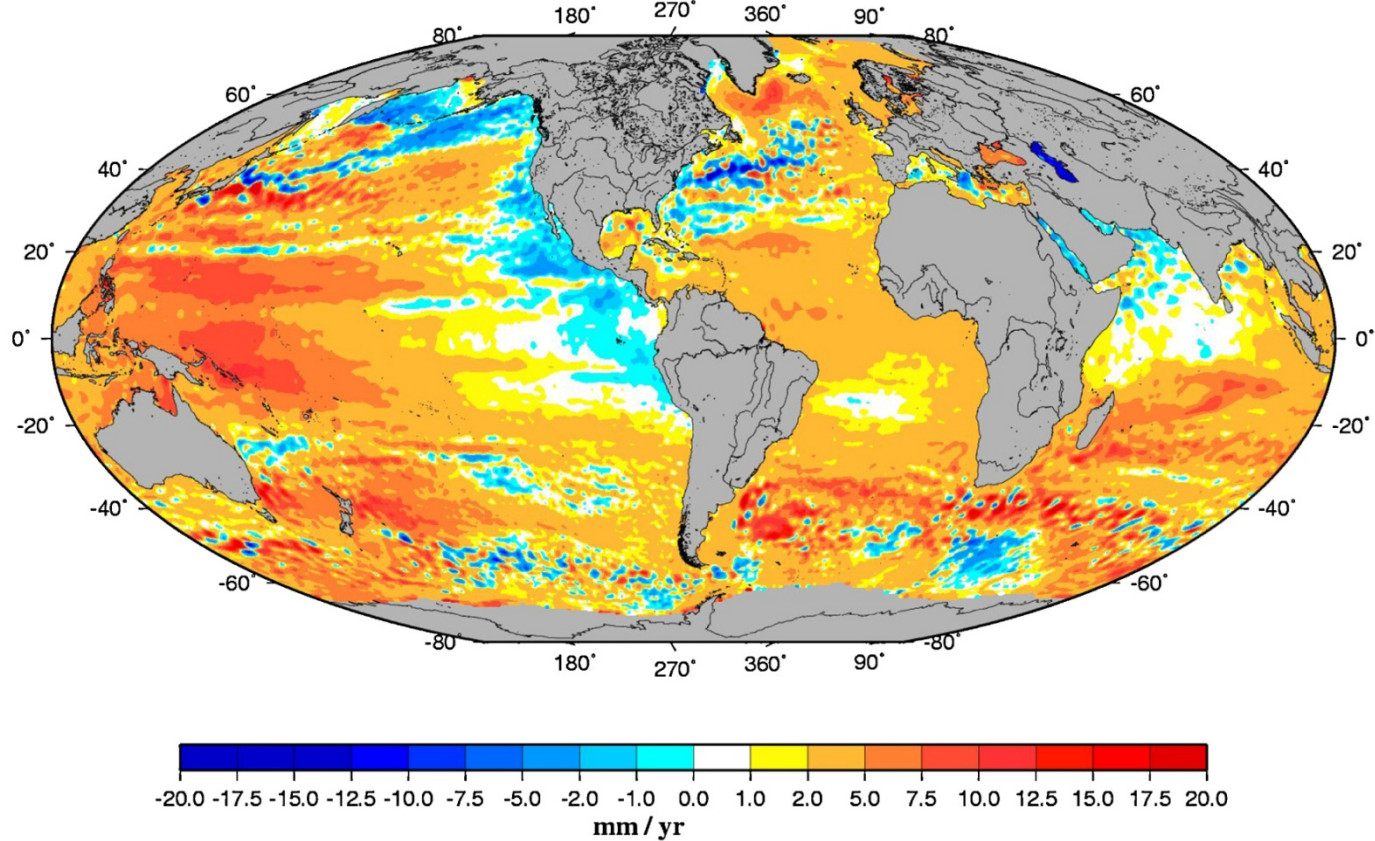
E. Rignot, Nature Geoscience, 2008



Krabil et al, GRL, 2004

Sea level trends from satellite altimetry (Oct.92-Jan.08)

LEGOS/CNES/CLS (May. 2008 netcdf qd CLS 22.05.08)



Cazenave, C. R. Geoscience, 2008



De parallelle veje ved Glen Roy, Skotland Diskuteret og overvejet af Charles Darwin og Andre Agassiz



Kangerlussuaq fjorden mod NØ, april 2015.



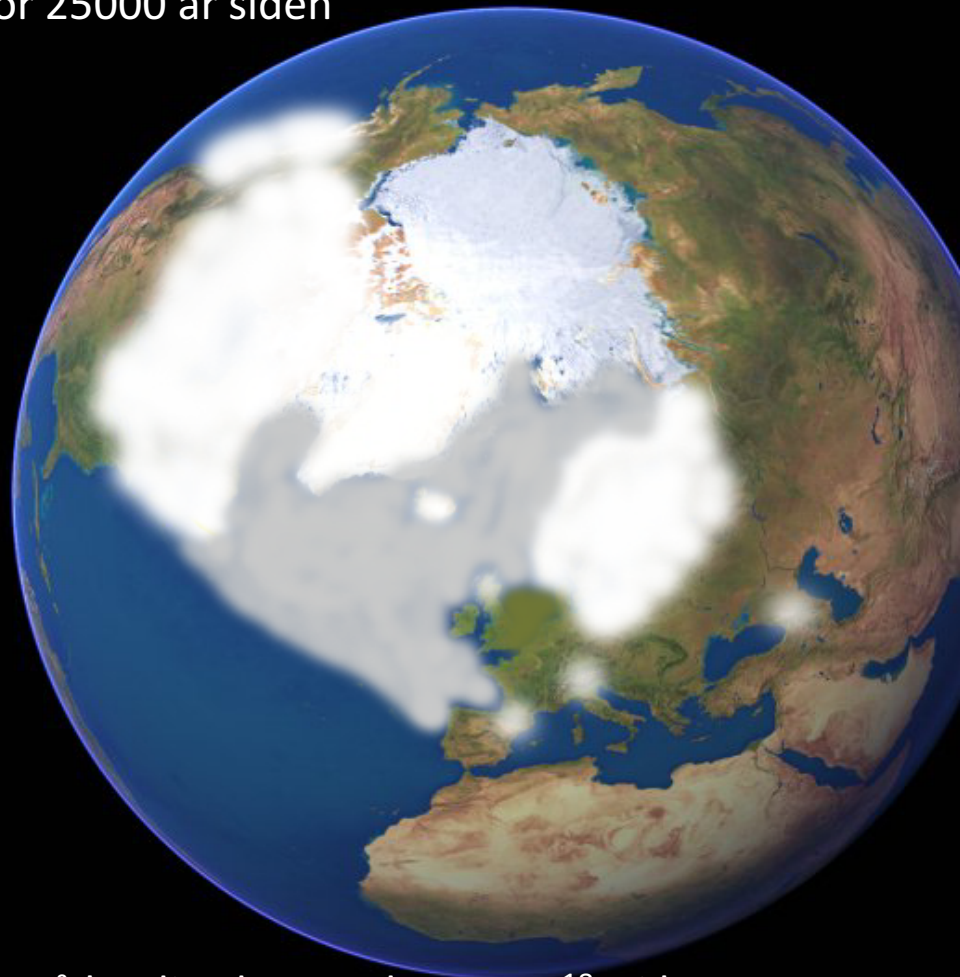
Tirslundstenen



Nu:

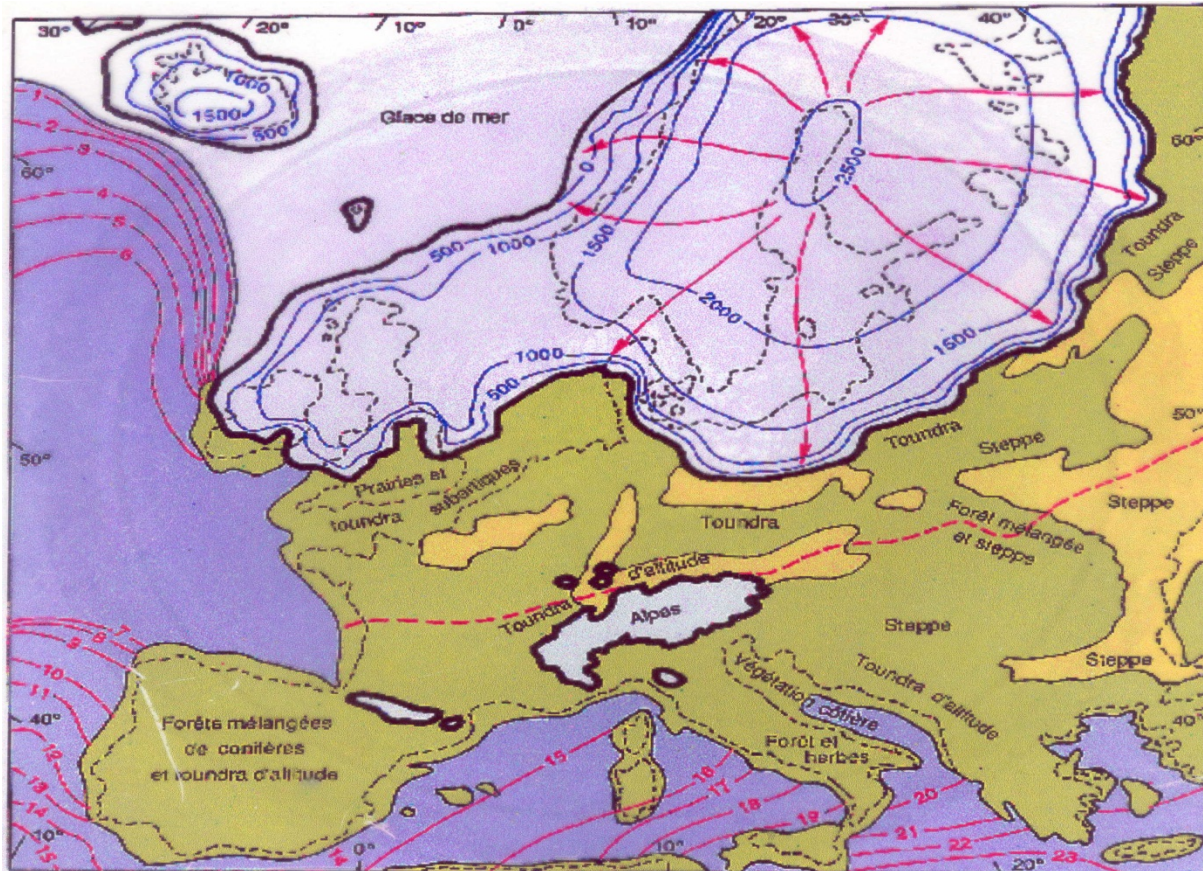


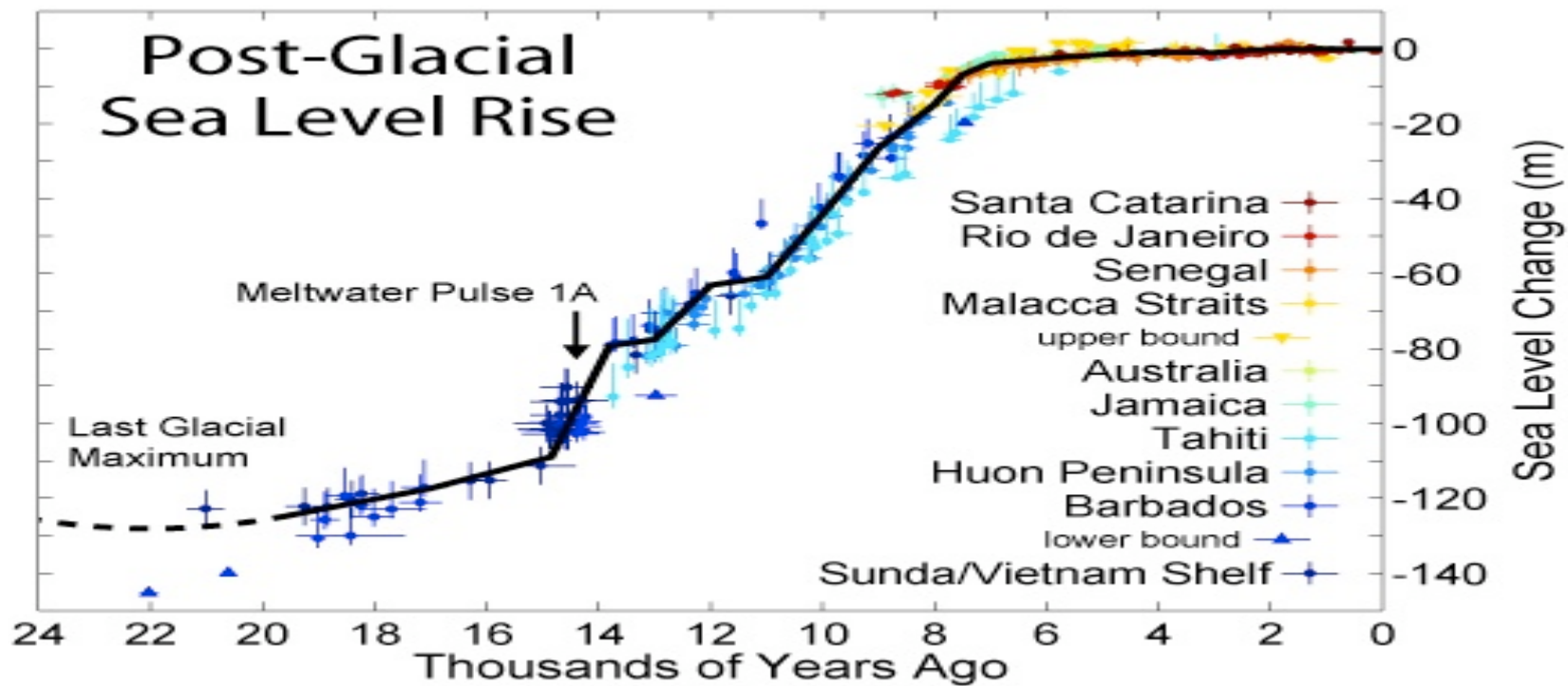
For 25000 år siden



Når der er meget is med lavt indhold af ^{18}O på landjorden, er der mere ^{18}O i havet.

Europa for 25.000 år siden





Lidt om mudder.

