

Istidsutviklinga og klimaendringar i Noreg

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Fjordlandskapet i Vest-Noreg

Nordfjorden

Sognefjorden

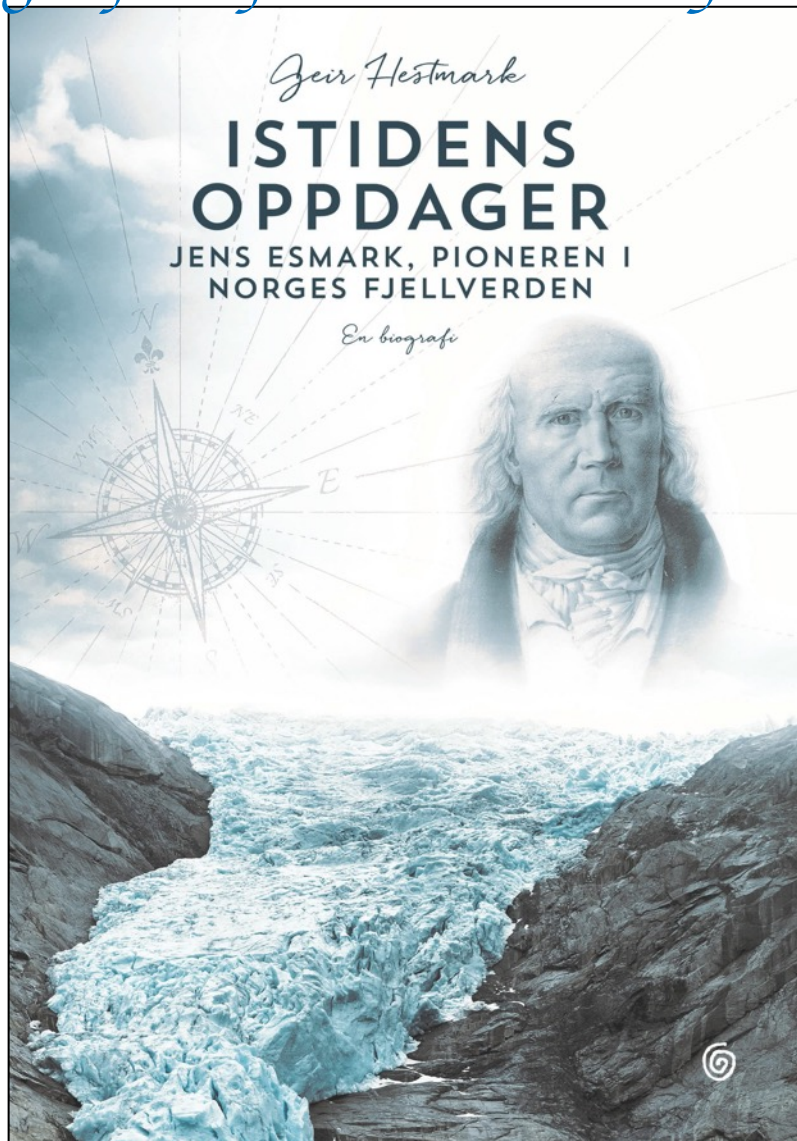
Bergen

Hardangerfjorden

Boknafjorden

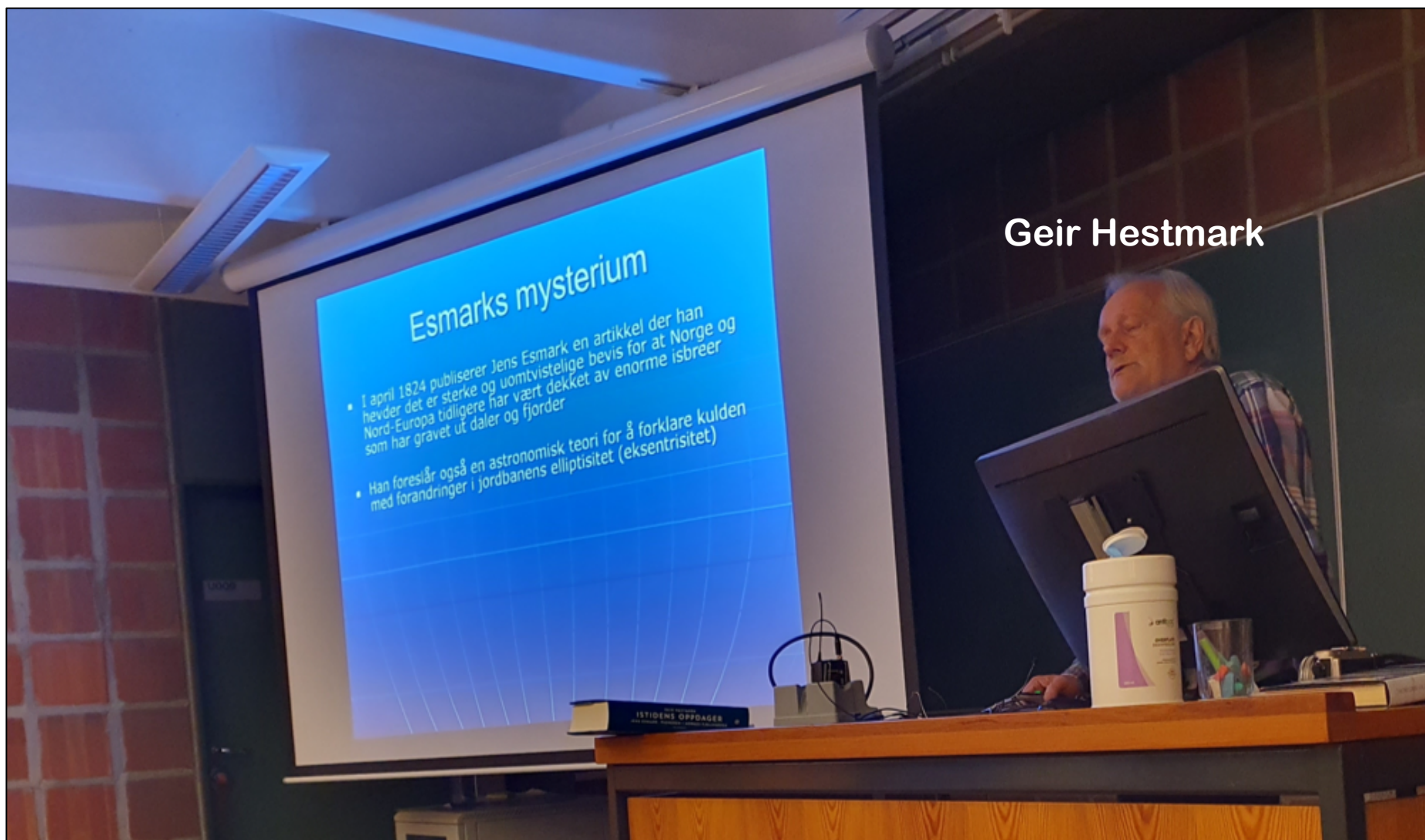
Stavanger

1823 – 2023 – 200 år sidan oppdaginga av istidene
«umiskjendelige Spor af Ismassernes uhyre Virkninger»



2017 Kagge Forlag AS

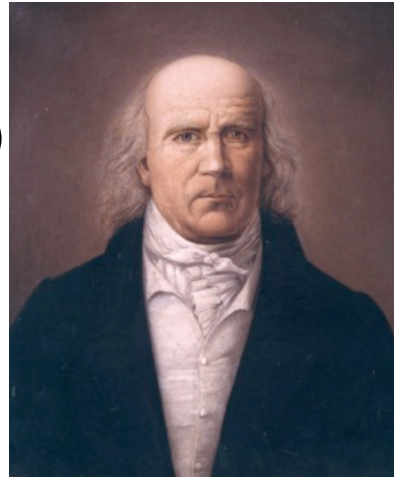
Esmark-seminar i Bergen 8. september 2023



Geir Hestmark

Rundreise i Sør-Noreg sommaren 1823 som førte til oppdaginga av istidene:

Jens Esmark (1763-1839)



Litografi av L. Fehr etter
teikning av C. von Plötz
(i Hestmark, 2017: 225)

Nils Otto Tank (1800-1864)



Måleri Wisconsin
Historical Society

Jan Theodor Kielland (1803-1844)



freepages.rootsweb.com

Reiseruta til Jens Esmark, Niels Otto Tank og
Jan Theodor Kielland 18. juni - 12. september 1823



- 1 - Christiania (Oslo)
- 2 - Rød, heimen til Otto Tank
- 3 - 'Esmarkmorenen'
- 4 - Steinsund, Sula-øyane,
med brepolert devon-
konglomerat ved havnivå
- 5 - Grimelid koparverk
- 6 - 'Otto Tanks morene'
- 7 - Mjøsa, moreneblokker

A – Tronfjell (1800)
B – Rondane (1800)



Litografi av L. Fehr etter teikning av C. von Plötz (i Hestmark, 2017: 225)

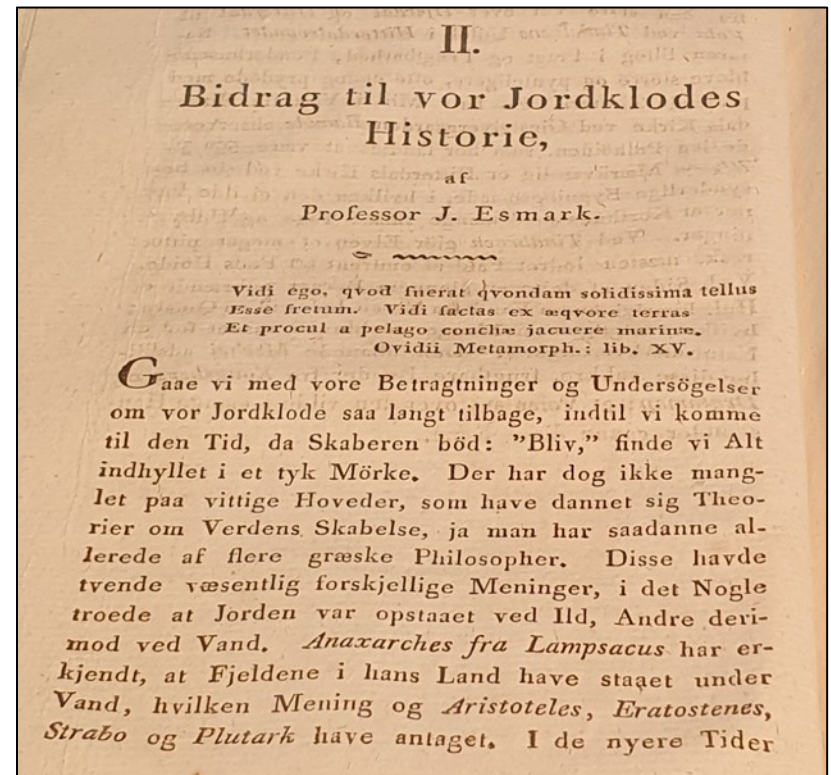


Foto: Atle Nesje

Sitat frå Jens Esmark sin publikasjon
(Esmark, J., 1824: «*Bidrag til vor Jordklodes Historie*»):

Funne bevis for ei istid: «*Det er især i Norge jeg har fundet mange Beviser paa uhyre, nu forsvundne lismassers Virkninger*»

Listar opp fleire argument: «*store löse Steenblokke*»...«*ført langt bort*»...av...
«*overordentlige store Masser af lis*»

«*Krafigste Beviis for*» basert på Vassryggen i Rogaland...«*existeret saadanne uhyre lismasser i Norge*»

Konkluderte med «*at denne Vold har sin Oprindelse av lismasser, som have fyldt hele Dalen og ved deres Utvidelse og Trykning tidlige have uthulet Dalens sole*»

...vidare: «*de Norske fjelde have været indhyllede i lis lige ned til Havet*», ein særskild nyskapande tanke på den tid.