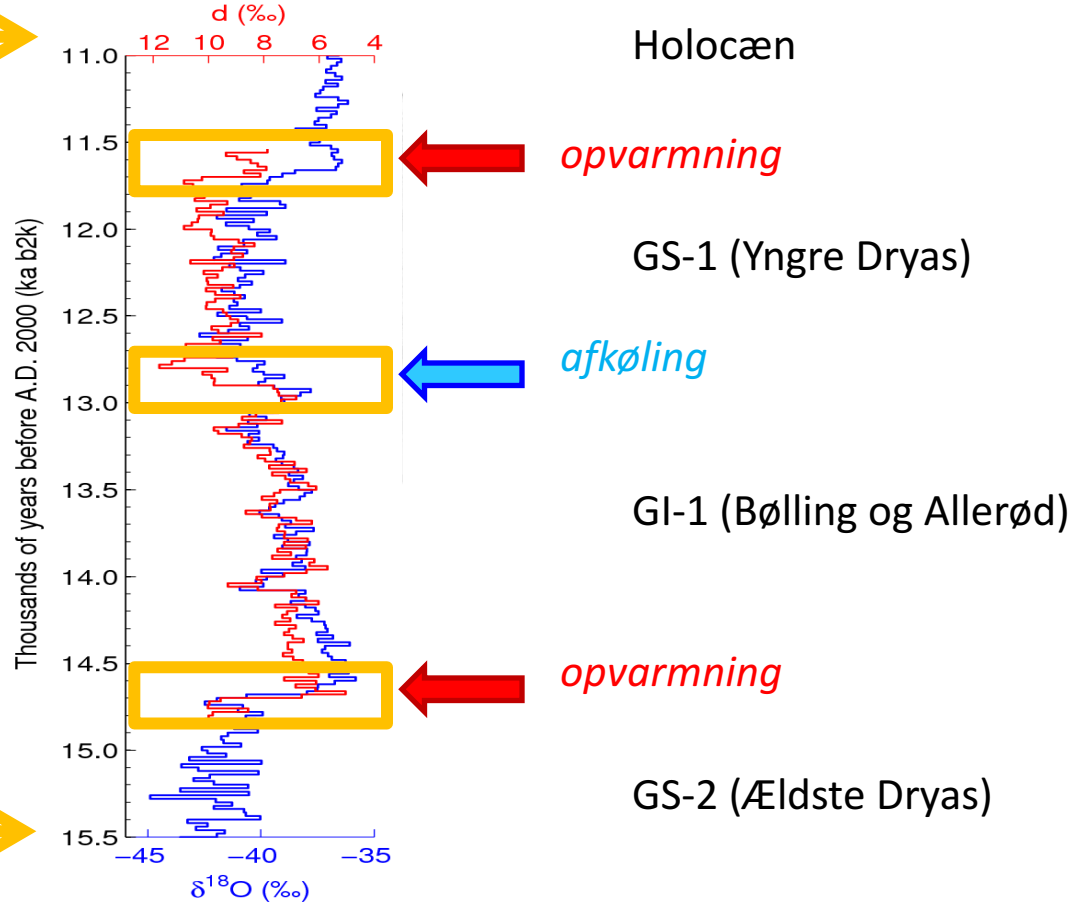
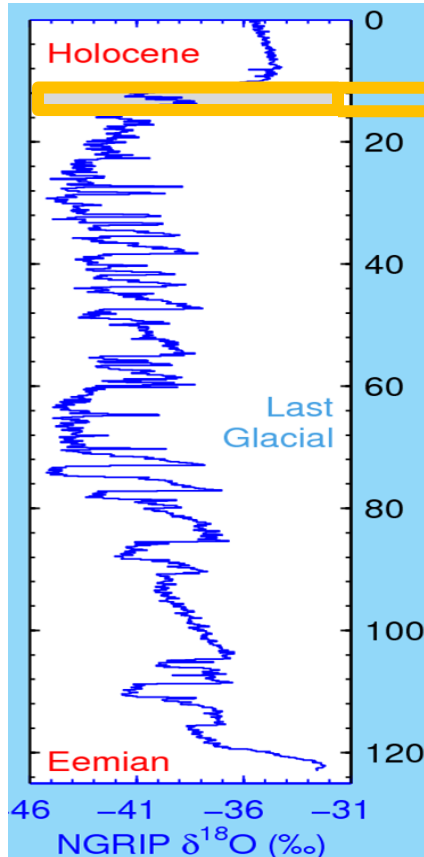


Mudderet indeholder ofte pollen

Les Cwynar ved Splan Pond i
New Brunswick , Canada



Studiet af dynamikken af abrupte klimæændringer



Slotseng bassinet

Nanna Noe-Nygaard



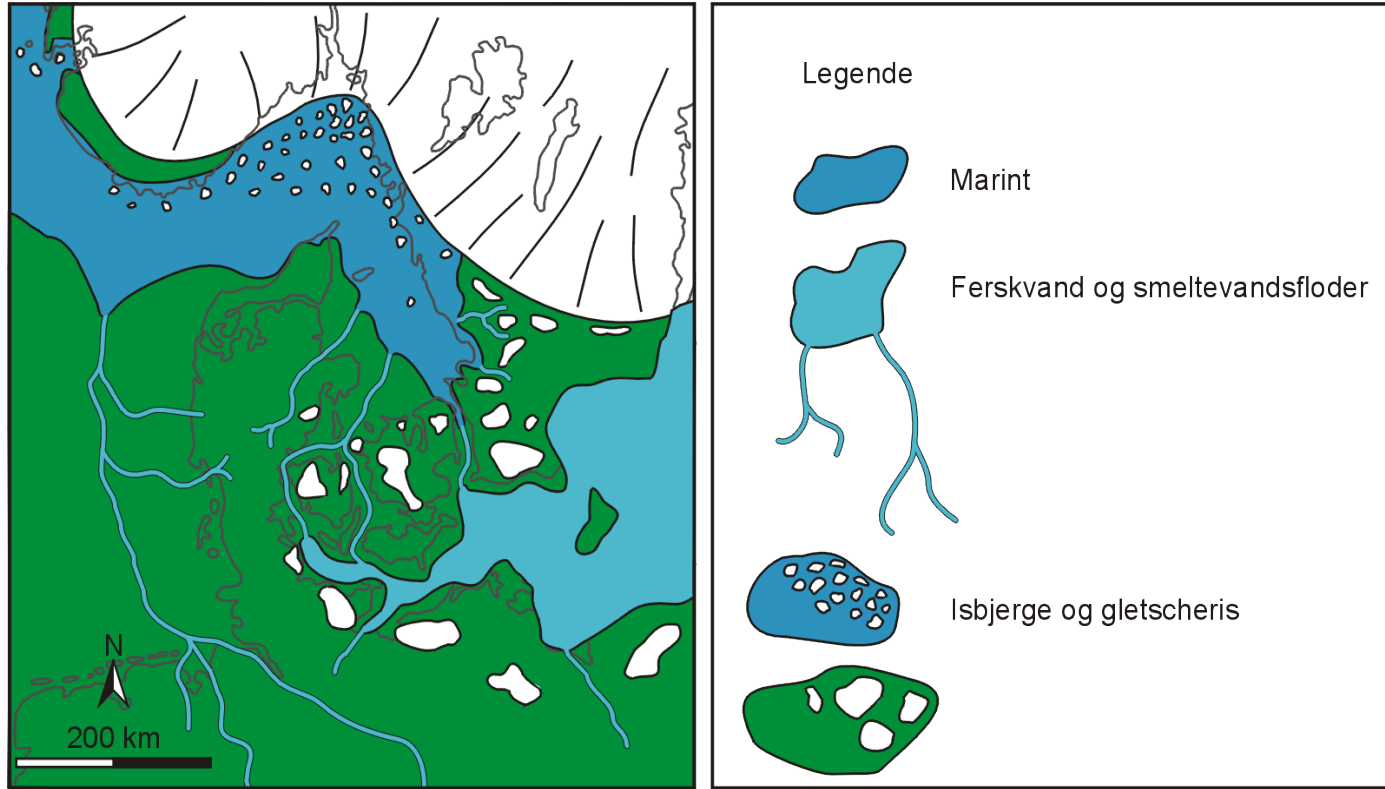
Bølling Allerød overgangen



Fodspor af rensdyr eller hjort i Allerød gyttje.
ca.14000 år gammelt

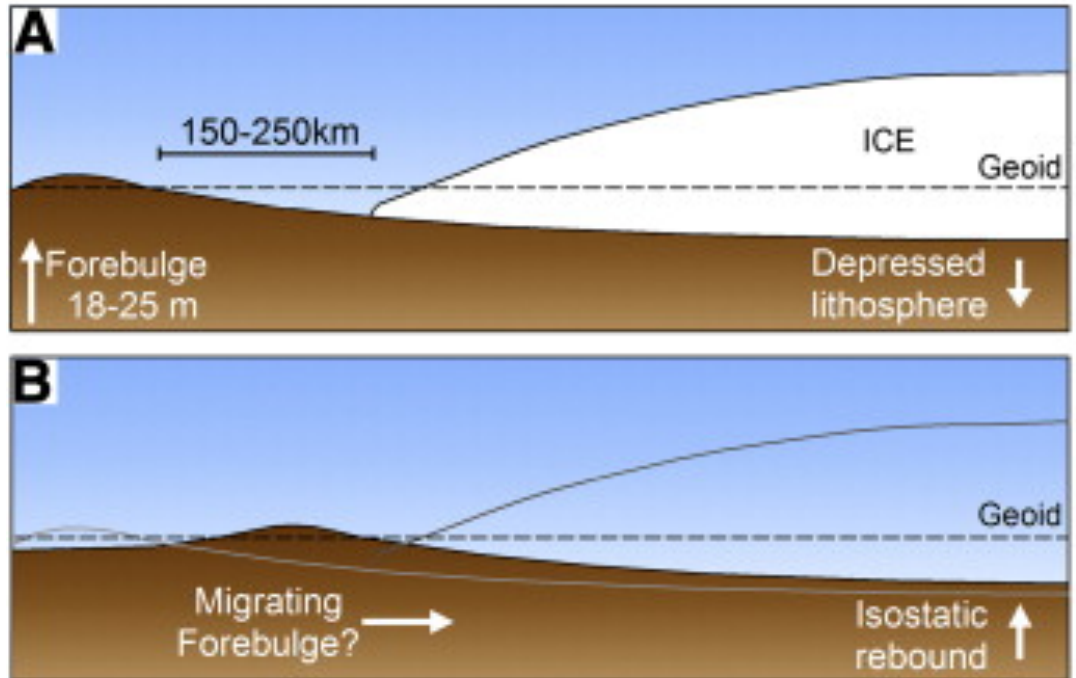


Den aktive is for 15-16.000 år siden Houmark Nielsen



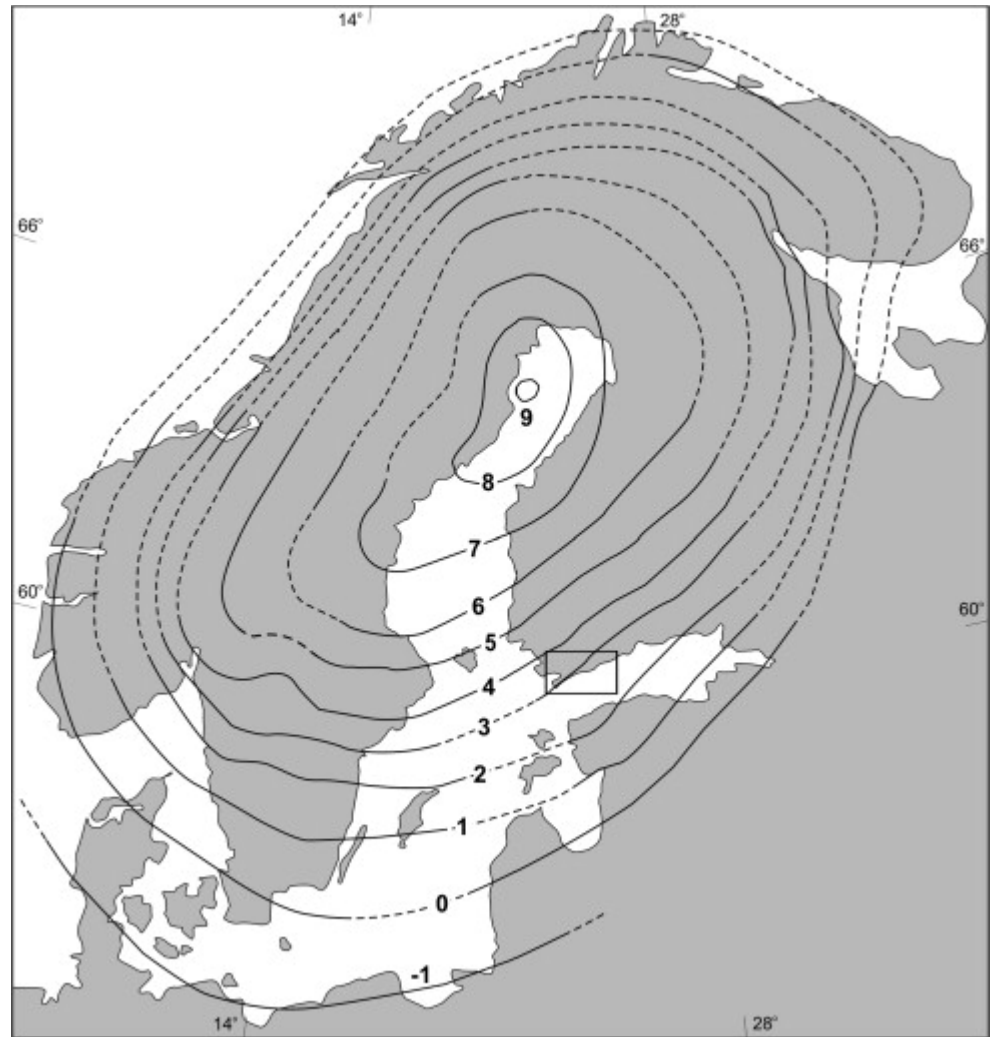
Tidlig opdagelse af klimavariationer ved istidens afslutning: Hartz, H. og V. Milthers (1901) Det sen-glaciale Ler i Allerød Teglværksgrav. Meddelelser fra Dansk geologisk Forening 8: 31-60.

”puklen” foran isen



- Nuværende rater for landhævning i mm/år.

Fra: Miettinen et al., Marine Geology 2007.



Vigtige isotoper i Palaeoklimaforskningen

- Stabile isotoper, f.eks. ^{16}O og ^{18}O i vand H_2O og i kalk (drypsten, koraller og skaller) CaCO_3 .
- Radioaktive isotoper i jordskorpen: ^{40}K (1,3 mia. år) som henfalder til ^{40}Ar (stabil). Og ^{238}U (4,5 mia.år) som henfalder til ^{234}U (247.000 år) og senere til ^{230}Th (80.000 år).
- Radioaktive isotoper dannet ved kosmisk stråling i atmosfæren: ^{14}C (5730 år), ^{10}Be (1,4 mio. år), ^{36}Cl (310.000 år) og ^{81}Kr (230.000 år)

One Thousand Centuries of Climatic Record from Camp Century on the Greenland Ice Sheet

W. Dansgaard, S. J. Johnsen, J. Møller, C. C. Langway, Jr.

One Thousand Centuries of Climatic Record from Camp Century on the Greenland Ice Sheet

Abstract. A correlation of time with depth has been evaluated for the Camp Century, Greenland, 1390 meter deep ice core. Oxygen isotopes in approximately 1600 samples throughout the core have been analyzed. Long-term variations in the isotopic composition of the ice reflect the climatic changes during the past nearly 100,000 years. Climatic oscillations with periods of 120, 940, and 13,000 years are observed.

Use of the oxygen-18 concentration in glacier ice as an indicator of past climatic conditions was proposed in 1954 (1). The concentration of O^{18} in precipitation, particularly at high latitudes, is determined mainly by its temperature of formation. Decreasing temperature of formation leads to decreasing content of O^{18} in rain or snow. Analysis of stable isotopes has become an important method in studies of ice

Few methods exist for dating a deep ice core. Some advances have been made with C^{14} dating (8) in which the carbon dioxide of occluded atmospheric air contained in huge blocks of glacier ice is measured for radiocarbon. Recently a technique for sampling C^{14} from ice *in situ* was tested in Greenland and Antarctica (9). These studies required a minimum of 1 ton of glacier ice.