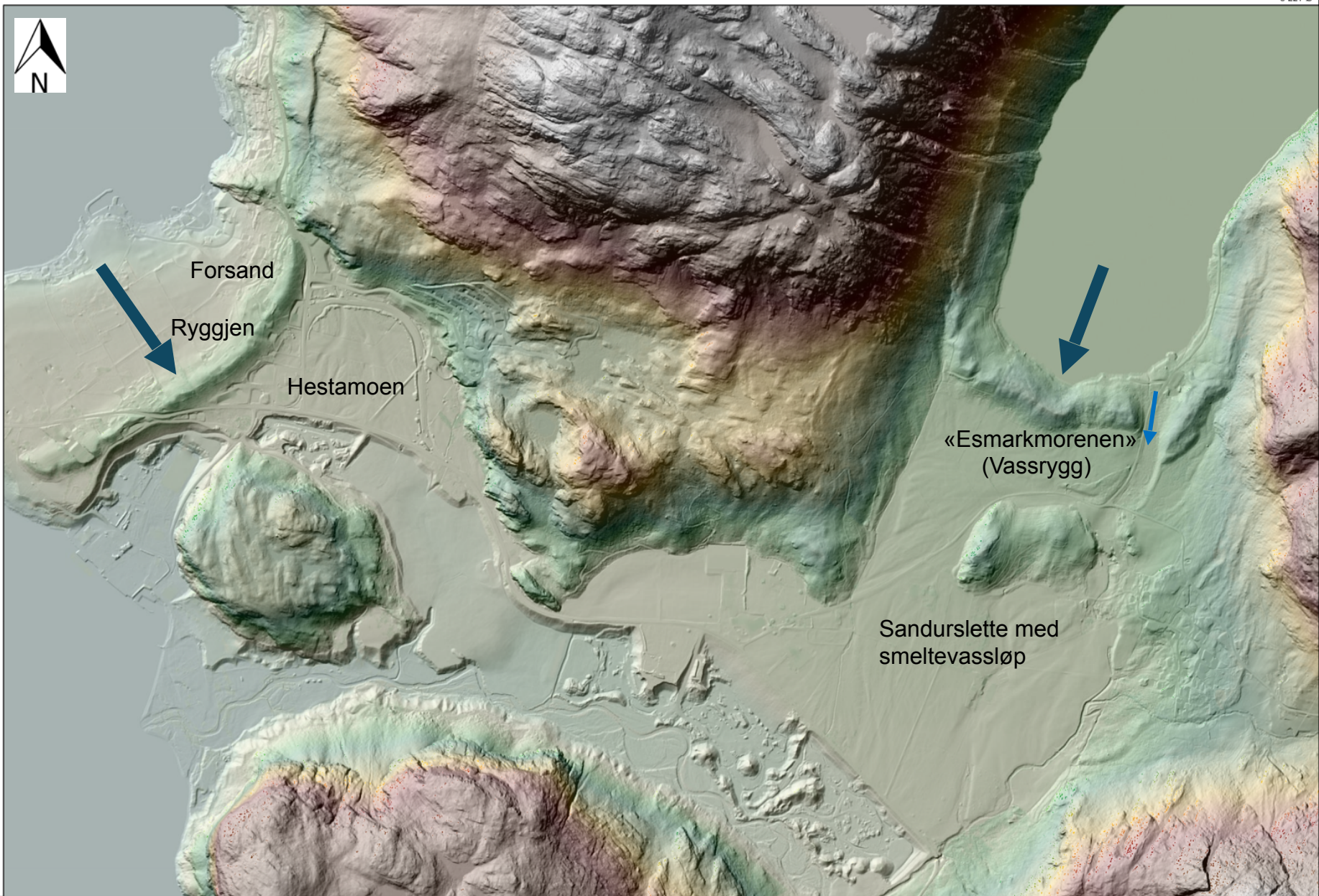
A

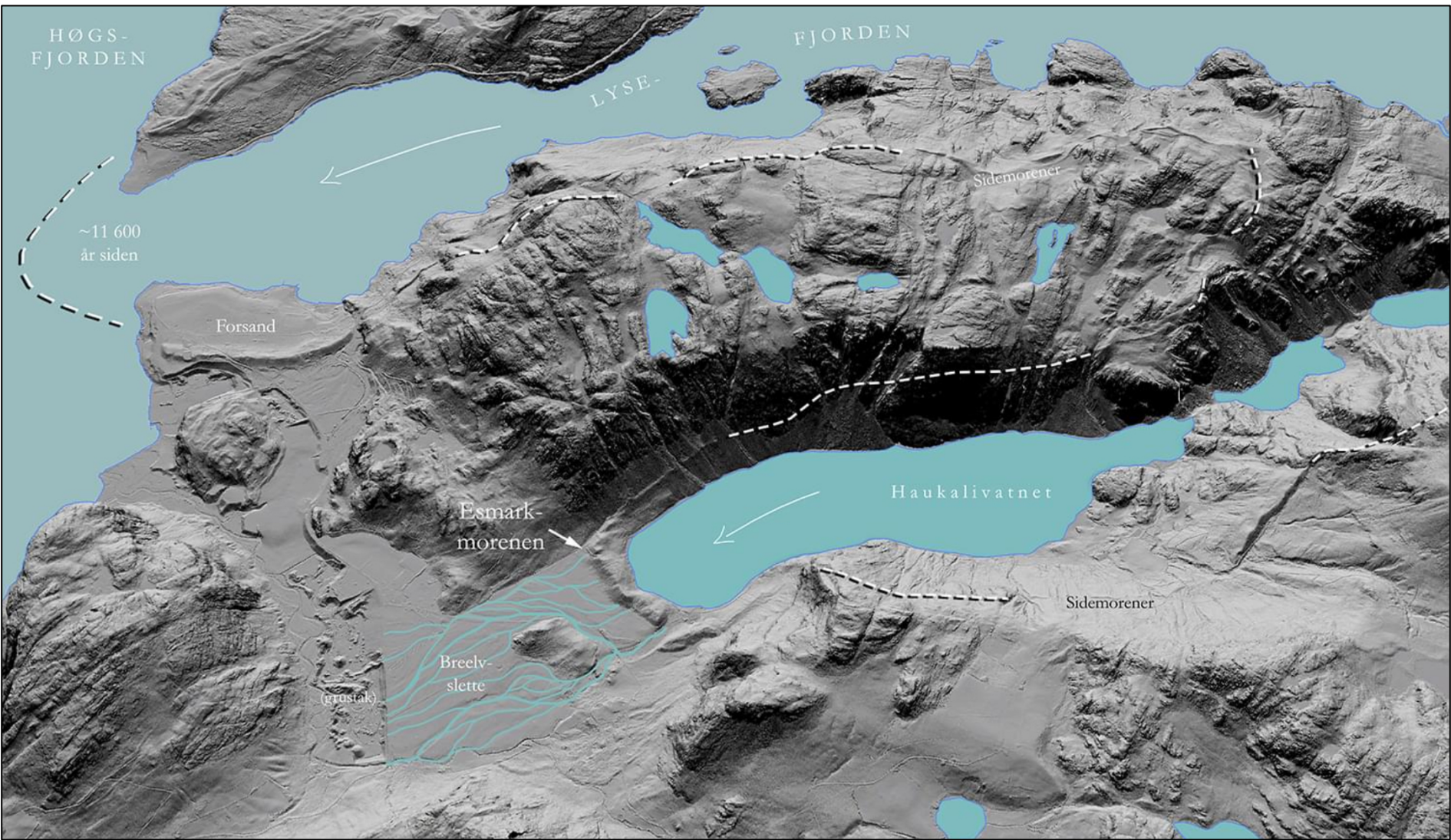
«Esmarkmorenen» (Vassrygg), Forsand

«Esmarkmorenen» (Vassrygg)

Haukalivatn (51 moh.)





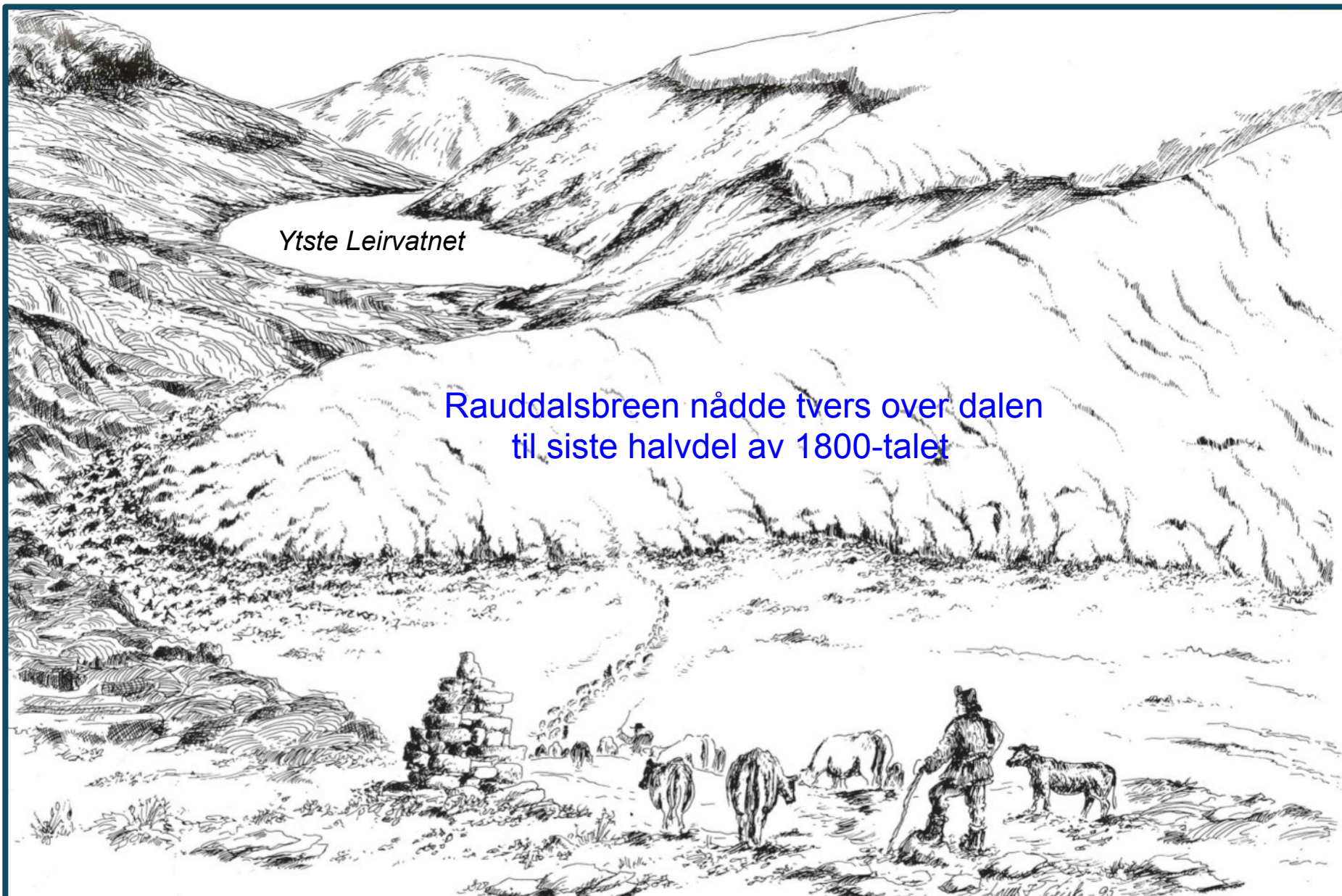


Illustrasjon: Fredrik Høgaas





Illustrasjon og foto: Geir Hestmark



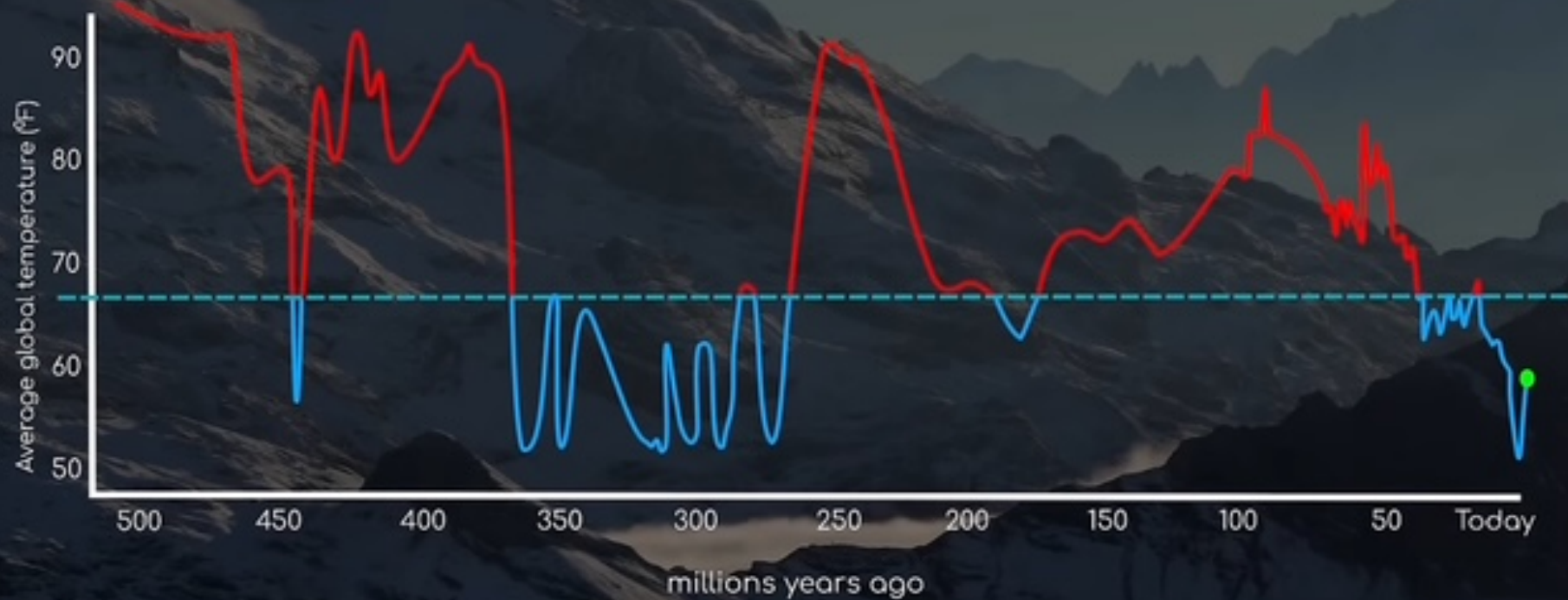
Rauddalsbreen nådde tvers over dalen
til siste halvdel av 1800-talet



«Otto Tanks morene» sett mot vest
Rauddalsbreen i bakgrunnen

Foto: Halfdan Carstens

Estimated global temperature over the last 500 million years



Bigganjargga-tillitten
Hans H. Reusch (1891)

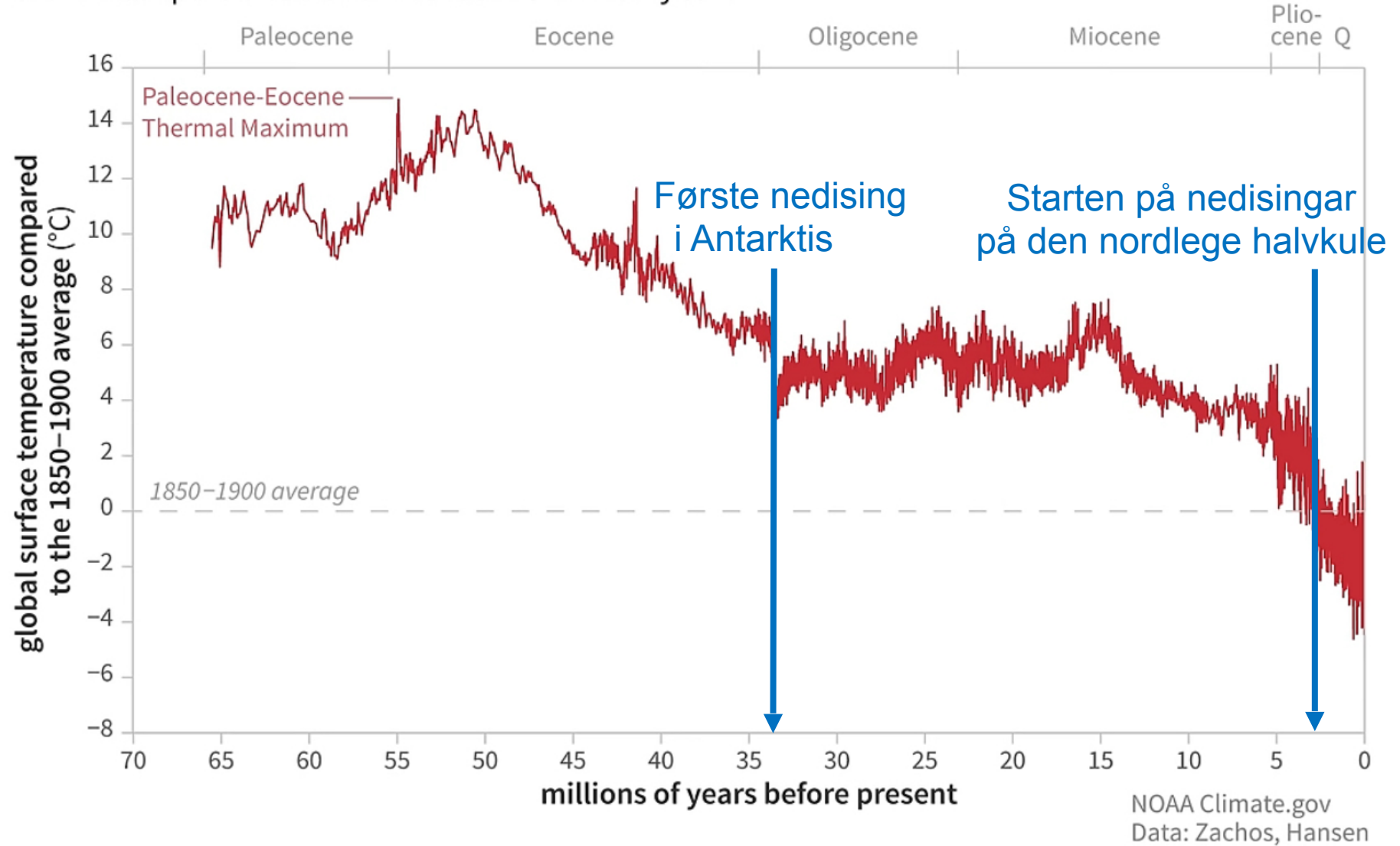


Morænekonglomerat over sandsten med isskuret overflade. Bigganjargga.