Another way of dating an ice core is to determine the annual layers by measuring the seasonal oscillations in the O^{18} content in small vertical increments containing about 10 cm^3 of the core and then to count the summer maxima continuously from the surface downward. Unfortunately, various processes tend to diminish the isotopic gradients in snow and ice. For example, molecular diffusion in the firn and solid ice, hastened by the progressive plastic thinning of the layers with depth, gradually obliterates the oscillations that remain after firnification. This process alone establishes a limit

V_x proportional to $x \cdot y$ from
 $y = 0$ to $y = h$ ($= 400 \text{ m}$),

V_x proportional to x , but independent of
 y , from $y = h$ to $y = H$ ($= 1367 \text{ m}$),

x being the distance from the ice divide, y the distance from the bottom, and H the thickness of the ice sheet in meters of ice. Here H equals 1367 m of ice, instead of 1390 m of core, to correct for the low firn densities in the upper layers.

Basic mass balance considerations led to the following expressions for the vertical velocity components:

$$V_y = -\frac{a}{2H-h}(2y-h), \quad H \geq y \geq h$$

$$V_y = -\frac{a}{h(2H-h)}y^2, \quad h \geq y \geq 0$$

and, thereby, to the age of the ice at a distance y from the bottom:

$$t = \int_H^y \frac{dy}{V_y}$$

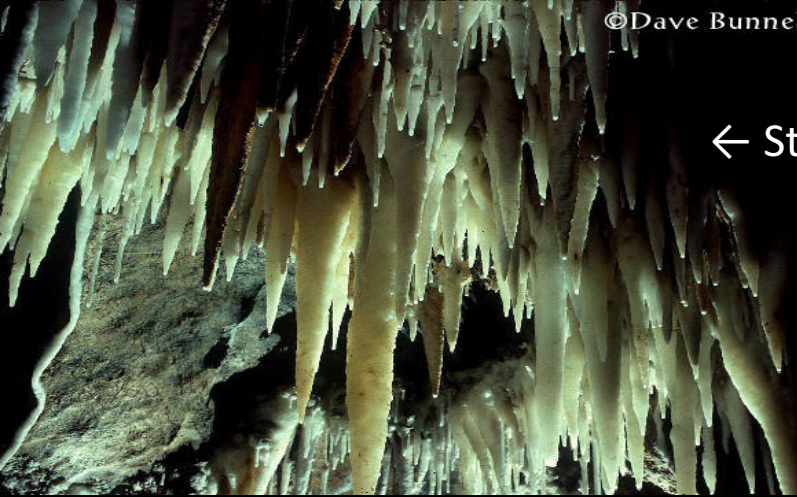
The results of the calculations are

Science, 1969.
 Iskernernes fødsel
 i studier af
 palaeo-klimaet

Drypsten, koraller og foraminiferer (Kalk, vand og kedelsten)

- Drypsten: Når regnvand løber gennem lag med kalk, opløses noget af kalken og vandets $^{16}\text{O}/^{18}\text{O}$ udveksles med kalkens O i CaCO_3 . Drypstenens kalk får derfor nedbørens $^{16}\text{O}/^{18}\text{O}$.
- Koraller og foraminiferer: Disse dyr benytter havets vand til dannelse af kalkskaller. Derfor har korallerne og skallerne det $^{16}\text{O}/^{18}\text{O}$ som havet havde på dannelsesstidspunktet.
- Alderen bestemmes ved Uran-Thorium metoden.

©Dave Bunnell



← Stalactites

©Dave Bunnell

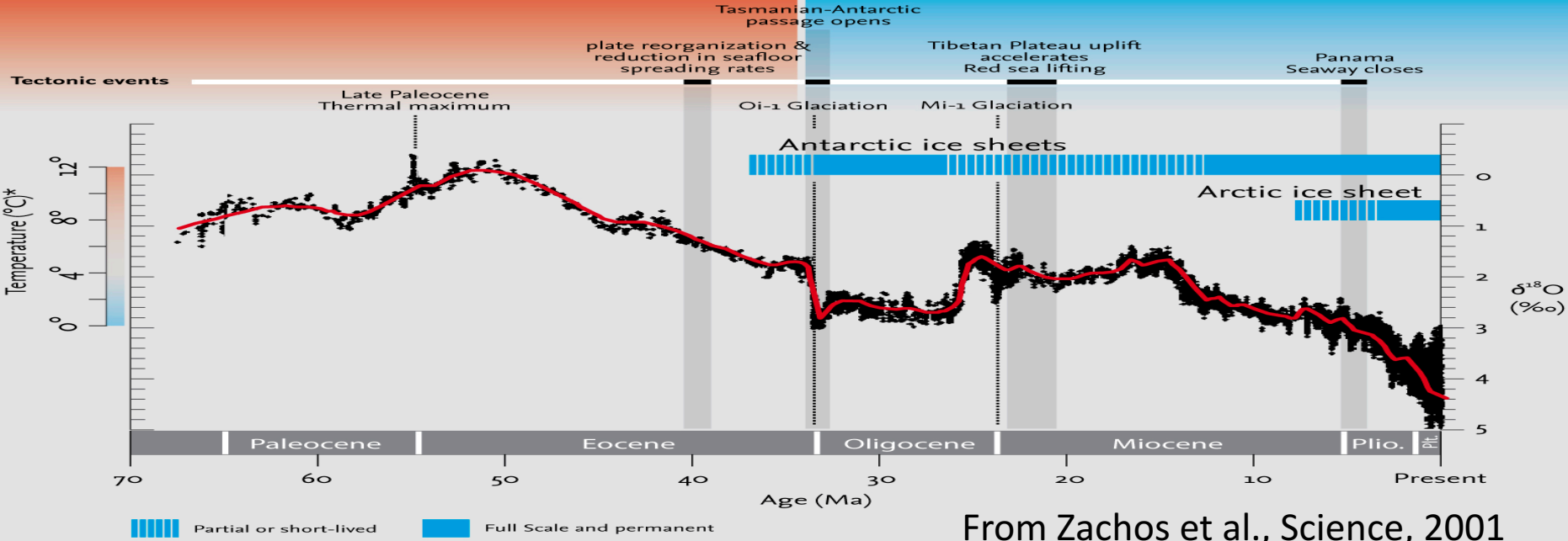


← Stalagmites



Green-House

Ice-House



From Zachos et al., Science, 2001

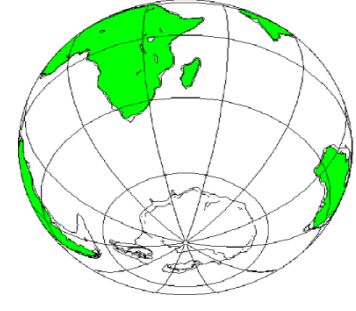
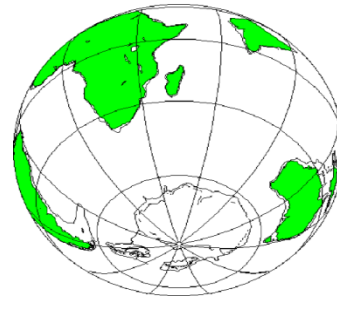
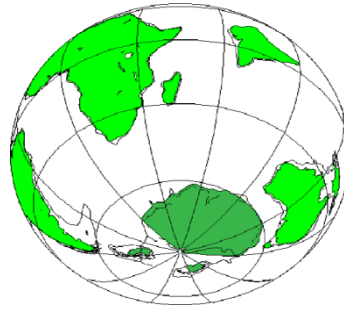
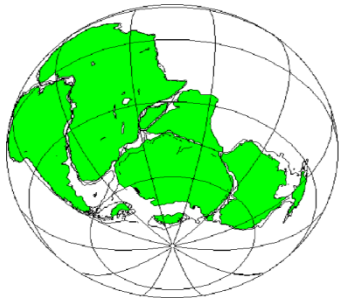
Gondwanaland: 160 Ma

Gondwanaland: 110 Ma

Gondwanaland: 50 Ma

Gondwanaland: 30 Ma

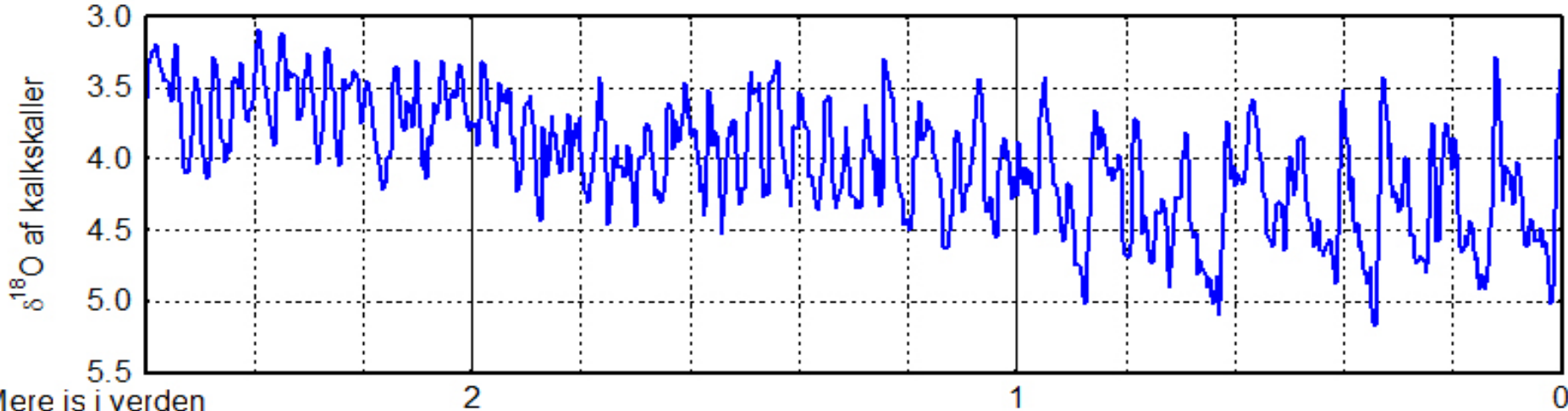
Gondwanaland: 0 Ma



Klimahistorien i de sidste 2.6 millioner år

Klimaet fra havbundssedimenter

Mindre is i verden



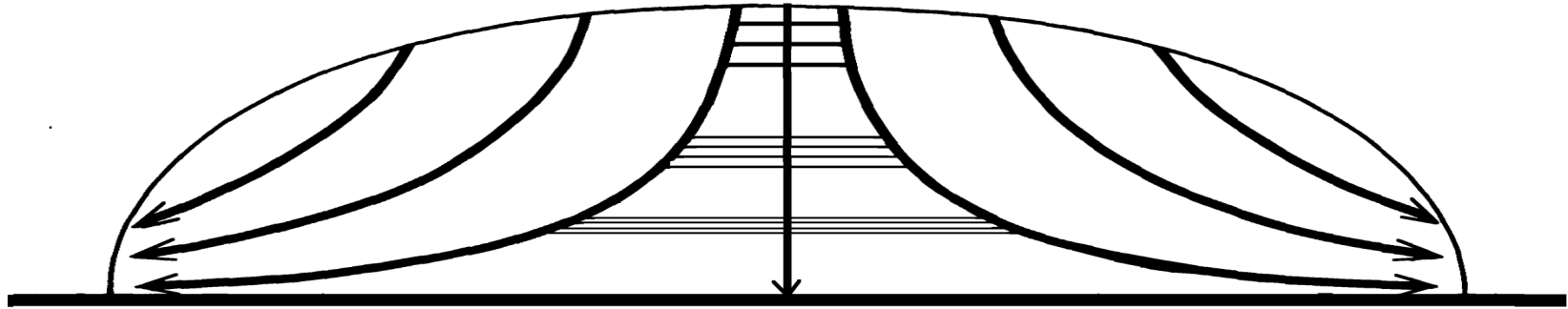
Mere is i verden

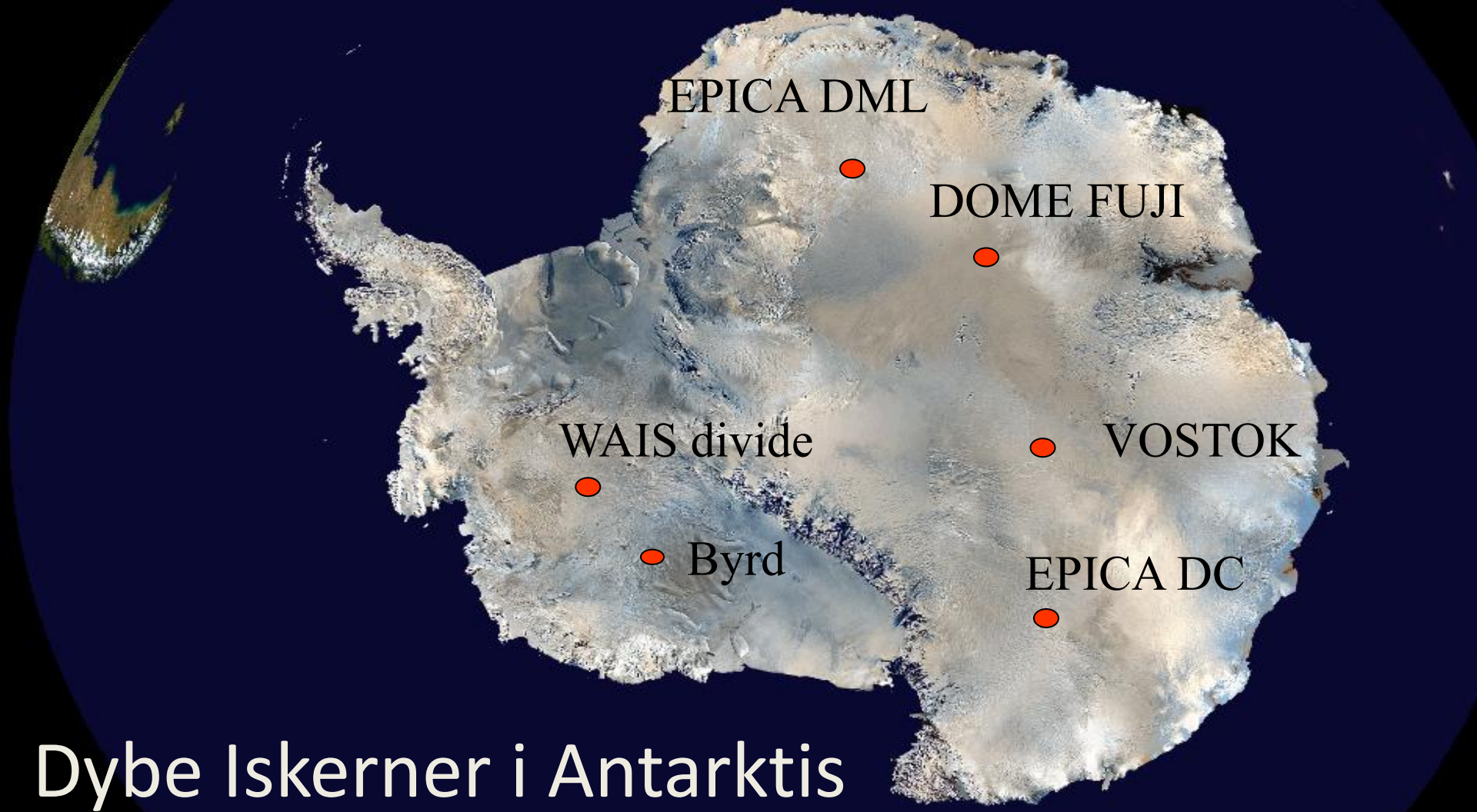
Millioner år før nu.