A SNOWBALL EARTH

Credit: Oleg Kuznetsov

Global temperatures over the last 65 million years



Endemorenar i Nord-Europa



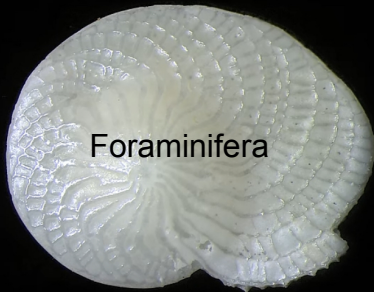
Sediment-kjerne fra Stillehavet

oxygen
isotopes
detection

^{18}O

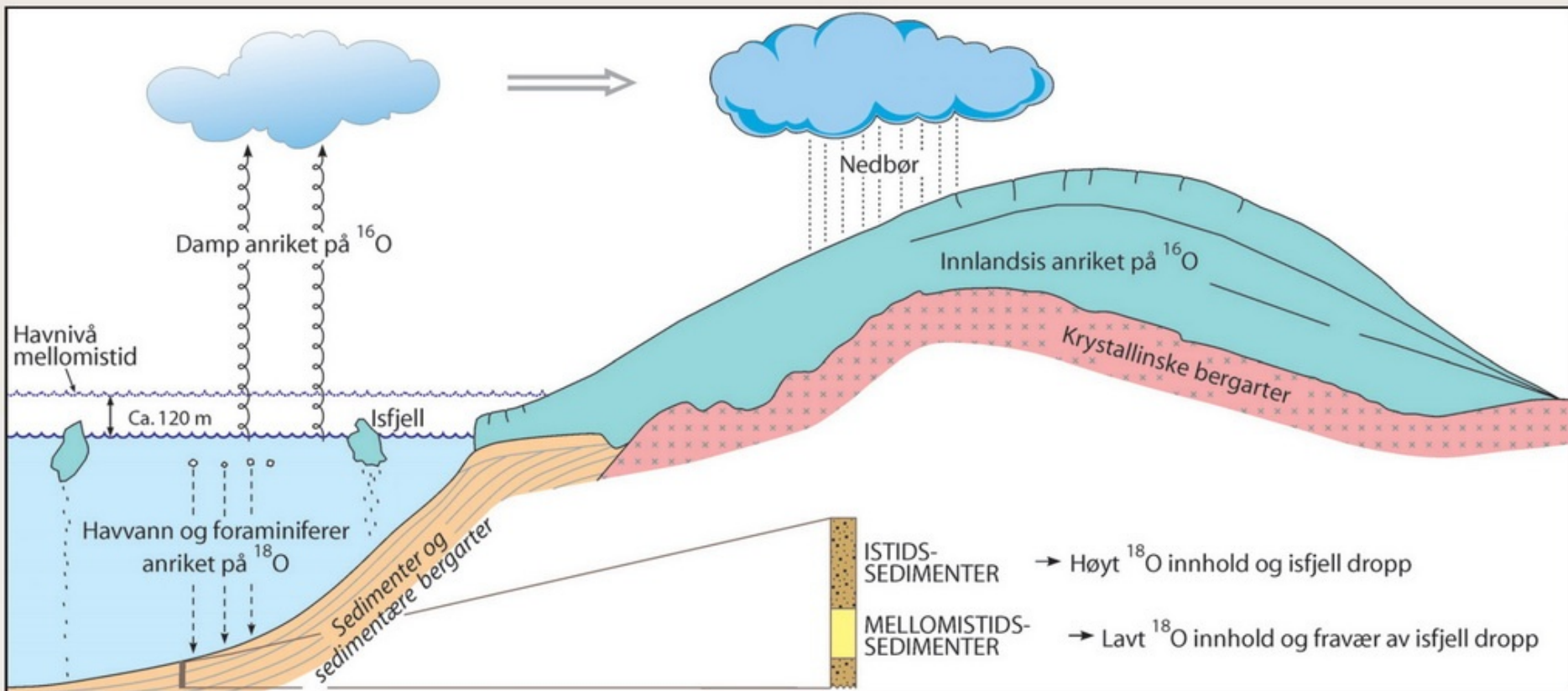
^{16}O

Foraminifera

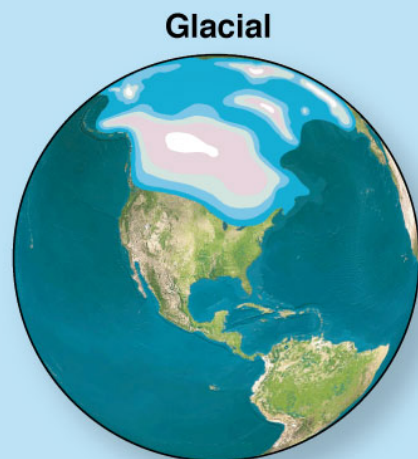


wikipedia.com

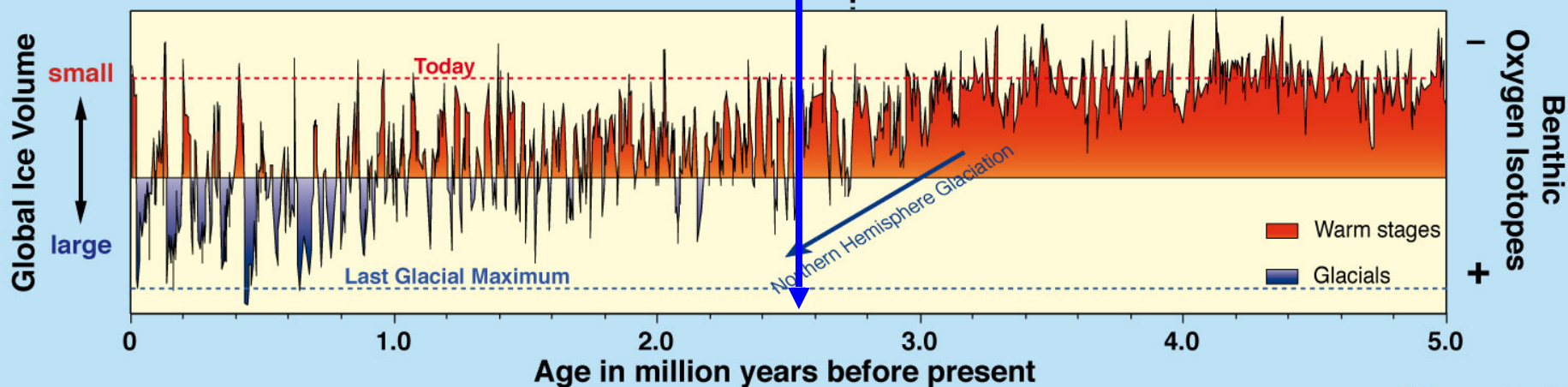
OKSYGEN I KALKSKALL OG BRE-IS FORTELLER KLIMAHISTORIE

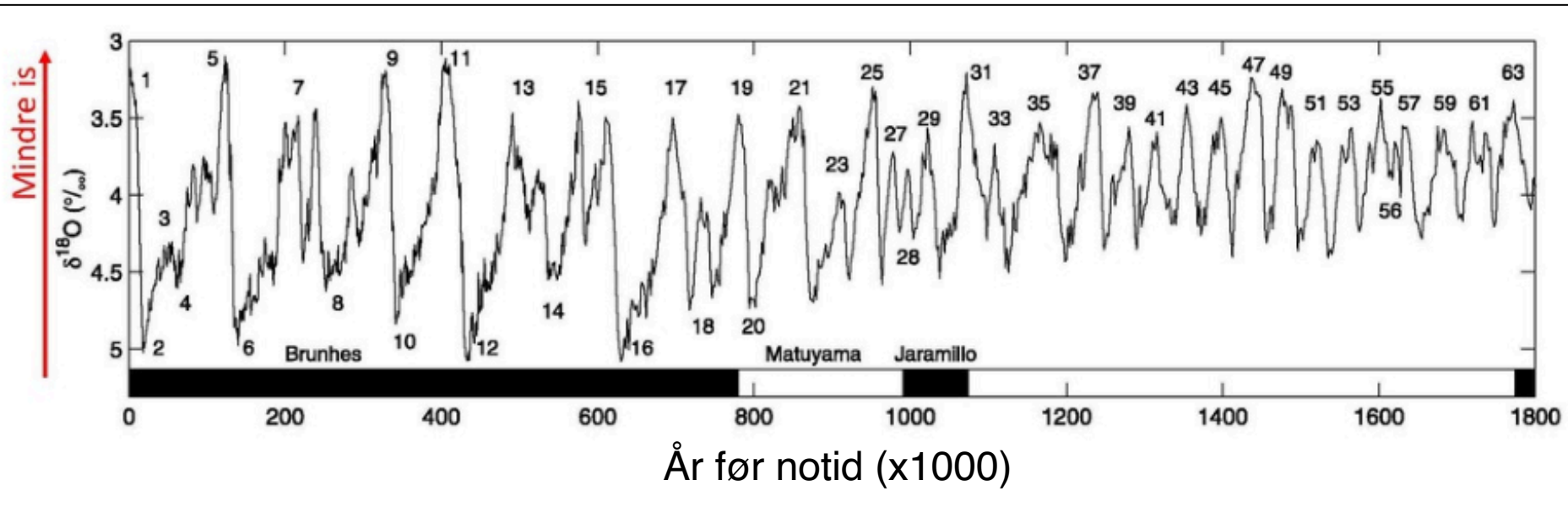


40-50 istider gjennom dei siste 2,58 millionar år



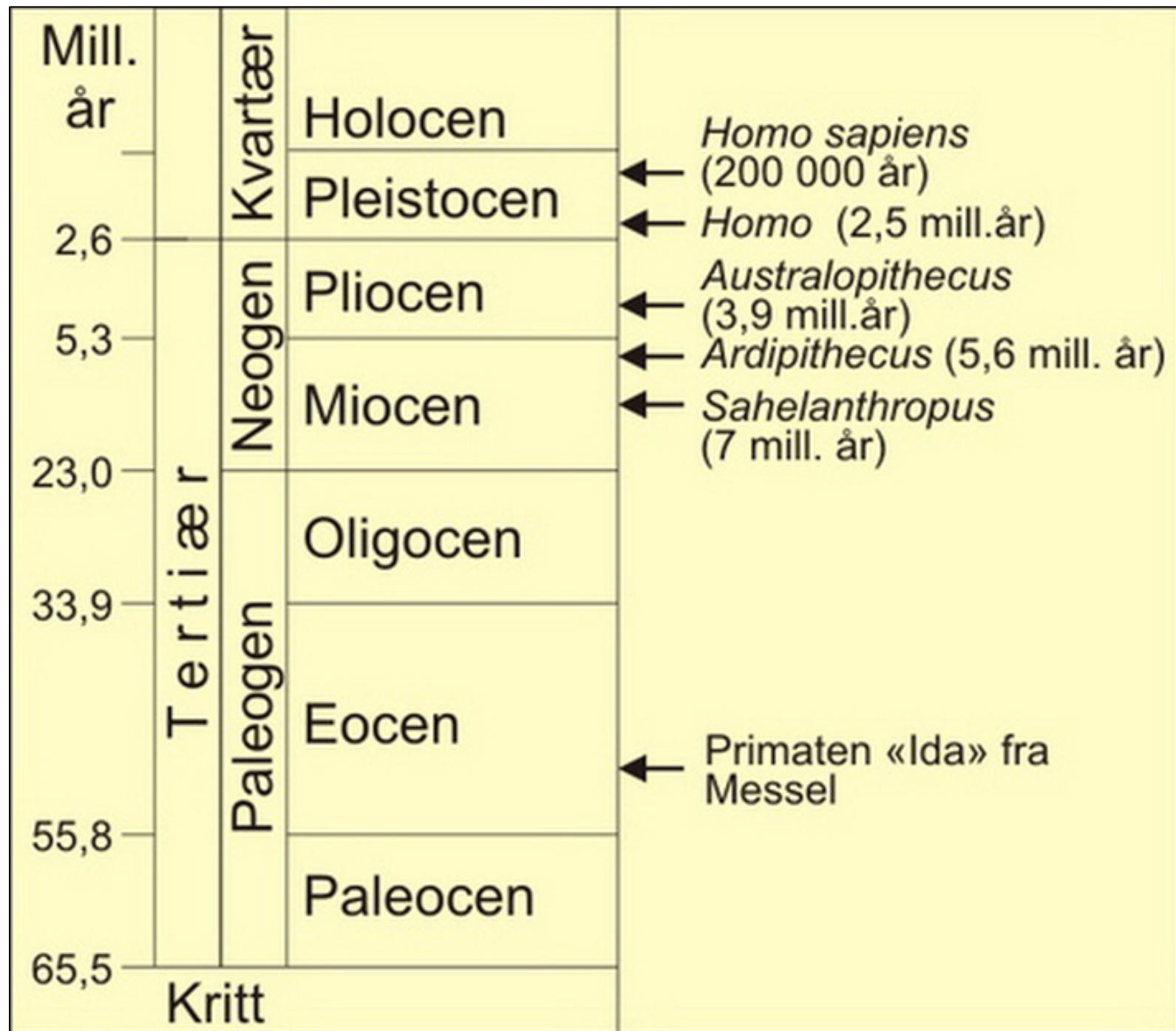
Ice ages started 2.58 million years ago on the Northern Hemisphere

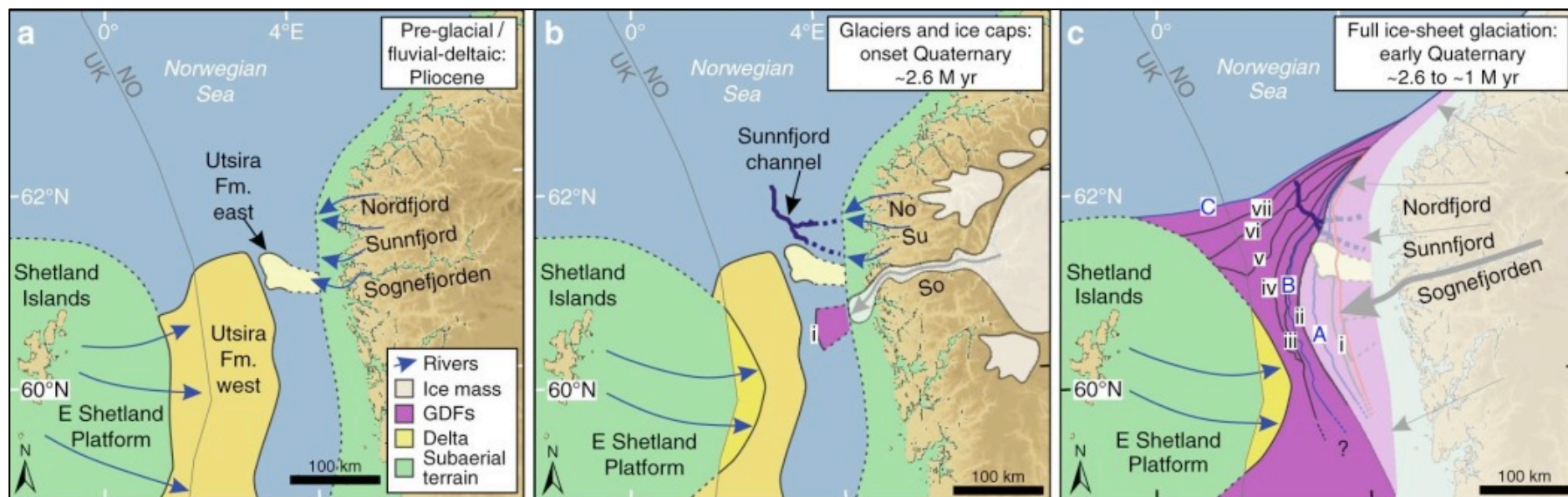




Kurve som viser hvordan ^{18}O -innholdet i havet har variert fra i dag og 1,8 millioner år bakover i tid. Tidsskalaen er gitt i tusenår, så 200 er 200 000 år. Navnene (og svart/hvitt) langs tidsskalaen viser magnetfeltets retning: I *Brunhes* var det som i dag, mens i *Matuyama* lå den magnetiske nordpol nær dagens sydpol. På kurven står tallene som brukes for isotoptrinnene, 1 er vår mellomistid, 2 er siste istidsmaksimum, 5 (egentlig 5e) er siste mellomistid.

Av Lorraine E. Lisiecki og Maureen E. Raymo.



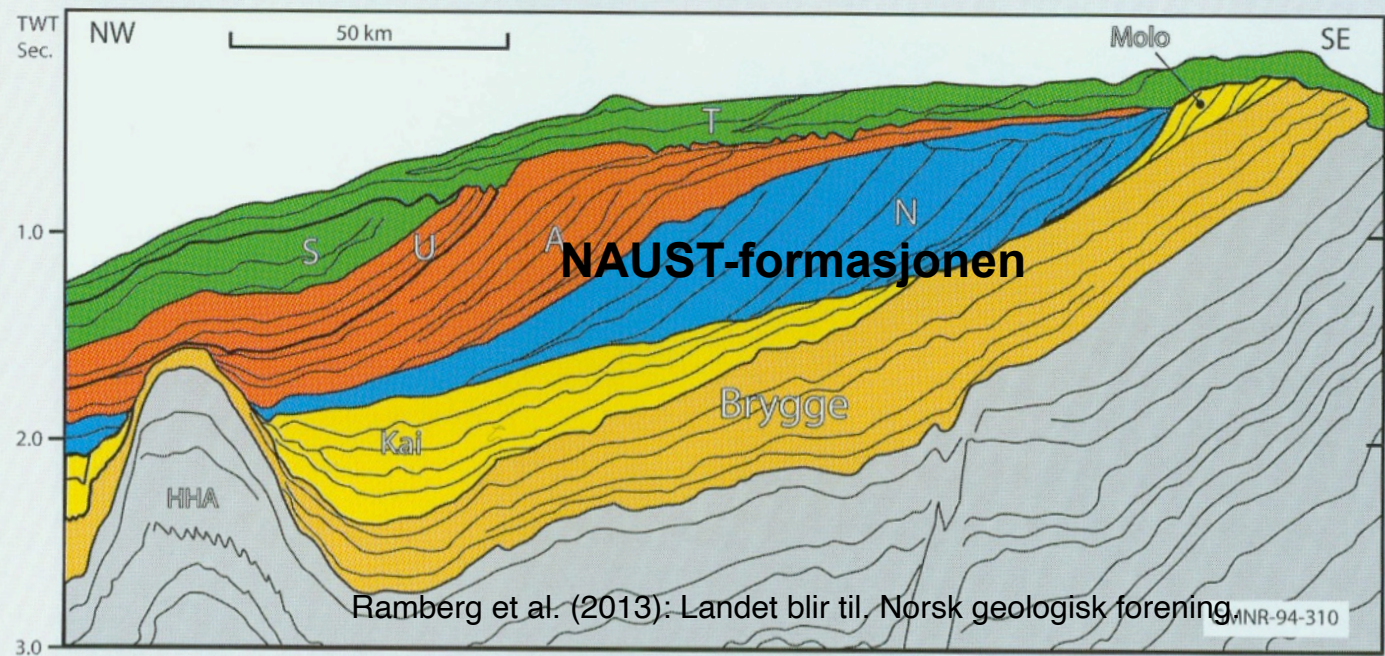
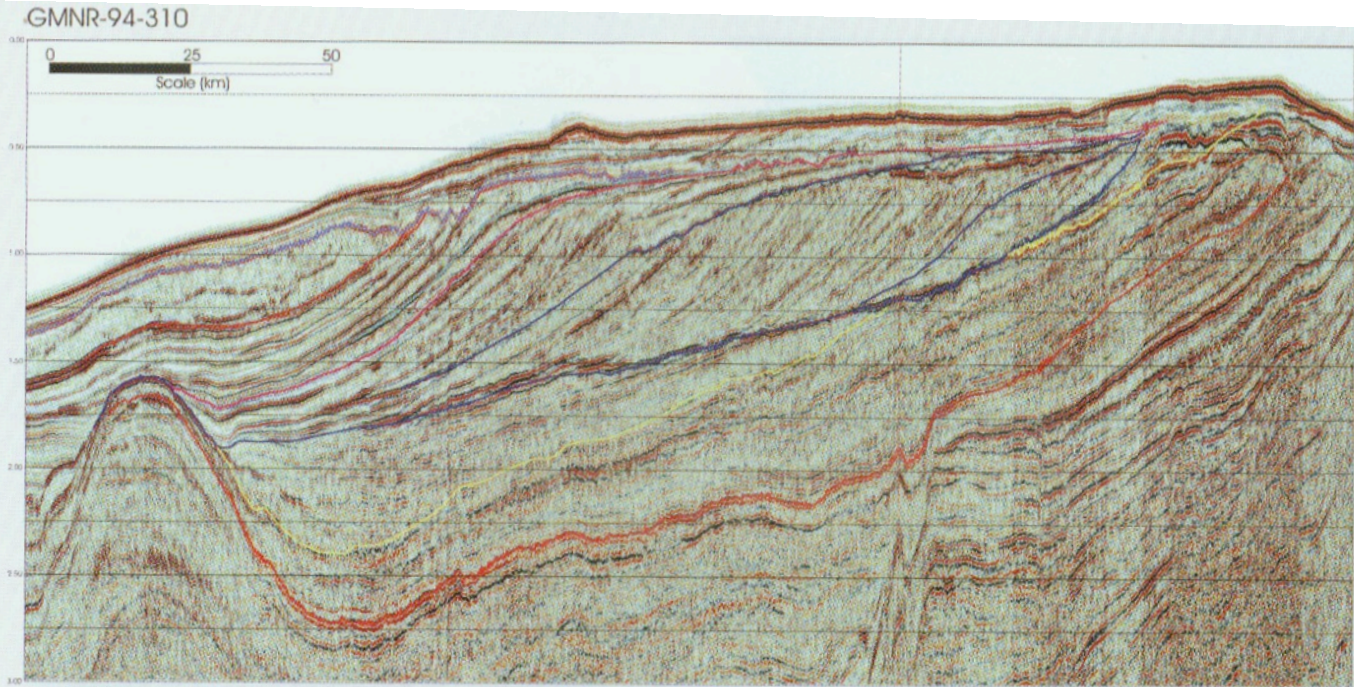


Figuren til venstre viser den rette kysten av Vest-Norge før istidene begynte, helt annerledes enn hva kysten vår er i dag. Fra det store Shetland-landet førte elver mengder av sedimenter ut i havet. Et elvedelta på havbunnen utenfor Sognefjorden er også markert.

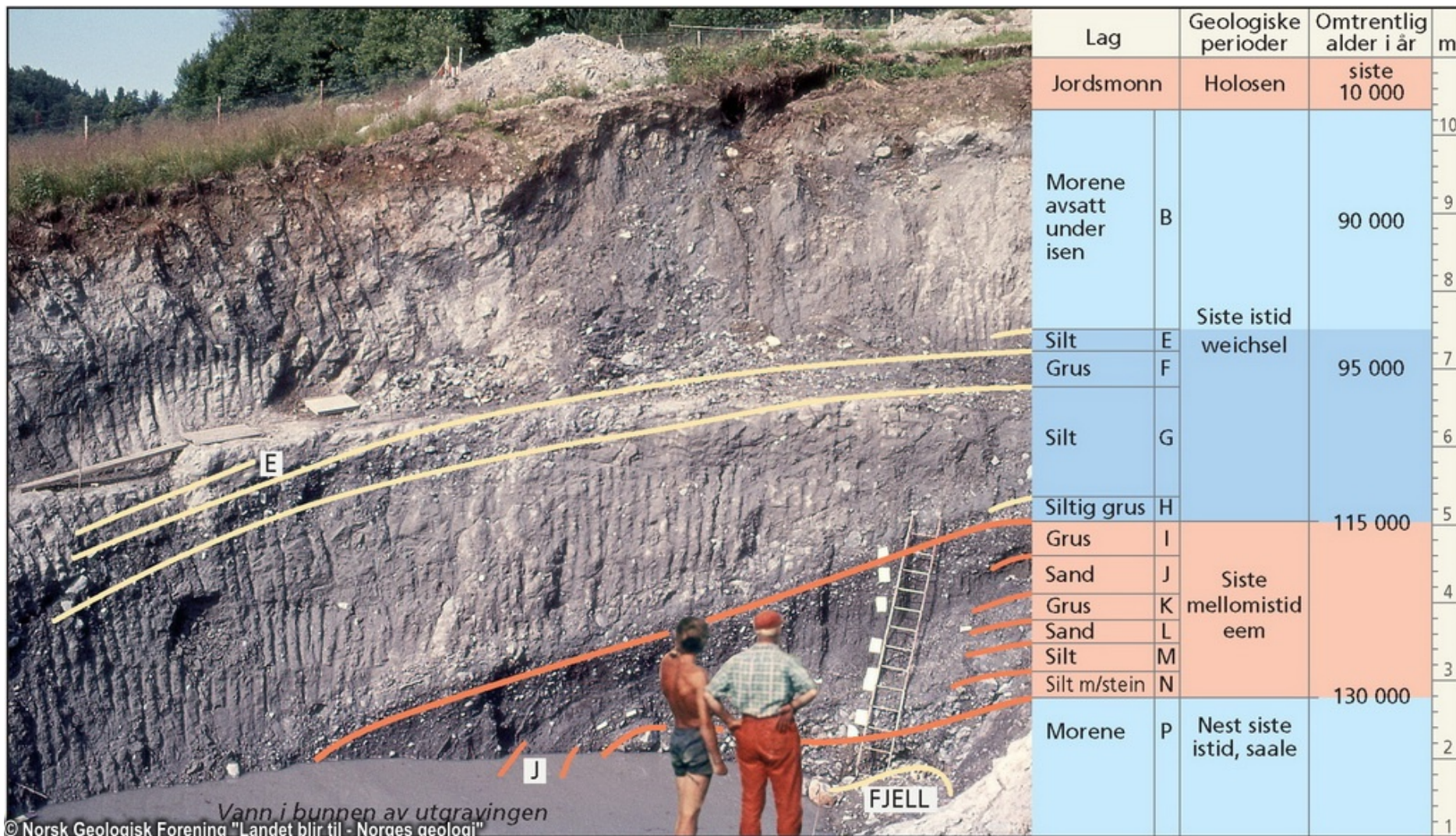
Figuren i midten viser begynnelsen på istidene og den aller første isen som kom ut Sognefjorden. Litt lenger nord ble Sunnfjordkanalen dannet av store mengder smelte vann.

På figuren til høyre er istiden i full gang. Iskappen (lilla) strakk seg helt vest til Shetland-landet. Mesteparten av ismassene kom ut Sognefjorden.

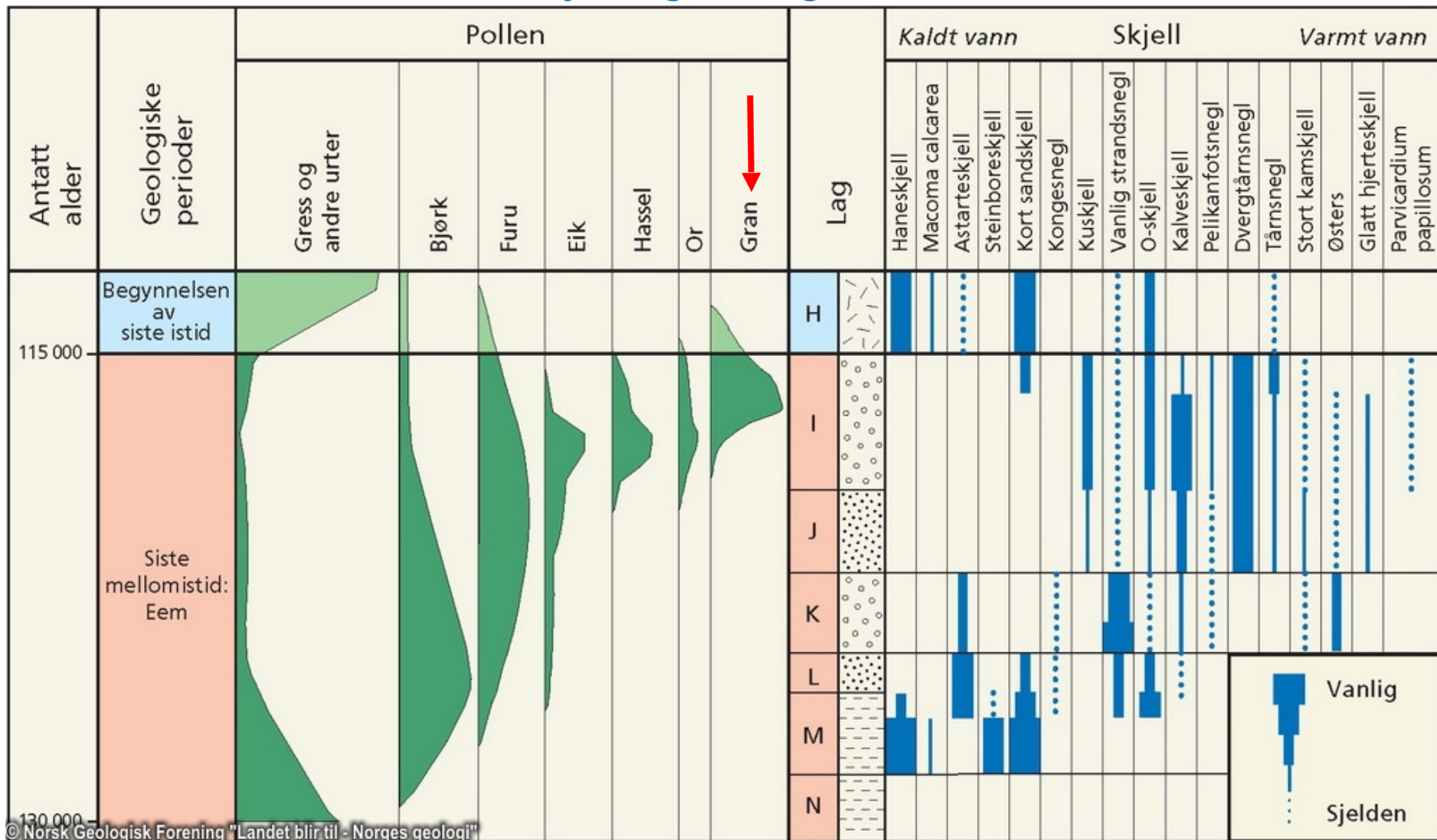
H. Løseth, J. A. Dowdeswell, C. L. Batchelor og D. Ottesen: «*3D sedimentary architecture showing the inception of an Ice Age*», Nature Communications, 2020.