Data fra ODP-677 (ODP, Ocean deep Drilling Programme)



Indlandsisen i tværsnit





EPICA DML

DOME FUJI

WAIS divide

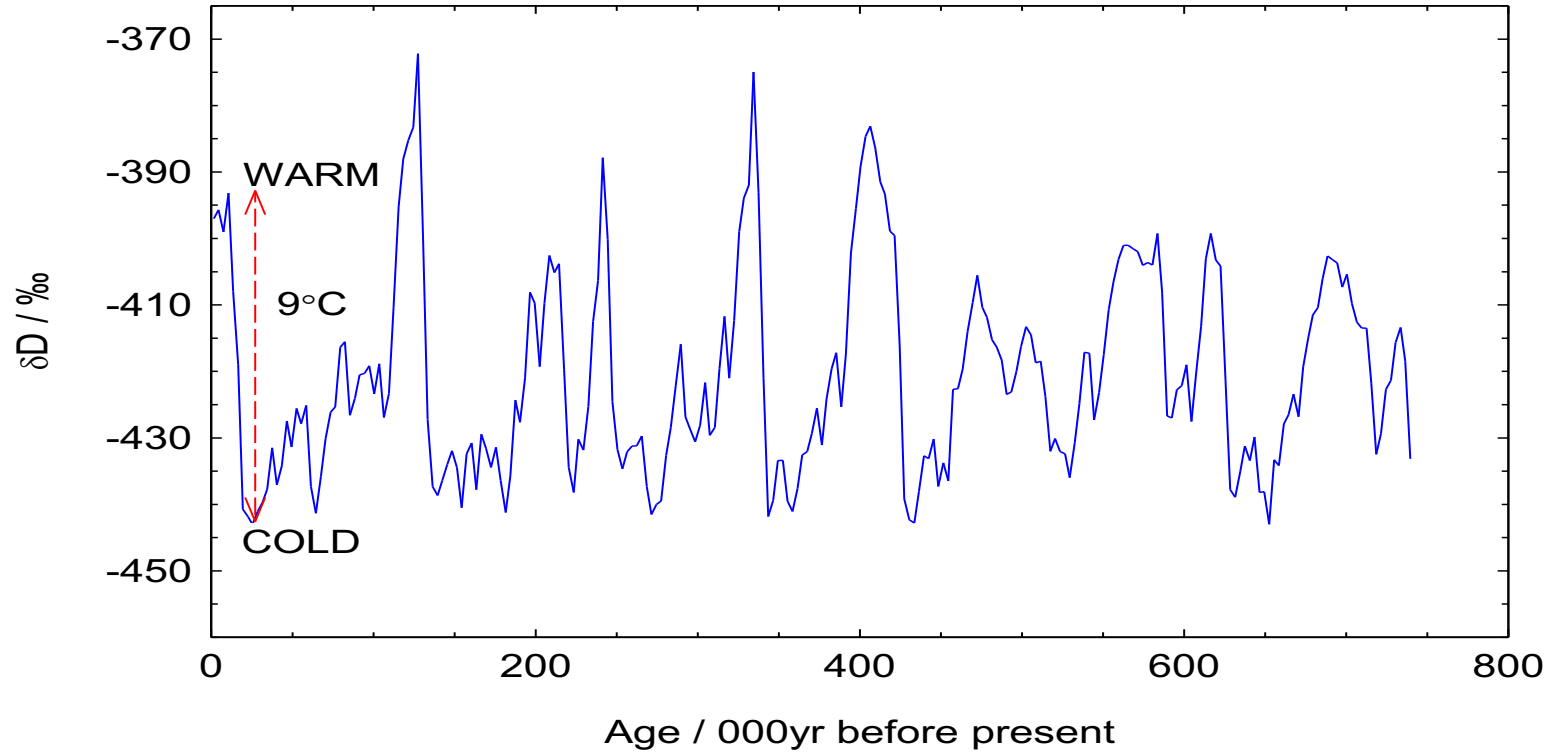
VOSTOK

Byrd

EPICA DC

Dybe Iskerner i Antarktis

Antarktisk klima i 740.000 år



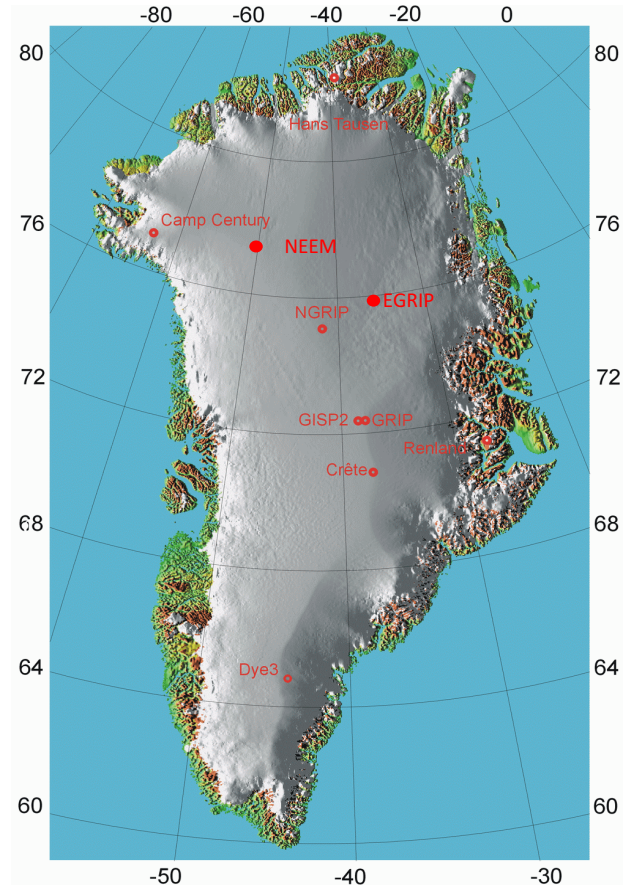


DomeC, 2004/2005

Dybe iskerner i Grønland

<u>Projekt</u>	<u>År</u>	<u>Dybde</u>
Camp Century	64-66	1390 m
Dye-3	79-81	2037 m
GRIP	89-92	3029 m
GISP2	89-93	3053 m
NorthGRIP	97-03	3085 m
NEEM	07-12	2540 m
EGRIP	15-20	(2550 m)

GRIP = Greenland Ice Core Project (EU)
GISP = Greenland Ice Sheet Project (US)



EGRIP lejren, august 2016



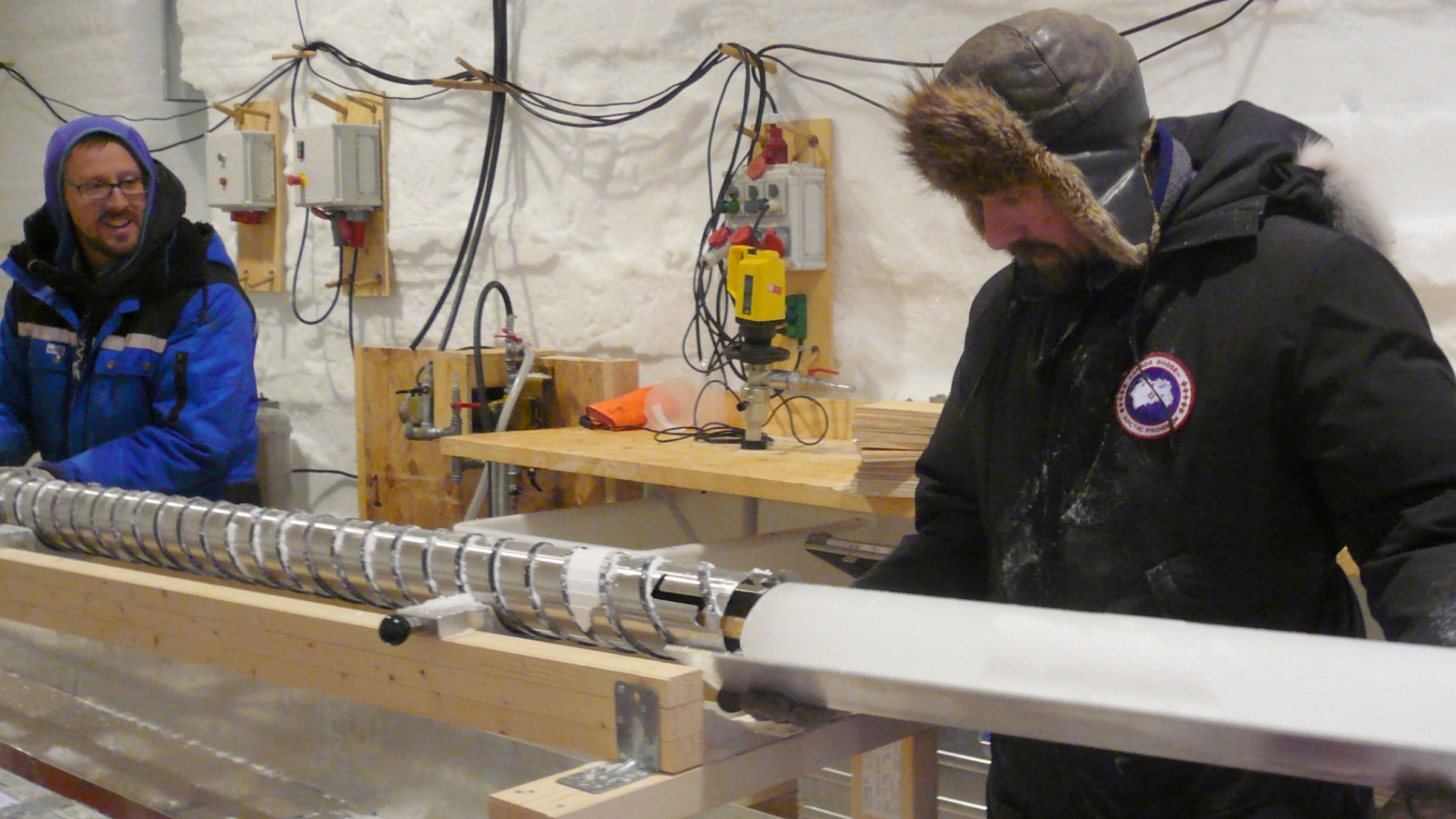
Forsyninger ankommer





Ice core drilling







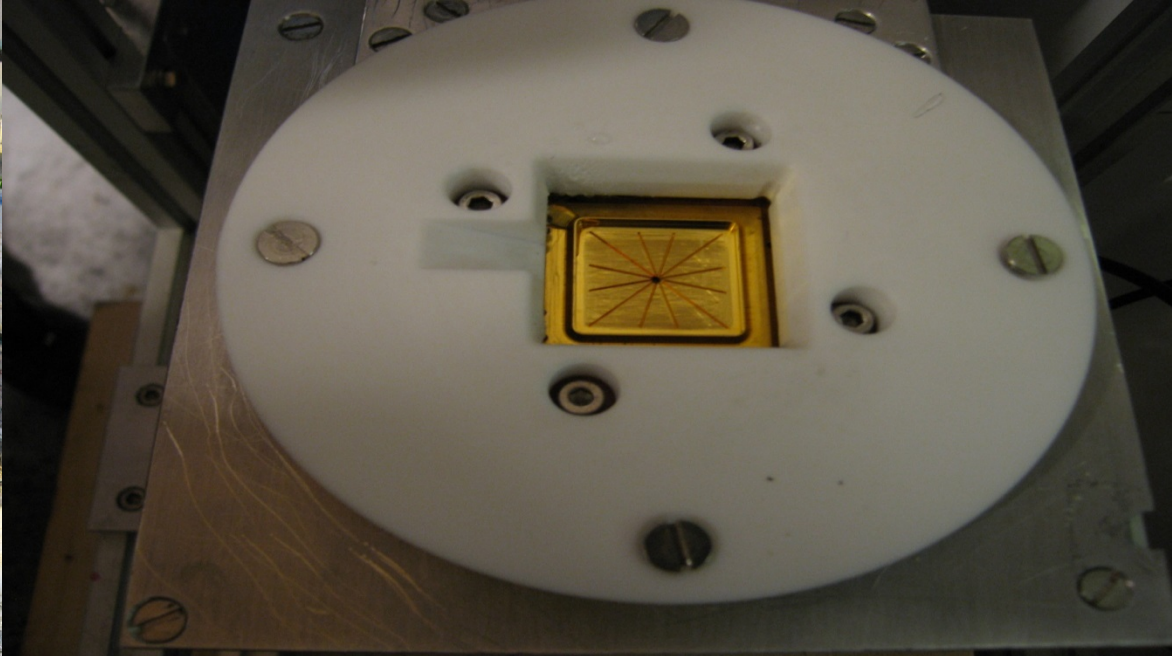
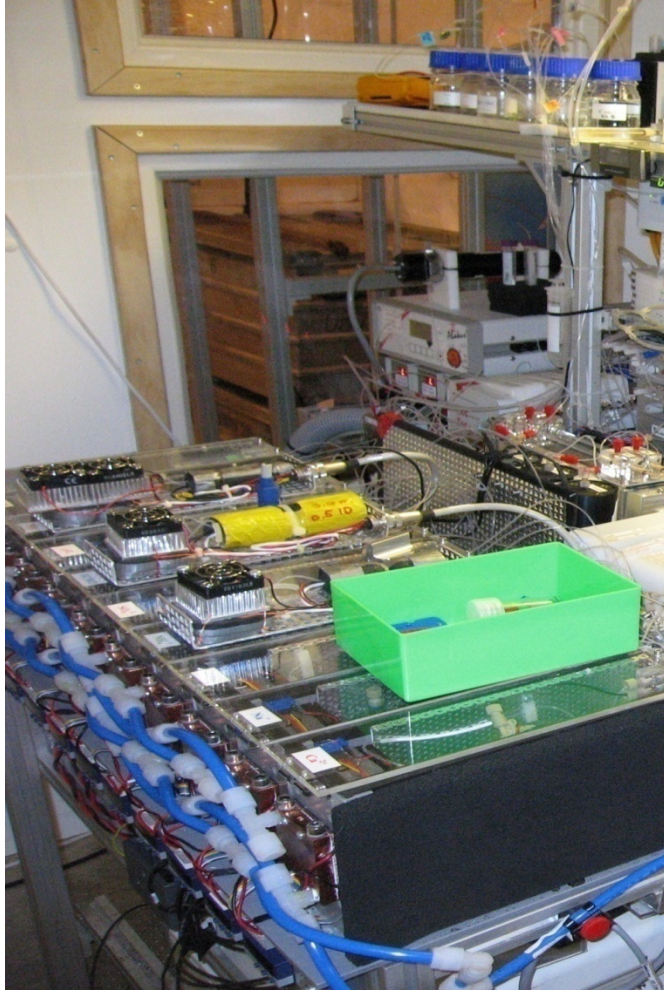
THE
NORTH
FACE