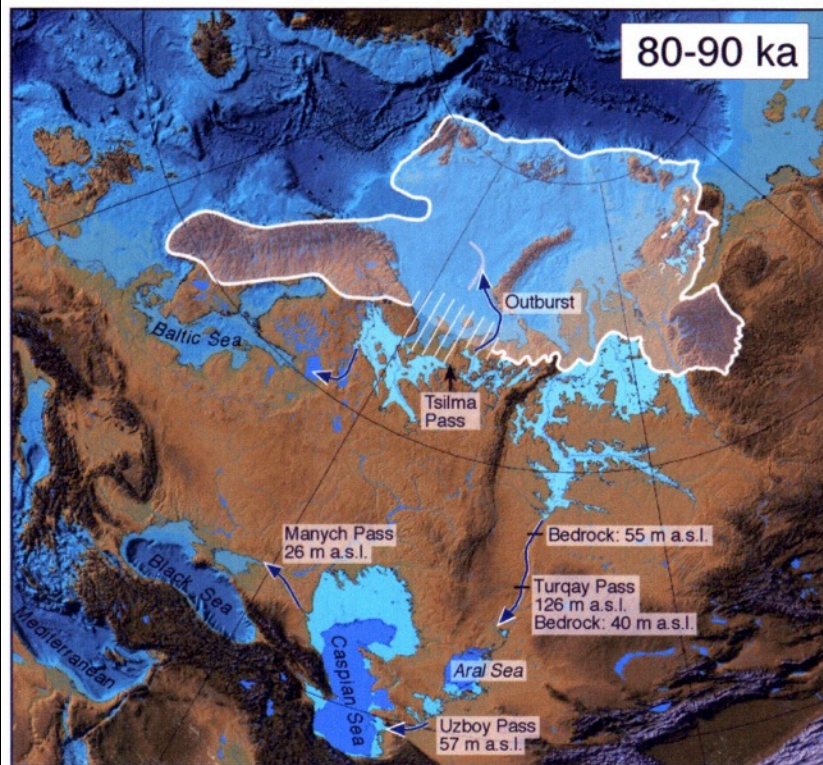
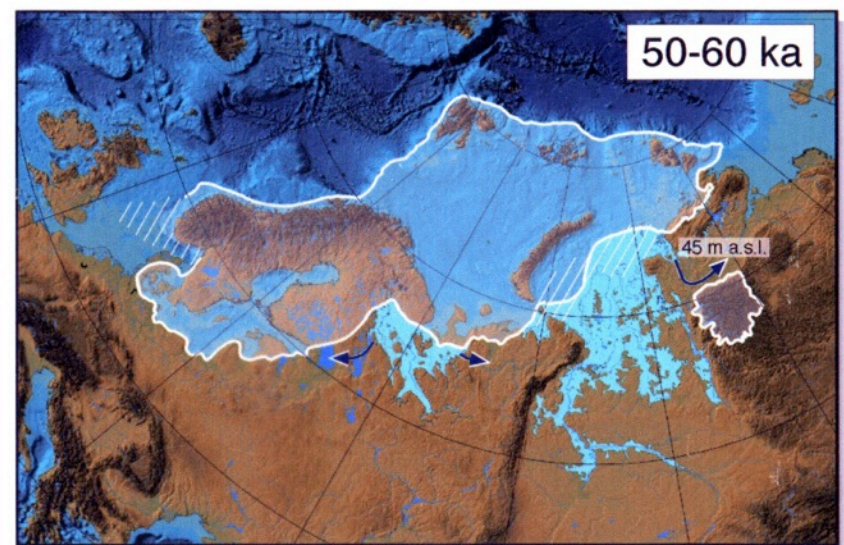
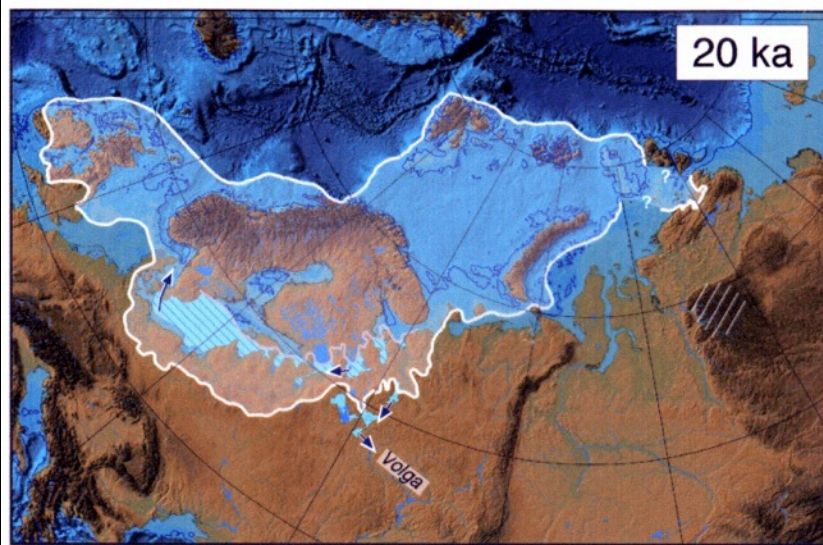


Fjøsanger, Bergen

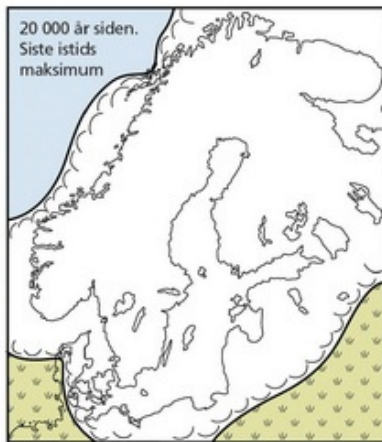
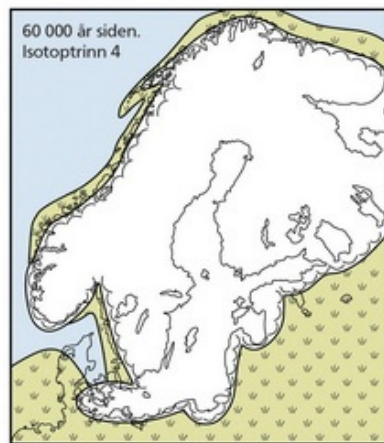
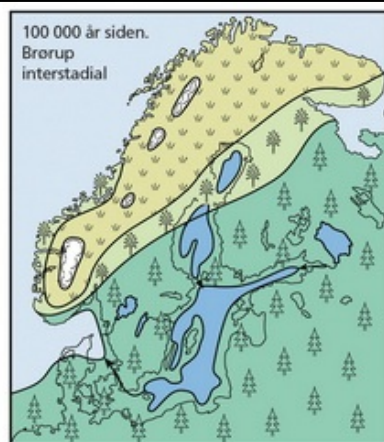


Fjøsanger, Bergen



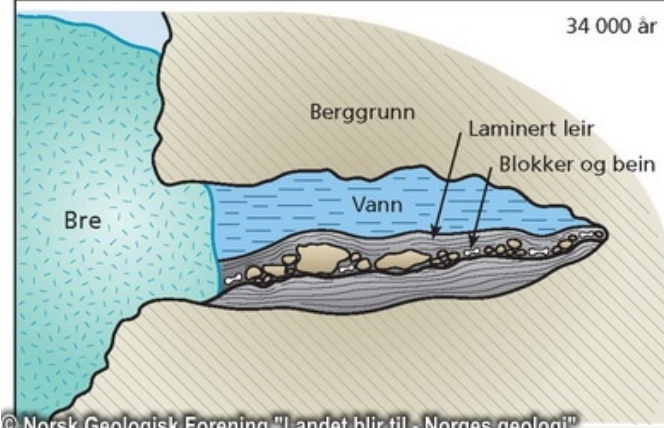
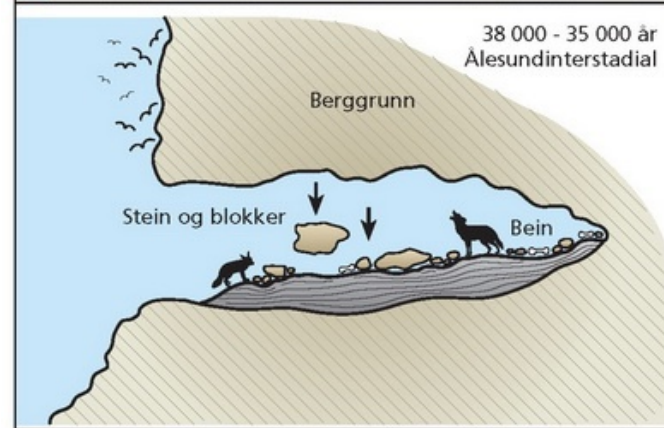
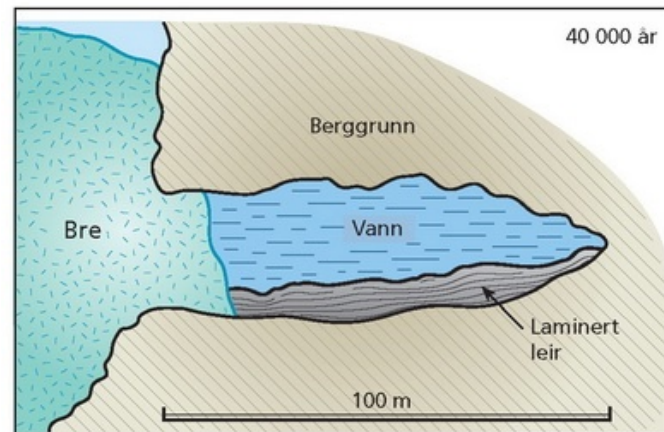


Svendsen et al. (2004)



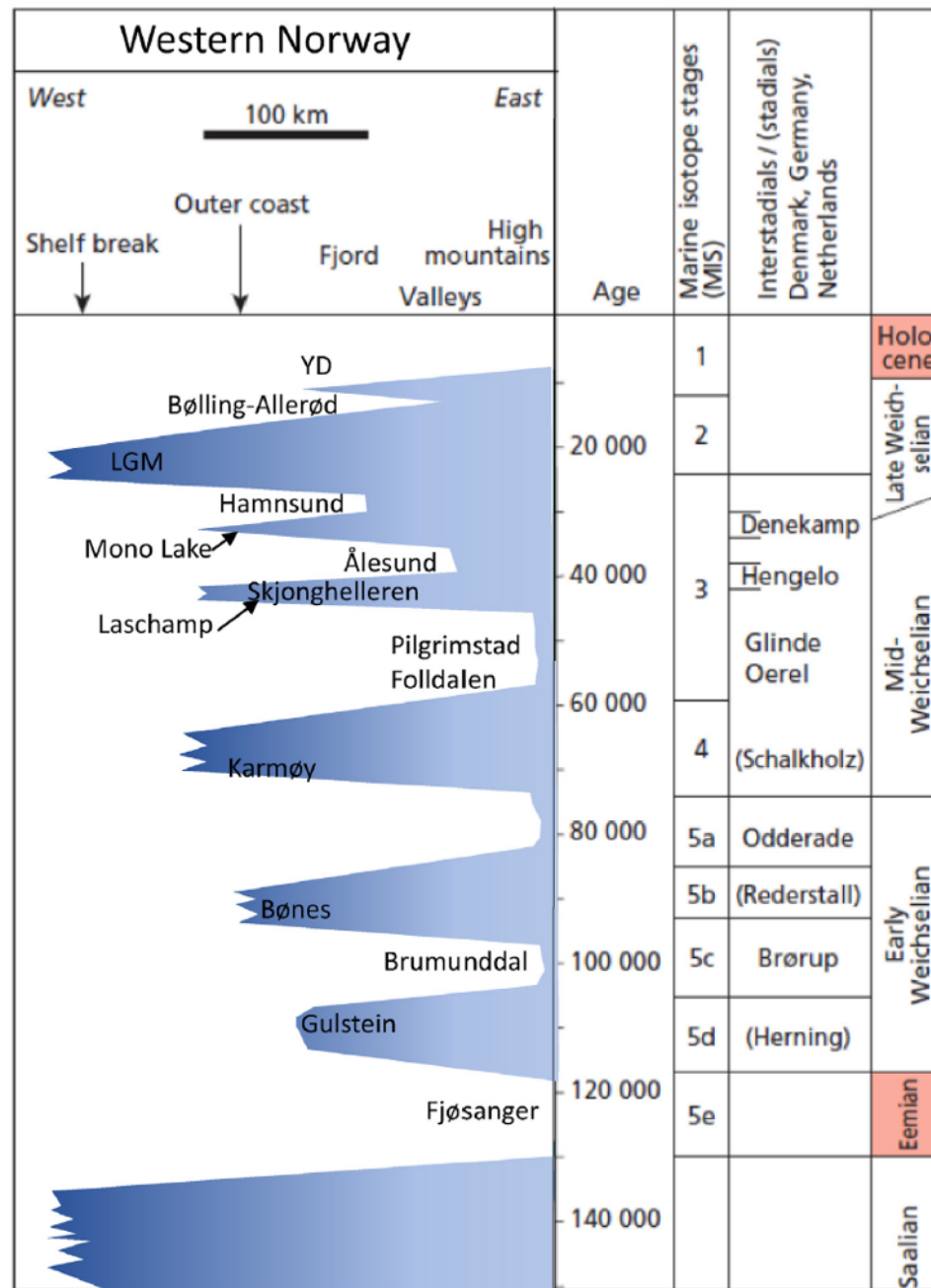
TEGNFORKLARING

-  Bre
-  Hav
-  Innsjø
-  Tundra og arktisk steppe
-  Bjørkeskog
-  Barskog
-  Eikeblandskog



© Norsk-Geologisk Forening "Landet blir til - Norges geologi"

Tid/distanse-diagram for innlandsisen sine fluktuasjonar under siste istid



Mangerud m.fl. (2023)

23 mammutfunn i Noreg i perioden 1886-2013



13 støttenner
6 kinntenner
1 skulderblad
1 virvel
1 ulna (albogebein)
1 bekken

Mammutter klarte seg nordøst i Sibir for inntil 7.300 år siden og på Tajmyrhalvøya så sent som for 3.900 år siden, viser ny DNA-studie.
(Illustrasjon: Daniel Eskridge / Shutterstock / NTB)

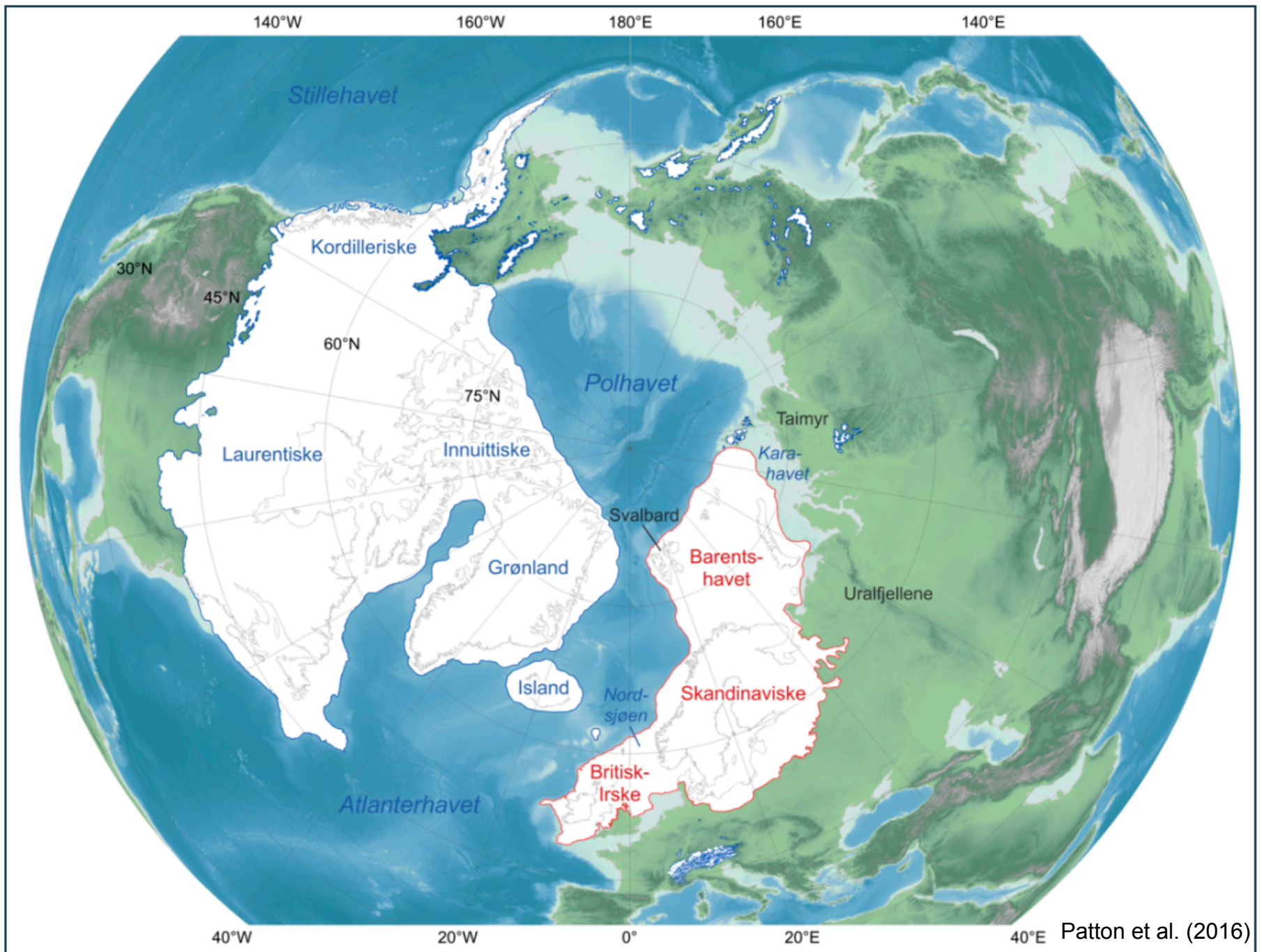




Fig. 1. Major drainage routes of the Eurasian ice sheet complex, adapted from Stokes and Clark (2001), Orsén et al. (2005) and Clark et al. (2012). Locations of major trough mouth fans (brown) adapted from Dahlgren et al. (2005) and Batchelor and Dowdeswell (2014). PB: Porcupine Bank; BDF: Barra and Donegal Fans; RB: Rosemary Bank; NSF: North Sea Fan; Bj: Bjarmayrenna Fan. Glacial limits are compiled from Ehlers and Gibbard (2007), Patton et al. (2015) and Stroeven et al. (2016). Recent evidence for the extension of the Celtic ice sheet onto Porcupine Bank (PB) (Patton et al., 2015) and into the southern Celtic Sea (Praeg et al., 2015) is also incorporated. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