Iskernedata en indkøbsseddel

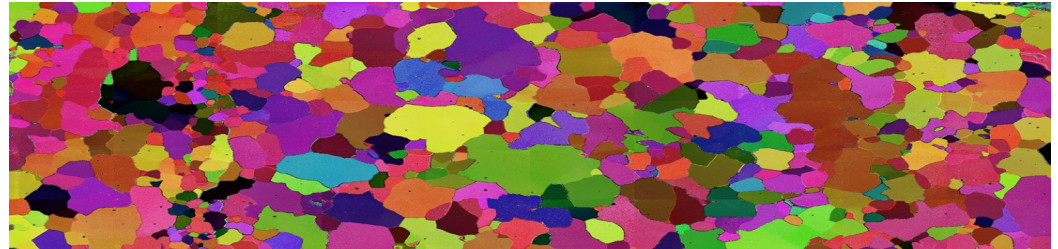
- Isen selv: ^{18}O , ^{17}O , ^{16}O , ^1H og ^2D
- Kontinentalt støv, vulkansk aske, mikrometeoriter og biologisk materiale.
- Ioner: Cl^- , NO_3^- , SO_4^{2-} , F^- , H^+ , Na^+ , K^+ , NH_4^+ , Mg^{2+} , Ca^{2+}
- Gas i luftbobler: CO_2 , CH_4 , O_2 , N_2 , SF_6 .
- Radioaktive isotoper: ^{10}Be , ^{36}Cl , ^{210}Pb , ^{32}Si , ^{14}C , ^{137}Cs , ^{90}Sr .
- DNA
- Isens fysiske egenskaber
- Borehulsopmåling: temperatur, geometri

*Natural ice through polarized light
(sample size : 4 x 10 cm)*

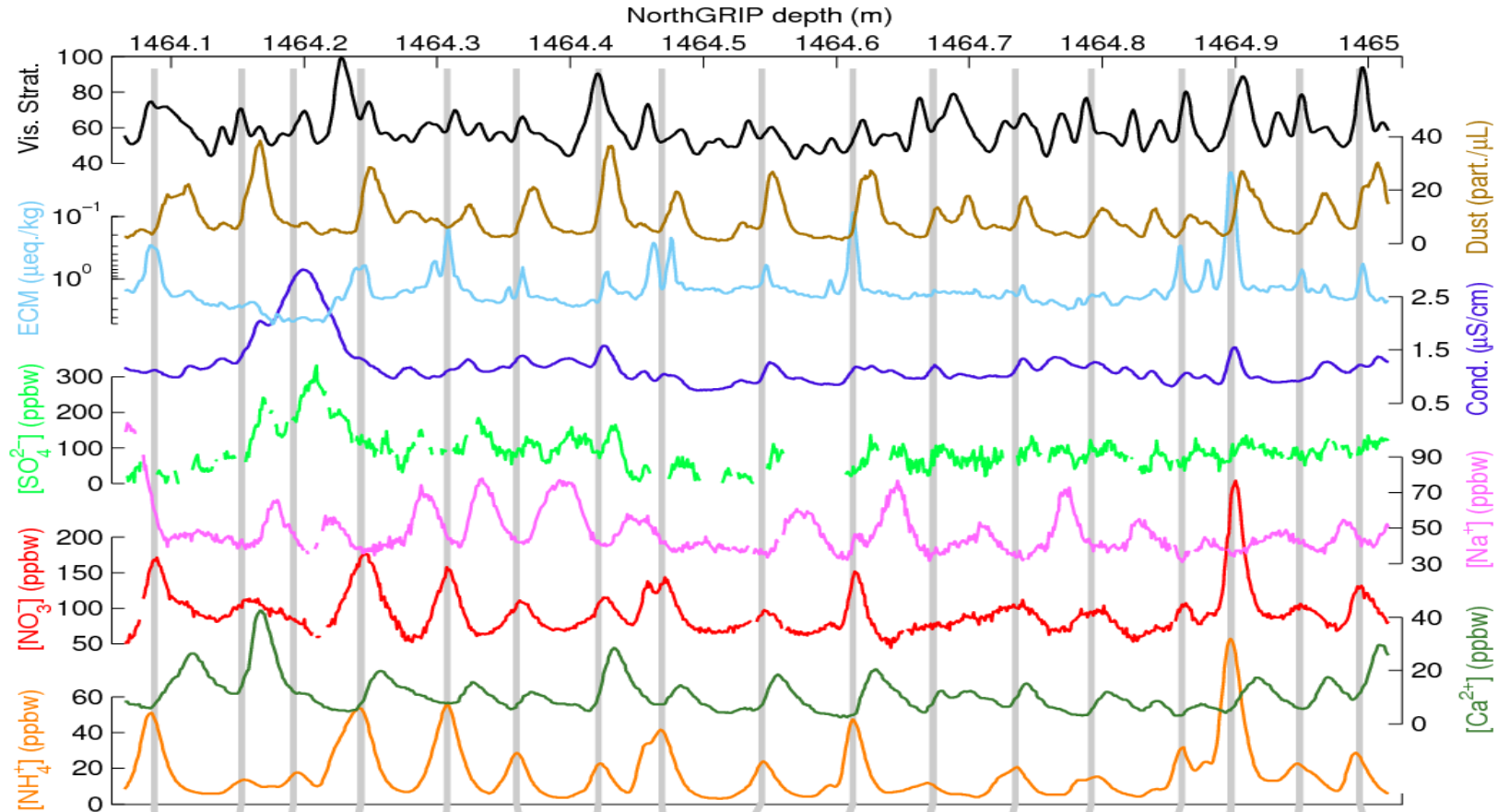


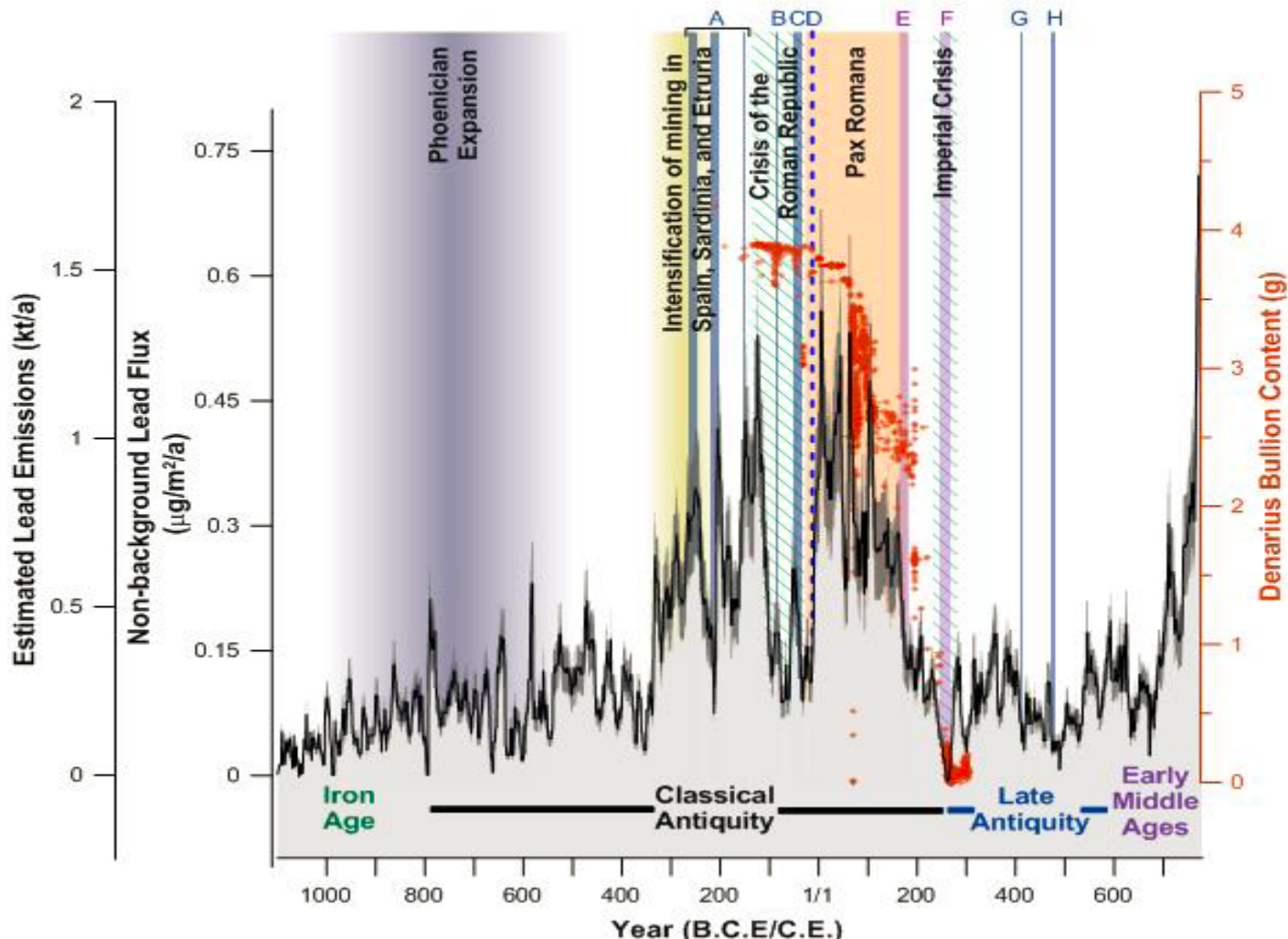


NEEM Fysiske egenskaber



Optælling af årlag i tidlig Holocæn





McConnell et al,
PNAS, 2018

SPECIAL REPORT

SCIENCE FOR THE CURIOUS

Discover

JANUARY/FEBRUARY 2019

THE STATE OF SCIENCE

2019

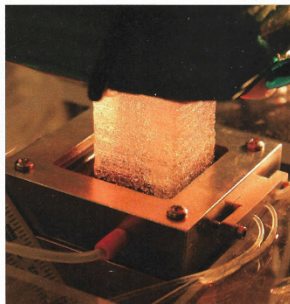
TOP STORIES IN ...

- MEDICINE
- ARCHAEOLOGY
- TECH
- GENETICS
- SPACE
- ... AND MORE



DISCOVERMAGAZINE.COM

FROM TOP: JOE MCCONNELL; CAVIATO AND ALBERTO TOMASEVICI/ANIMAL BIOMEDICAL SCIENCE; DANIELE ANDROS; BLACK SEA MARITIME EXPEDITIONS



Ice core samples from Greenland show fluctuations in lead measurements that match historical records of changes in metal production in ancient Rome.

Ice Capsule to Ancient Europe

A column of Greenland ice has offered insight into the politics and economics of ancient Rome.

Layers of Greenland's ice contain lead and other metals that had drifted hundred of miles from Europe between 1235 B.C. and A.D. 1257, according to a May paper in *PNAS*. Researchers found that fluctuations in the lead measurements matched historical records of changes in European metal production related to wars, epidemics and imperial expansion.

Researchers have previously studied lead in ice cores using a time-intensive method that provided less precise information. The instrumentation used in the new study, however, is faster and able to produce far more complete data. By sampling a column of ice from the center of a larger ice core, the new method also reduces the risk of contamination from modern sources. Researchers obtained over 21,000 measurements of minute lead concentrations from an ice column 423 meters long — just over a quarter of a mile. They assigned lead values to specific years by finding the ice layer with the highest sulfur concentrations, which formed during a volcanic eruption in A.D. 1257. Researchers then counted each annual layer backward in time.

The team focused on an ancient Roman period, roughly from the third century B.C. to the third century A.D. They found that lead levels increased with Phoenician trade and the Pax Romana, a period of economic prosperity, and decreased during the Punic Wars and Antonine Plague.

Lead author Joseph McConnell and colleagues hope to do a detailed analysis of Greenland ice cores further back in time.

FURTHER AFIELD

Maya Megalopolis

For the first time, archaeologists glimpsed the enormity of the Maya civilization, which peaked about 1,500 years ago. Planes flew over 800 square miles of northern Guatemala as an onboard lidar system pulsed lasers downward and measured the reflecting beams, that revealed archaeological features hidden by vegetation.

Some 60,000 previously unknown structures were revealed by the images, says Thomas Garrison, co-leader of the project. The findings tripled population estimates of the Maya civilization to 15 million. The team aims to survey an additional 4,000 square miles.



Pathogens of the Past

Advances in capturing and reading pathogen aDNA from skeletons led to several breakthrough 2018 studies on ancient human diseases, leprosy and syphilis.

In May, two separate teams found hepatitis B sequences in Eurasian remains up to 7,000 years old. Some of the virus strains are now extinct, while others resemble modern African strains — suggesting that the virus, which today affects nearly 260 million people, has a complicated, globe-trotting history.



The First Bakers

Bakers may have preceded farmers, based on 24 bread crumbs found in stone hearths built by hunter-gatherers in Jordan 14,000 years ago. In a paper published in *PNAS* in July, archaeologists analyzed the samples' speck-sized air bubbles and plant bits, concluding they were once unleavened flatbread, made from wild grains and tubers. It would be another 4,000 years until Near Easterners domesticated cereals.

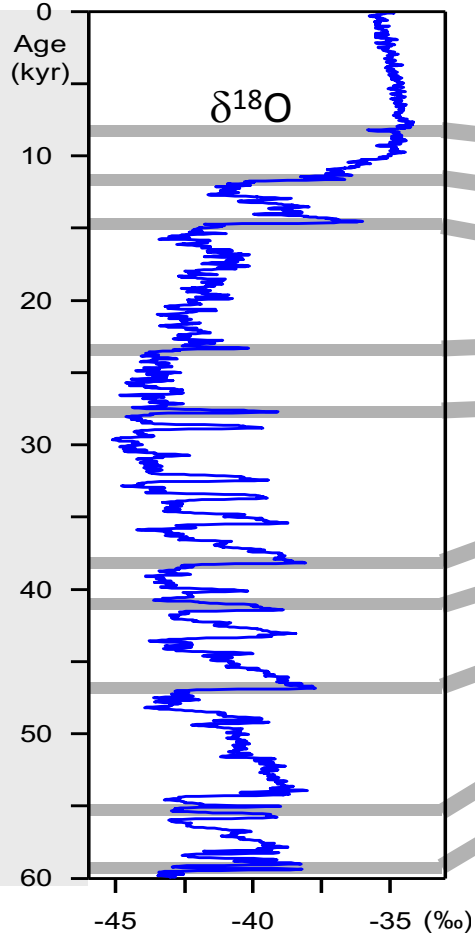


Under the Sea

Thanks to the Black Sea's unusual chemistry — 90 percent of the water column is oxygen-starved and can't support wood-eating microbes — archaeologists have found numerous ancient shipwrecks, still in excellent shape, over the years. In October, researchers announced their greatest find yet: a 2,400-year-old Greek merchant ship, the oldest intact shipwreck on Earth. Located more than a mile beneath the waves, the well-preserved vessel is the first example of a Greek ship previously known only from depictions in art.



GICC05 aldre



Begivenhed Alder (b2k) MCE

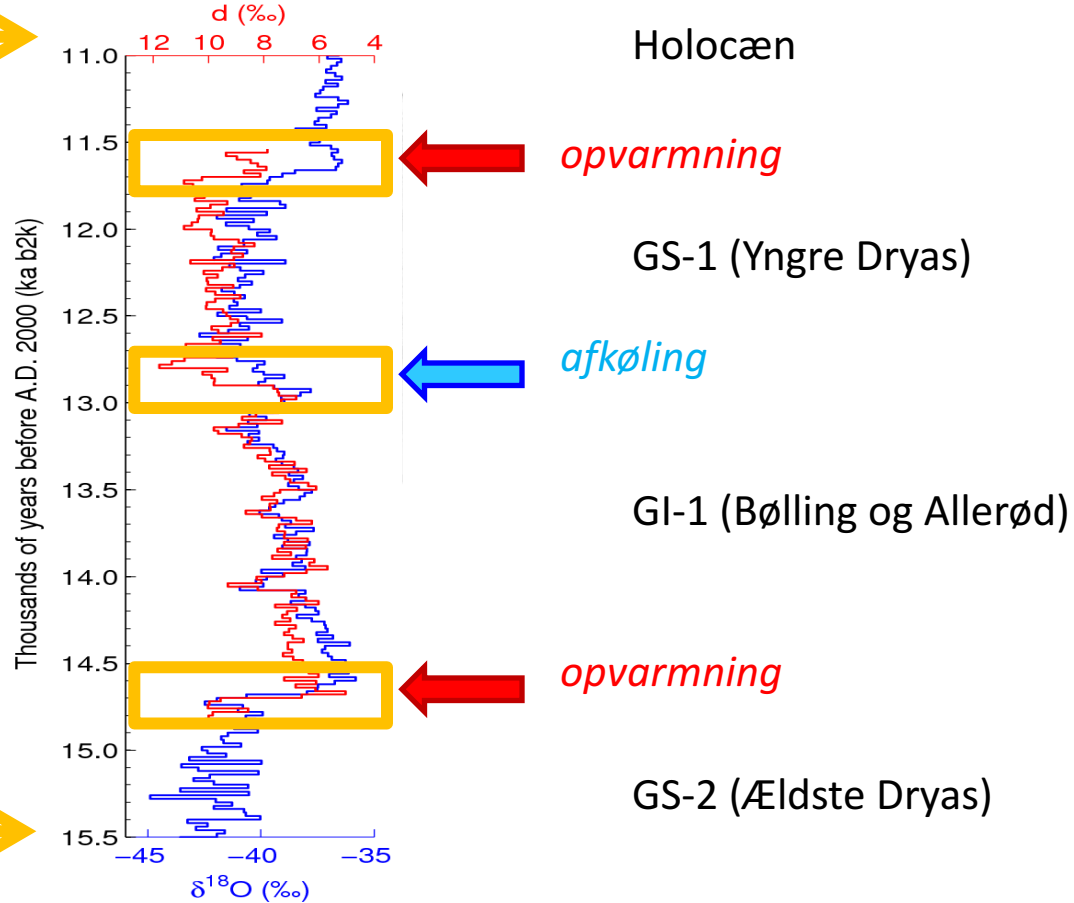
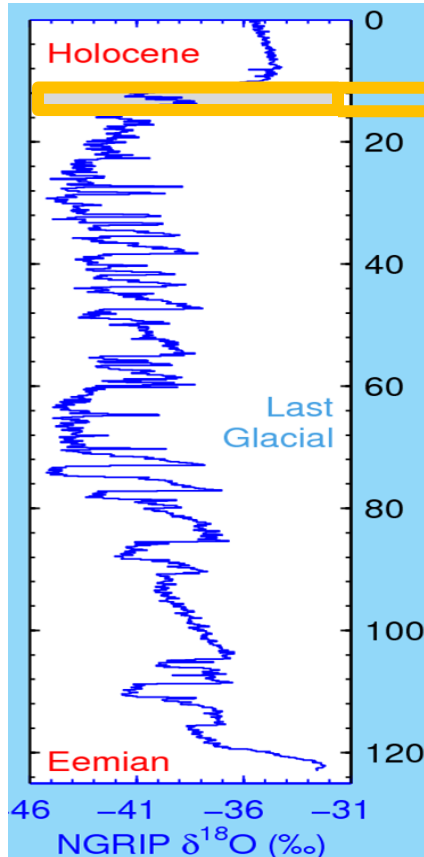
8.2 begivenheden	8,236 ± 47
Transitionen	11,703 ± 99
Bøllings start	14,692 ± 186
GIS 2 begyndelse	23,350 ± 600
GIS 3 begyndelse	27,800 ± 850
GIS 8 begyndelse	38,200 ± 1450
Laschamp	41,250 ± 1650
GIS12 begyndelse	46,900 ± 1800
Z2 askelag	55,450 ± 2150
GIS17 begyndelse	59,450 ± 2300

b2k = Før A.D. 2000 (BP = b2k – 50yr)

MCE = Maximum tællefejl

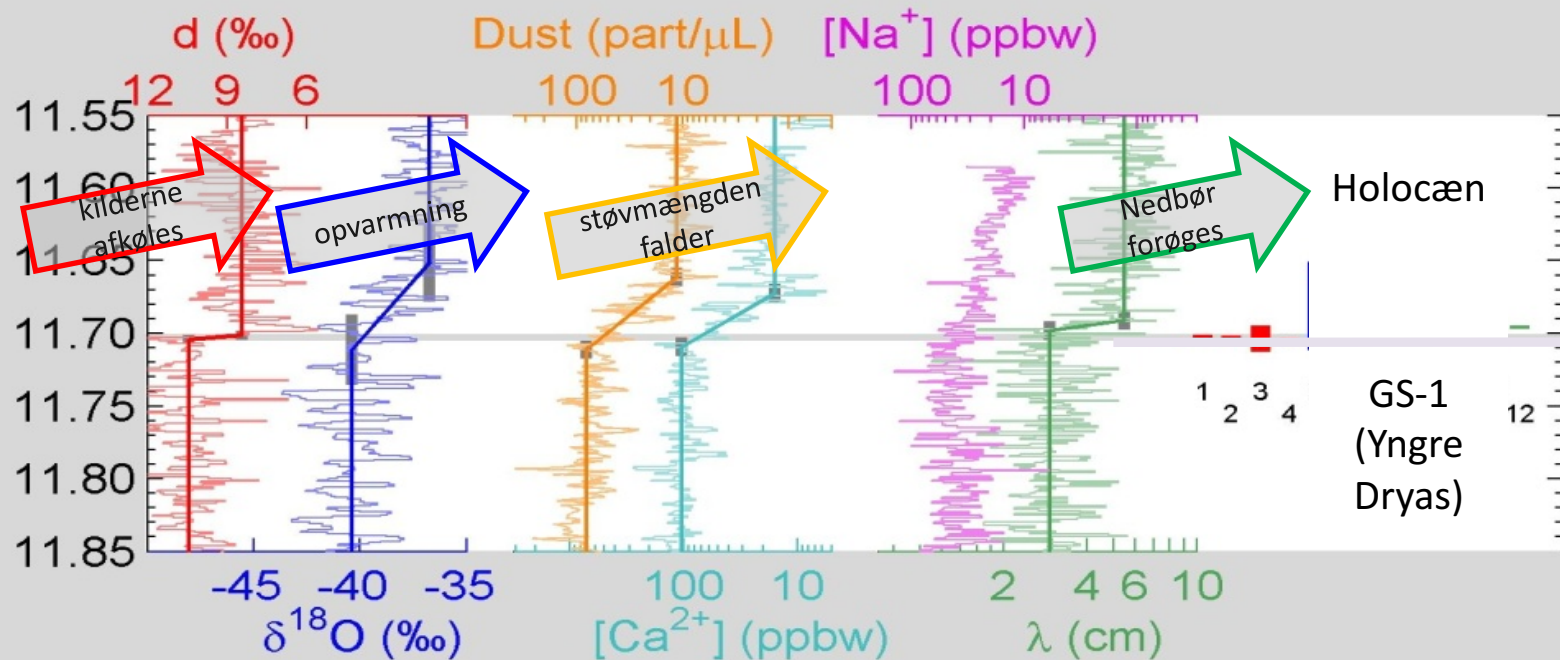
GIS = Grønland Interstadial

Studiet af dynamikken af abrupte klimæændringer



Abrupt opvarmning fra GS-1 to Holocæn (begyndelsen af Holocen)

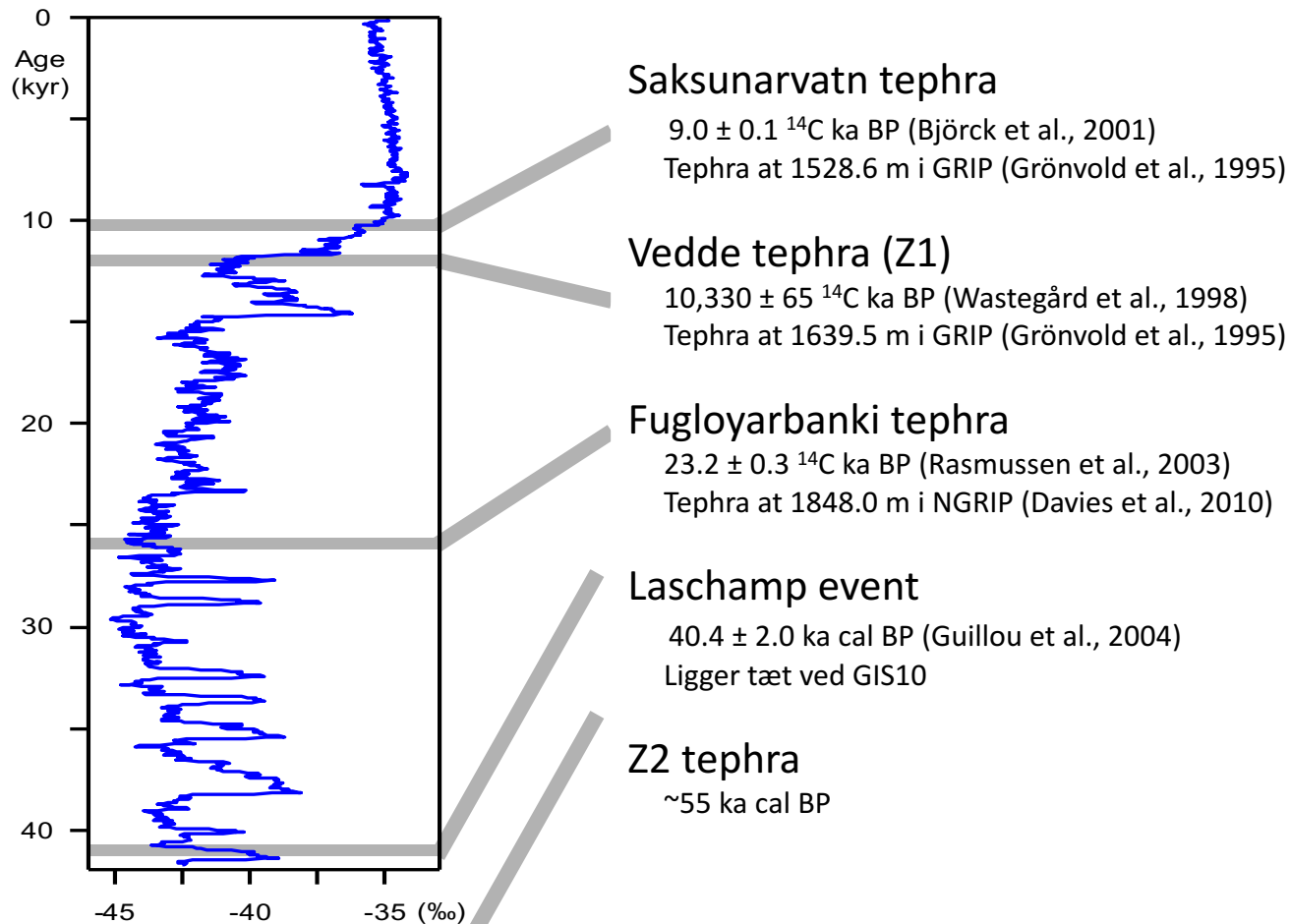
Thousands of years before A.D. 2000 (ka b2k)



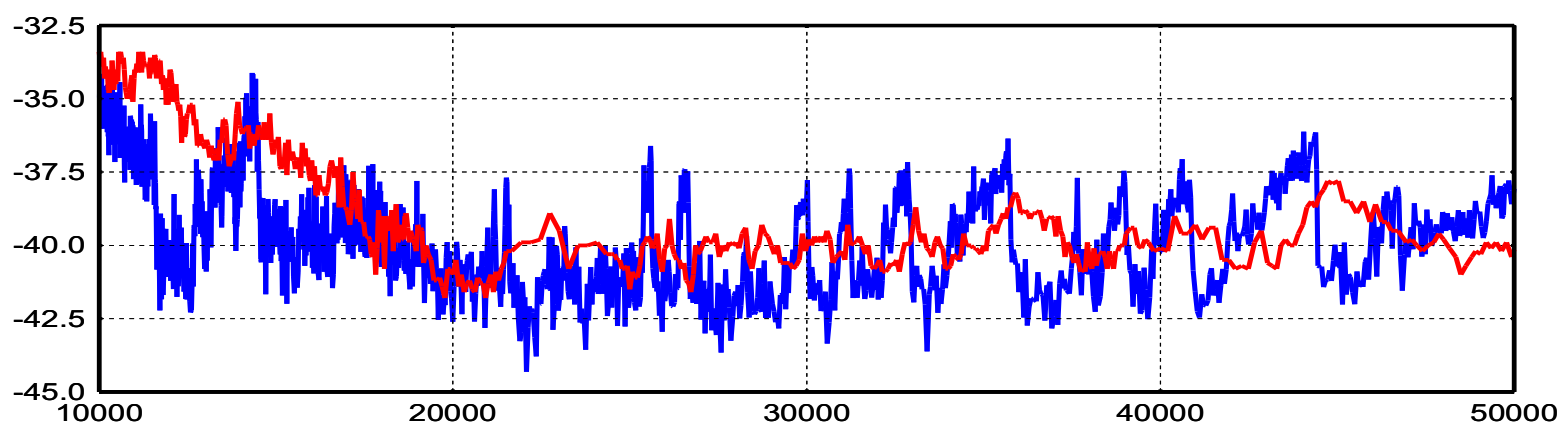
Isranden 42 km NØ for Kangerlussuaq, juli 2016.



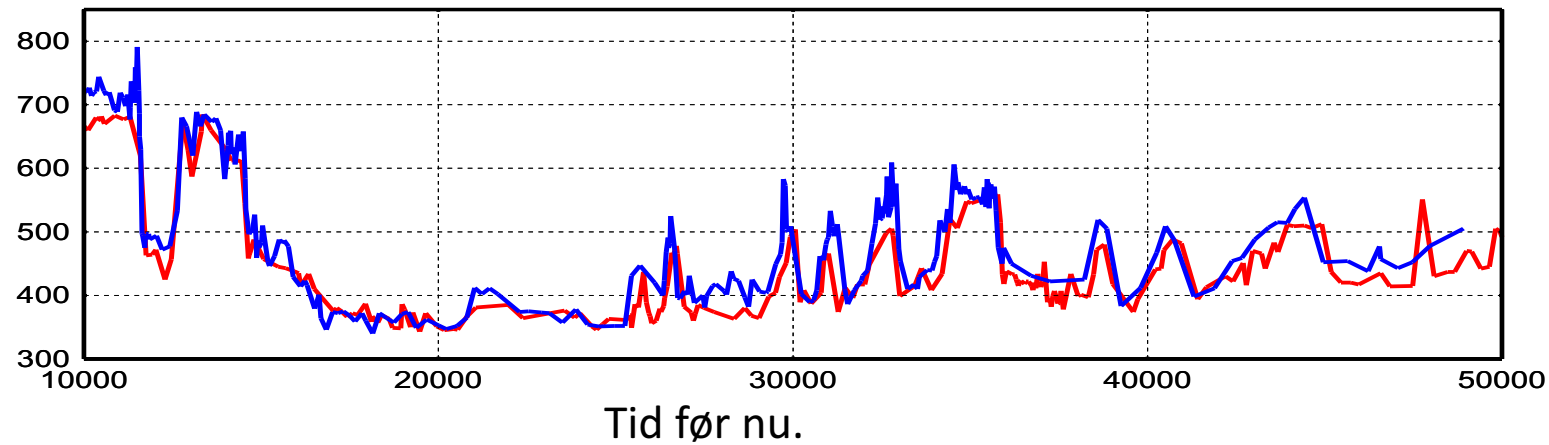
Referencehorisonter



Isotoper
(Temperatur)



Metan konc.
(ppbv)



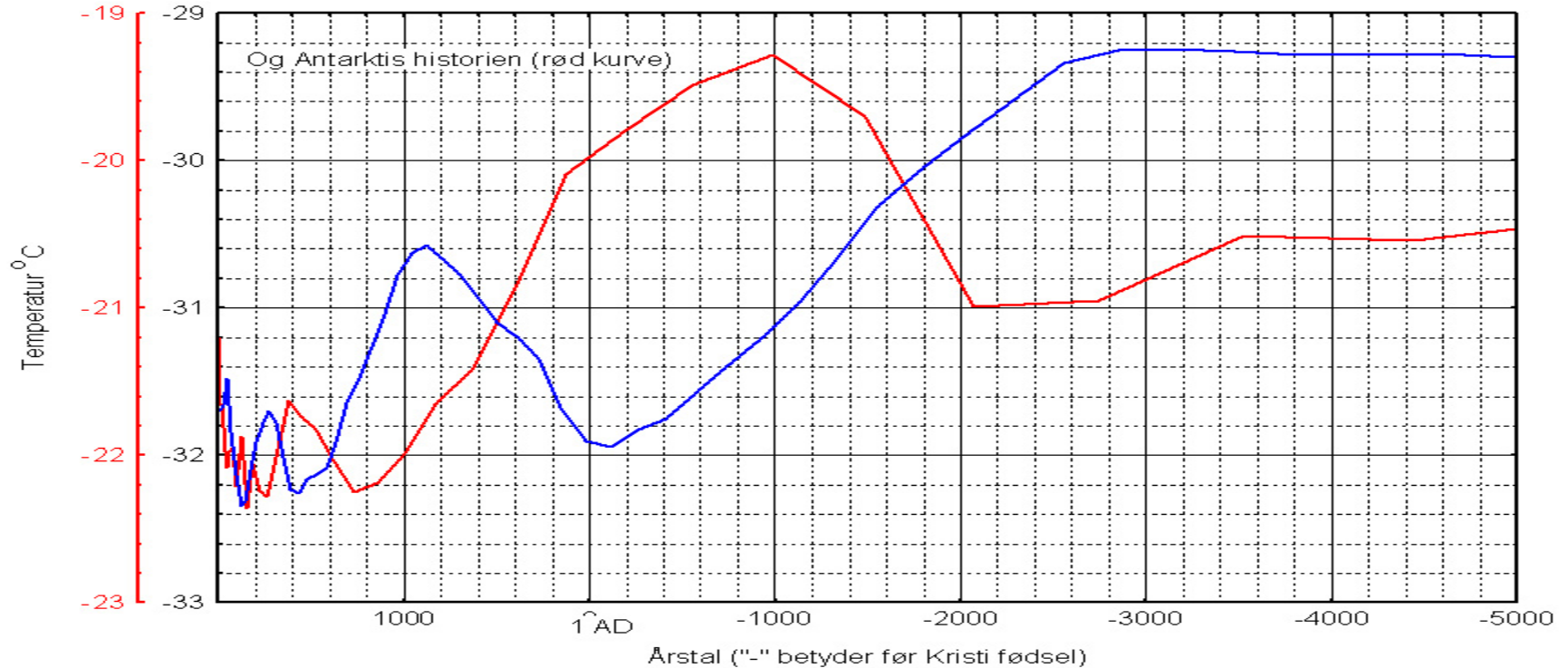
Bå kurve: Grønland; Rød Kurve: Antarktis

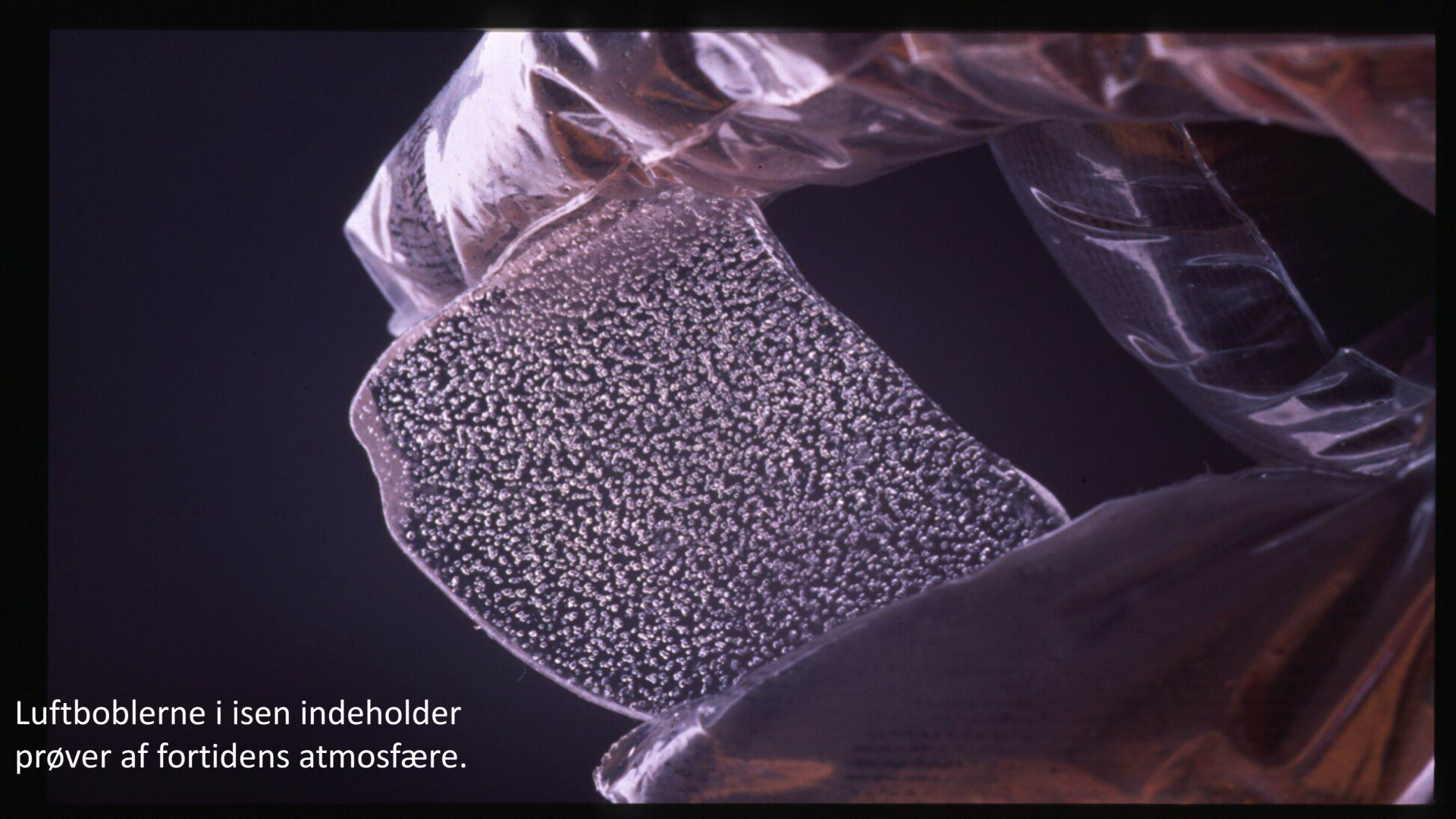
Kilde: Blunier et al., 1998, Nature



Temperaturhistorien siden istiden

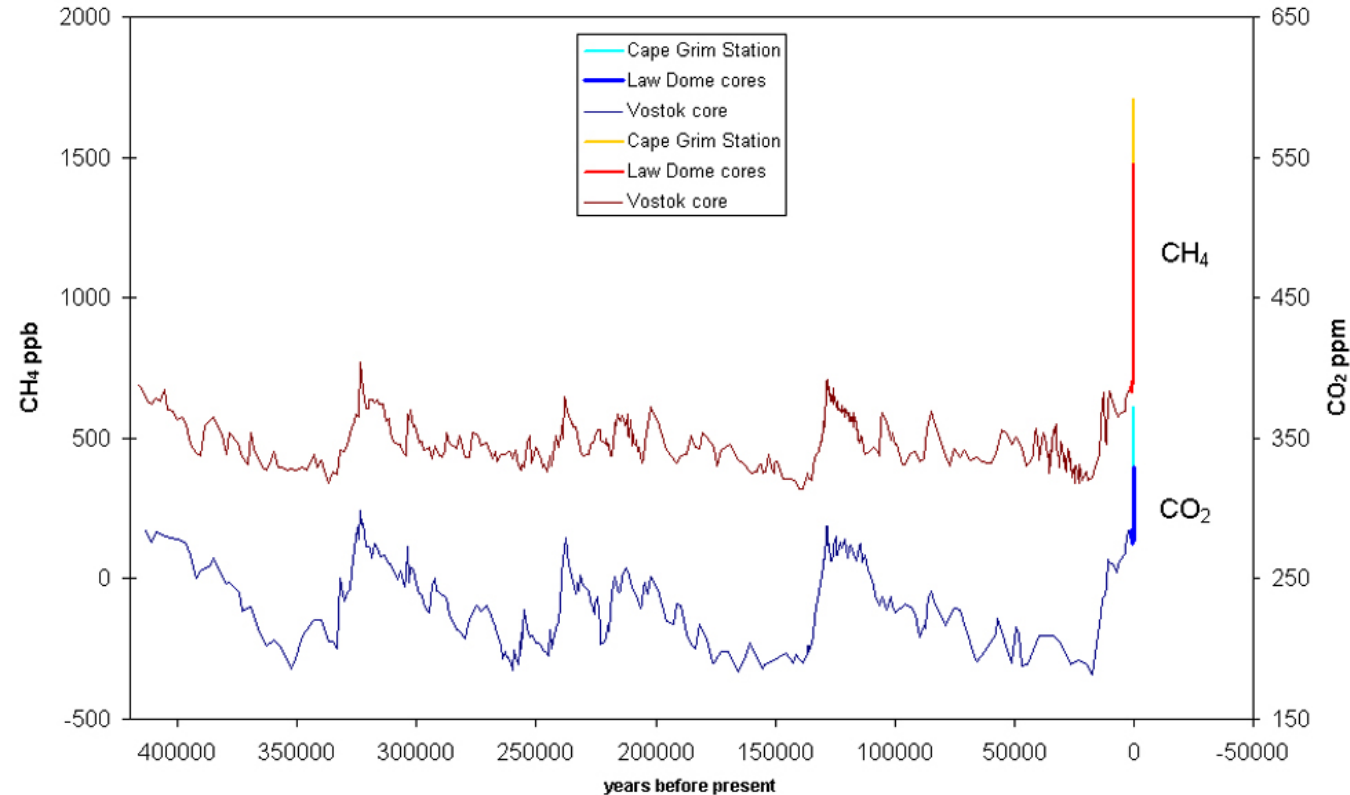
Grønlands temperaturhistorie (blå kurve)





Luftboblerne i isen indeholder prøver af fortidens atmosfære.

Stigningen i CO₂ og metan.



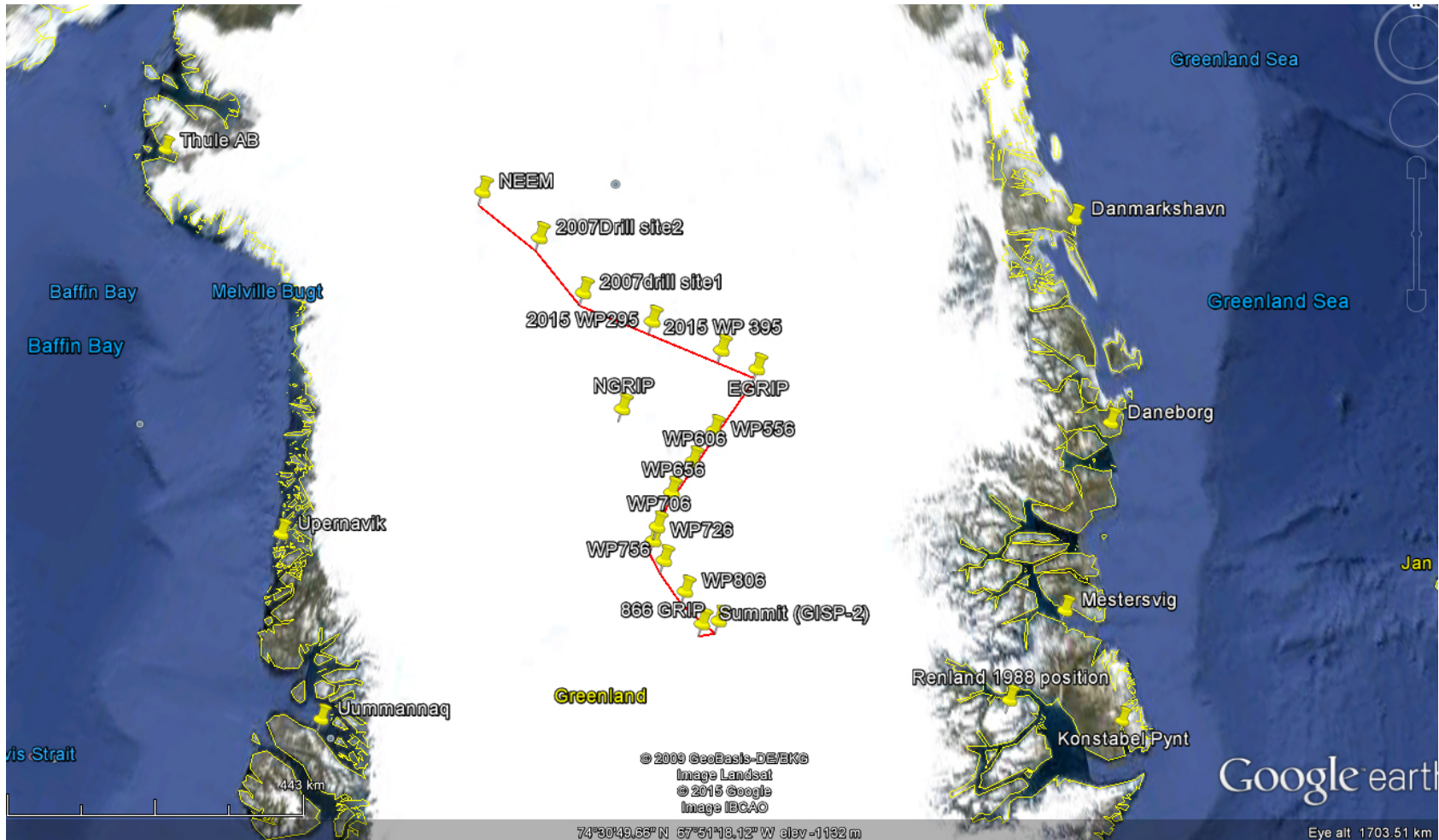
Data compiled by David Etheridge, CSIRO



Bunden ved 2538 m, juli 2010



Vil du vide mere ?
www.iskerner.dk
www.isarkiv.dk



74°30'49.65" N 67°51'13.12" W elev -1192 m

Eye alt 1703.51 km

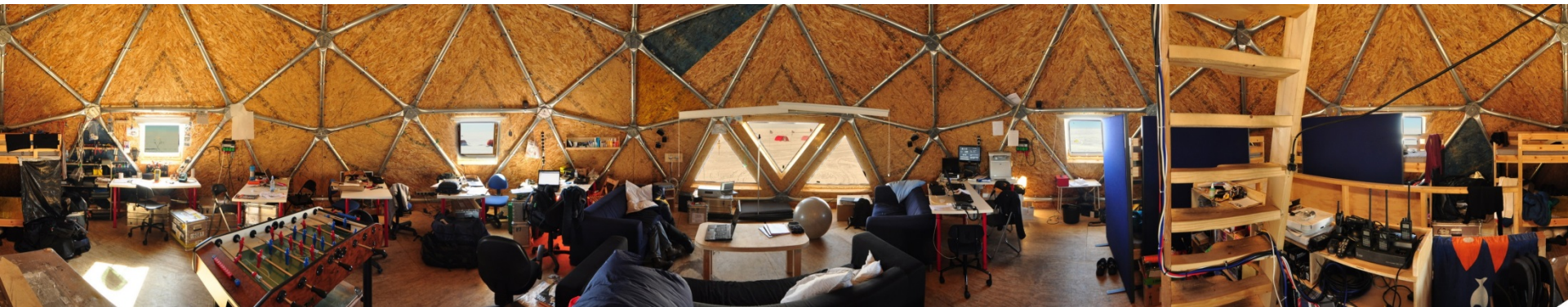
NEEM lejren 2015







Stuen og 1.sal i domen.

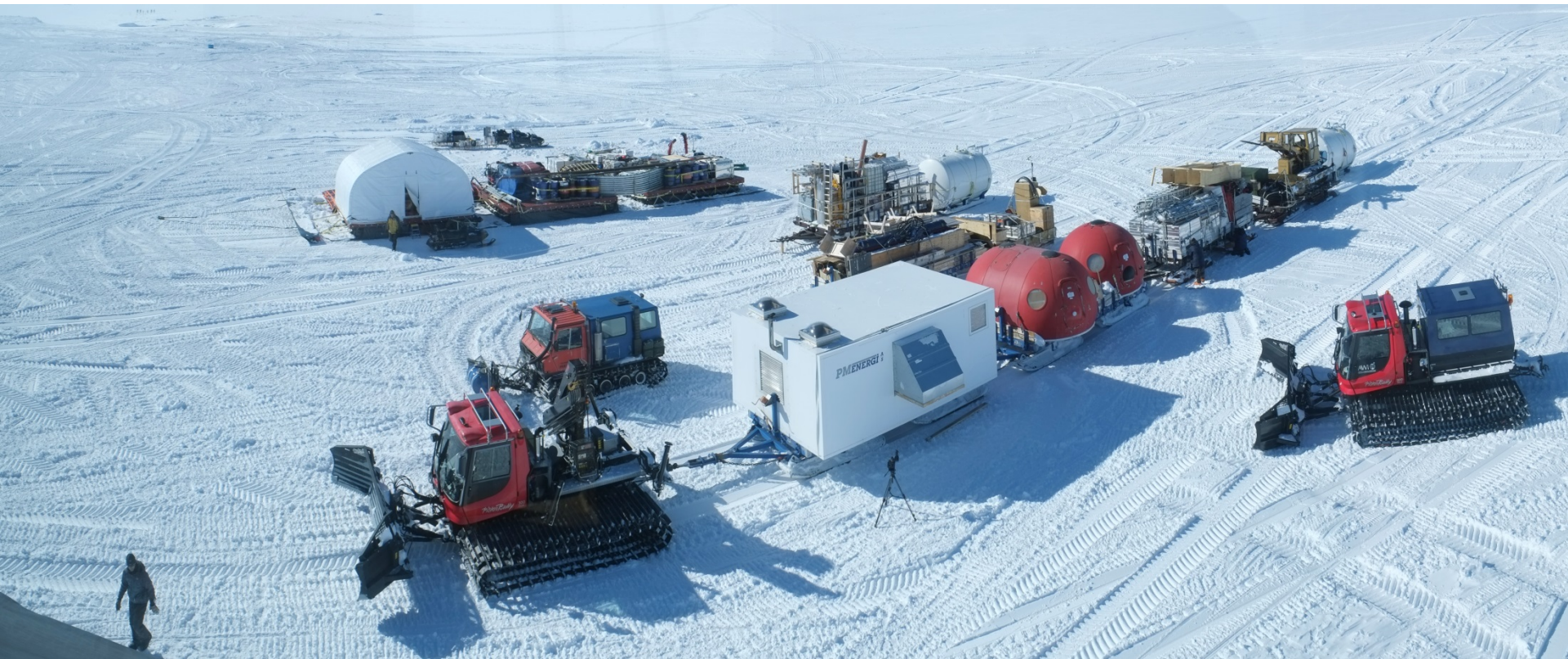


Opholdsstuen





Klar til 440 km traktortræk



Ankomst EGRIP, maj 2015



Udgravning af snehuler, EGRIP maj 2016.



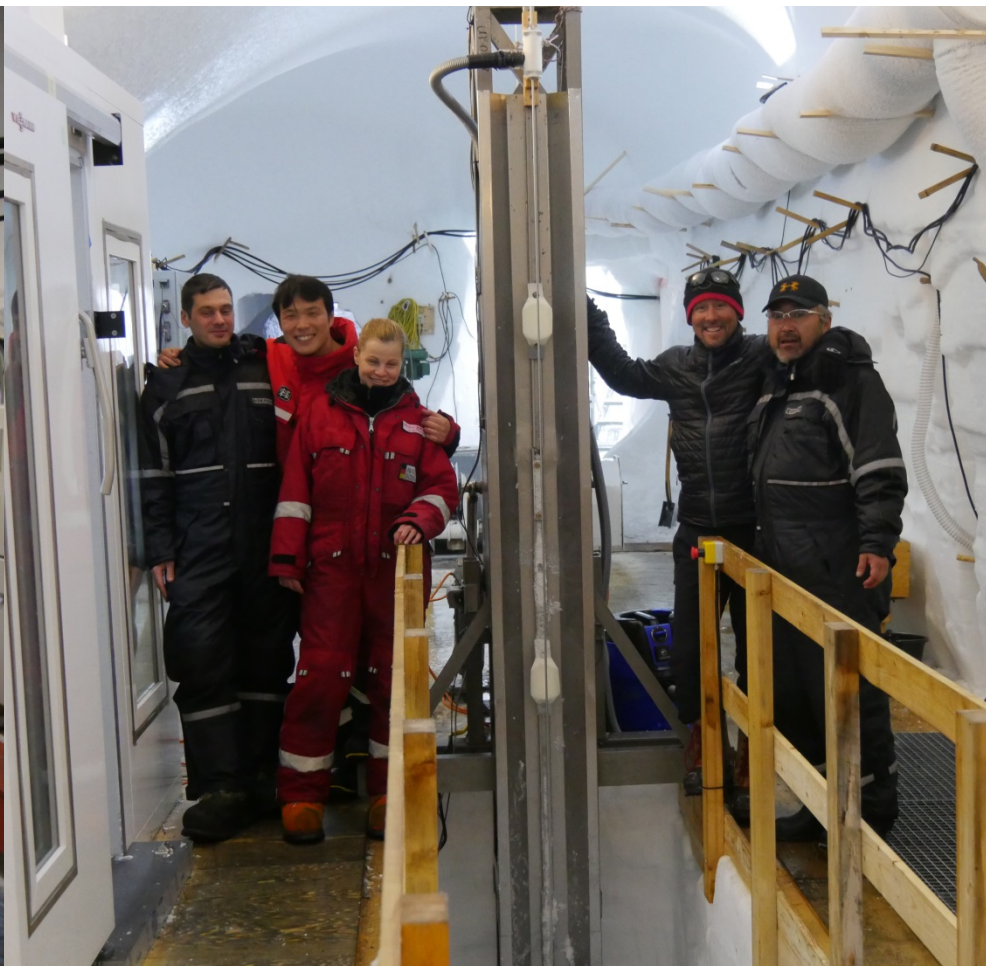


Balloner på plads, EGRIP maj 2016.

Den rå snehule, EGRIP maj 2016.



NEEM boring og EGRIP boring

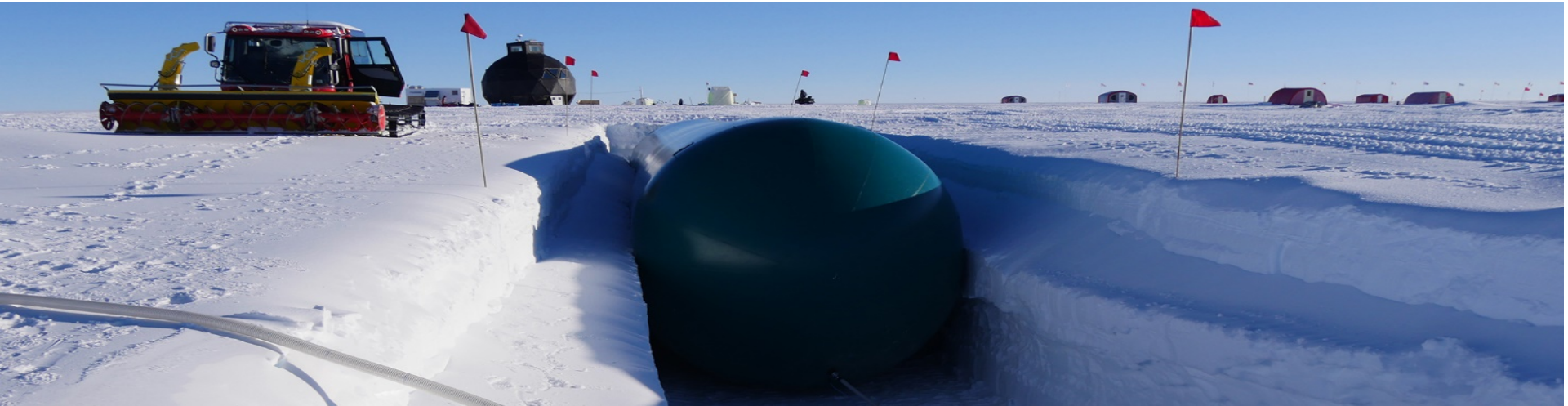




Borehallen tilpasset det lange bor.



Bygning af ny koncertsal

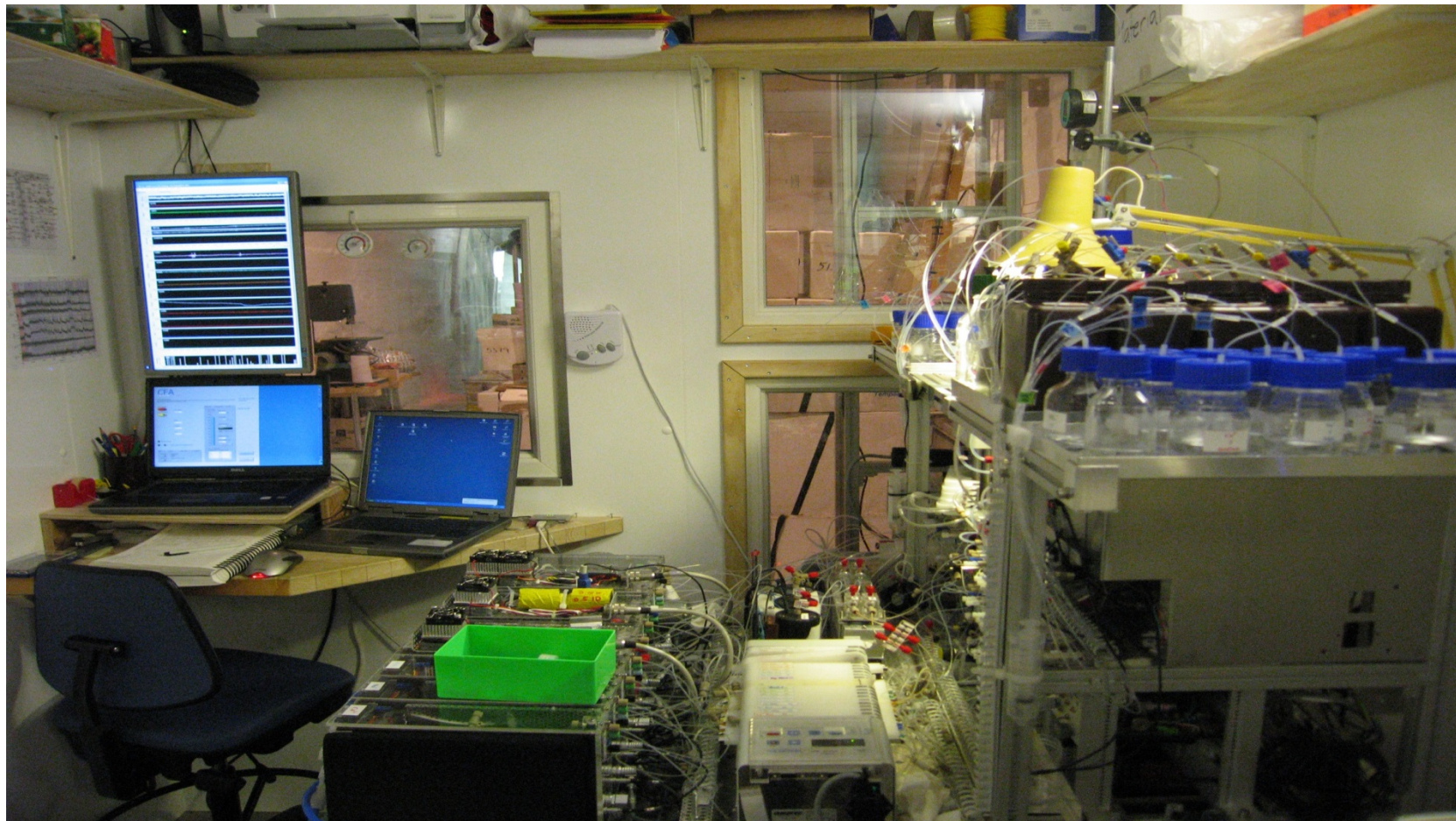


Det færdige produkt. Ismusiker: Terje Isungset.



Interessante tal i klimadiskussionen.

- 1 kg oksekød giver 14 kg CO₂
- 1 liter Jet A-1/benzin giver 2,64/2,40 kg CO₂
- Standard flyøkonomi: 0,027 liter per passager km.
- Flytur t/r Thailand 20.000 km 540 liter = 1425 kg CO₂
- Dette svarer til 100/400 kg oksekød/svinekød.
- Bemærk: Kødberegning er fra CO₂ ækvivalenter af metan. Kulstoffet er "genbrugt" fra planter og solskin. Brændstoffet er netto tilførsel af kulstof fra undergrunden. Disse ting er ikke direkte sammenlignelige.



Tøvelte på Møn