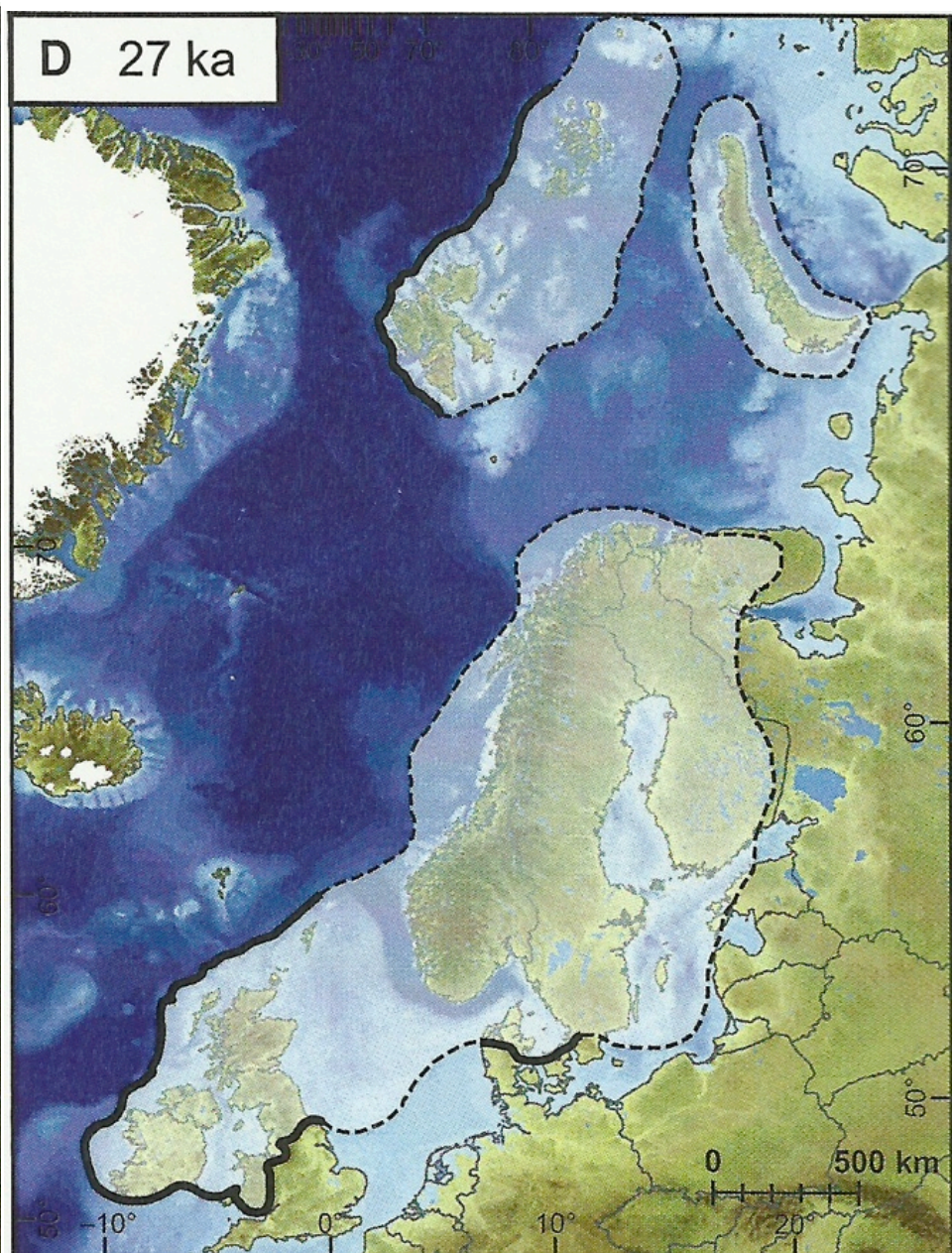
TMF - Trough mouth fan



C 29-28 ka



D 27 ka



Nordsjøen under maksimum av siste istid

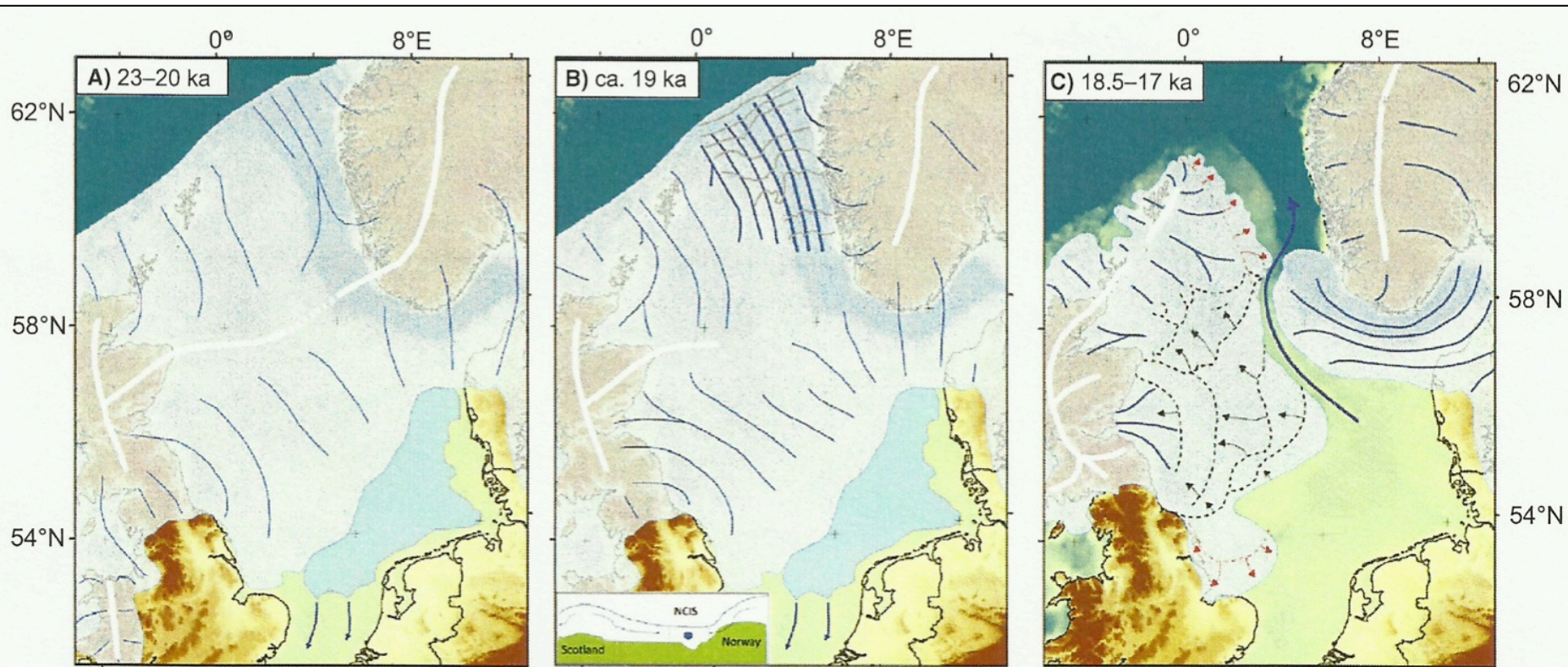
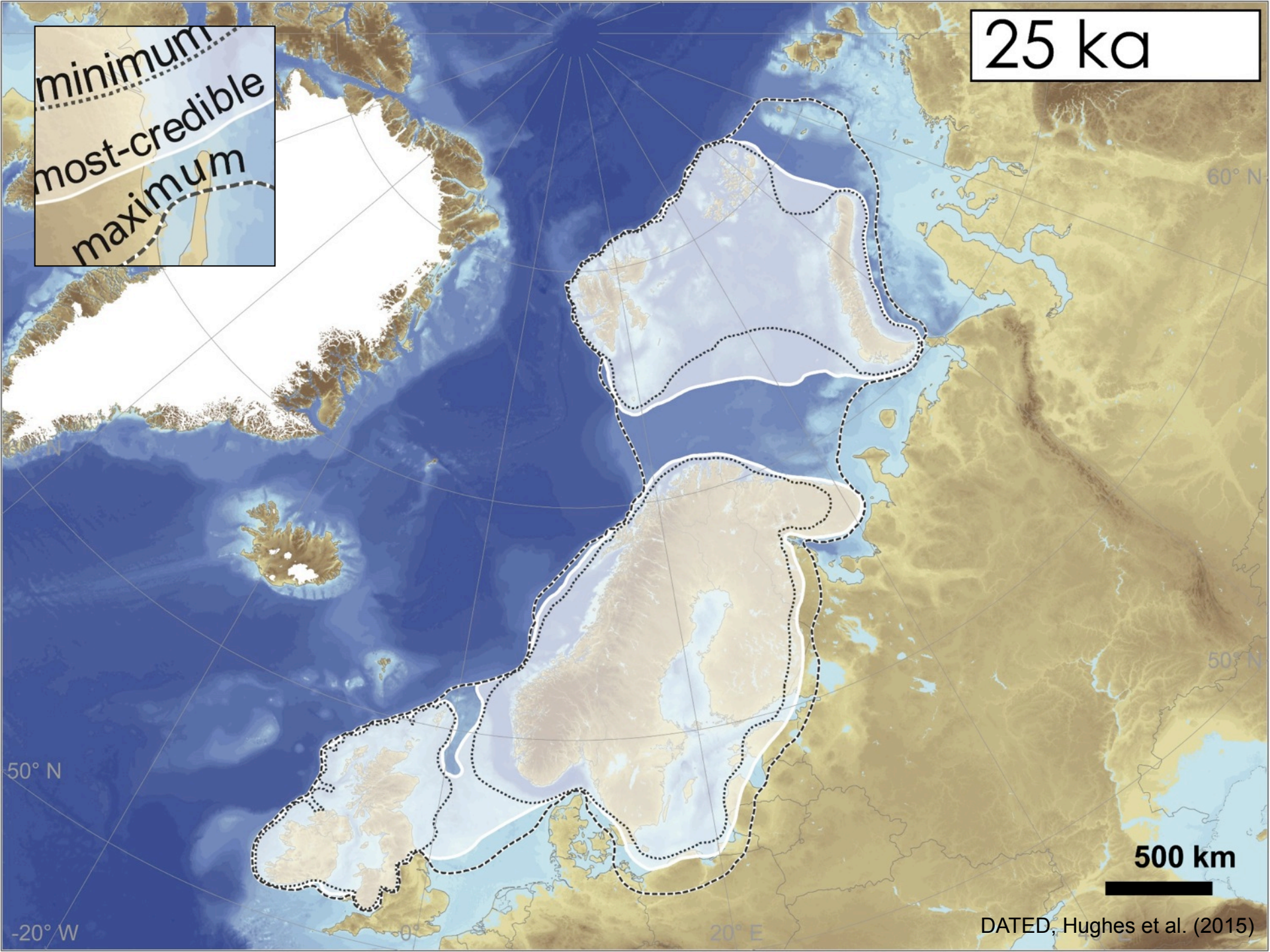


Figure 3. Reconstructions of maximum ice extent. A: Maximum configuration with ice divides meeting in a saddle and an ice-dammed lake. B: Initiation of collapse. Norwegian Channel Ice Stream (NCIS) grew (dark blue lines), increasing the drawdown of ice and destroying the ice divide. Grounding line retreat (gray) up the Norwegian Channel debuttressed ice on either side as it thinned and withdrew (inset). C: Unzipping and collapse. NCIS narrows down and separates from British ice and the ice-dammed lake discharges through the Ling Bank drainage channel (blue arrow). Known readvances are in red.

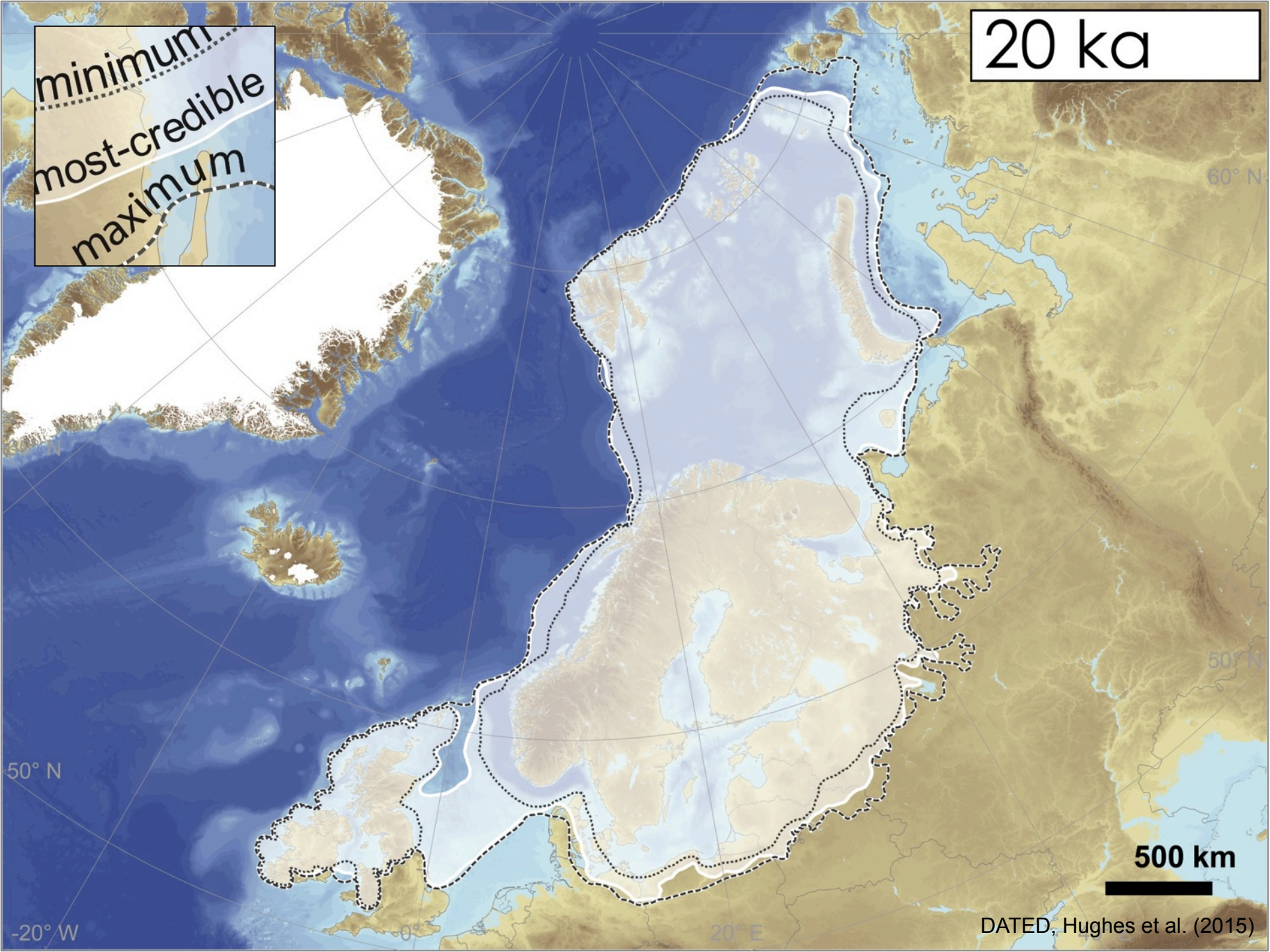
25 ka

minimum
most-credible
maximum



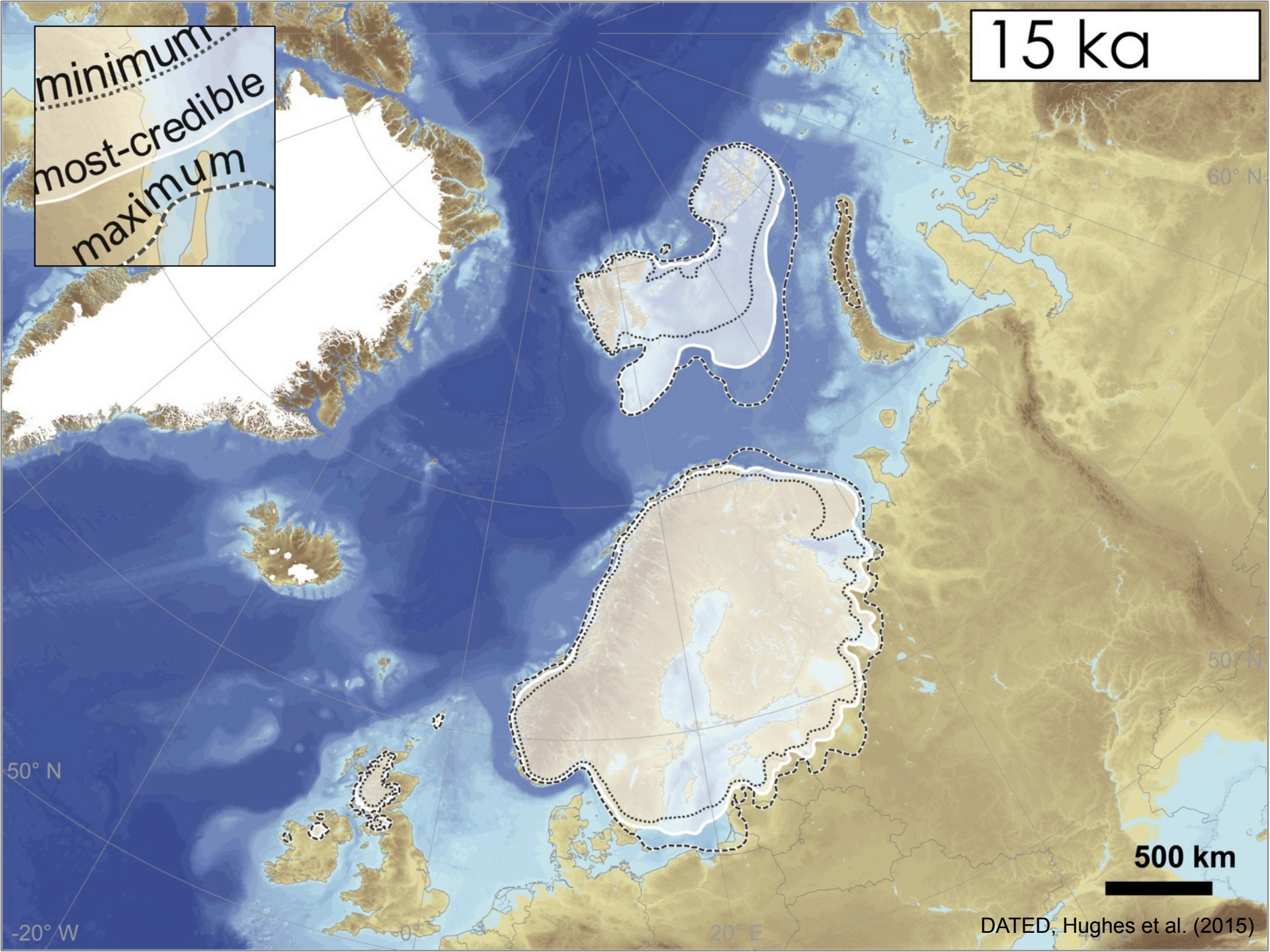
20 ka

minimum
most-credible
maximum



15 ka

minimum
most-credible
maximum

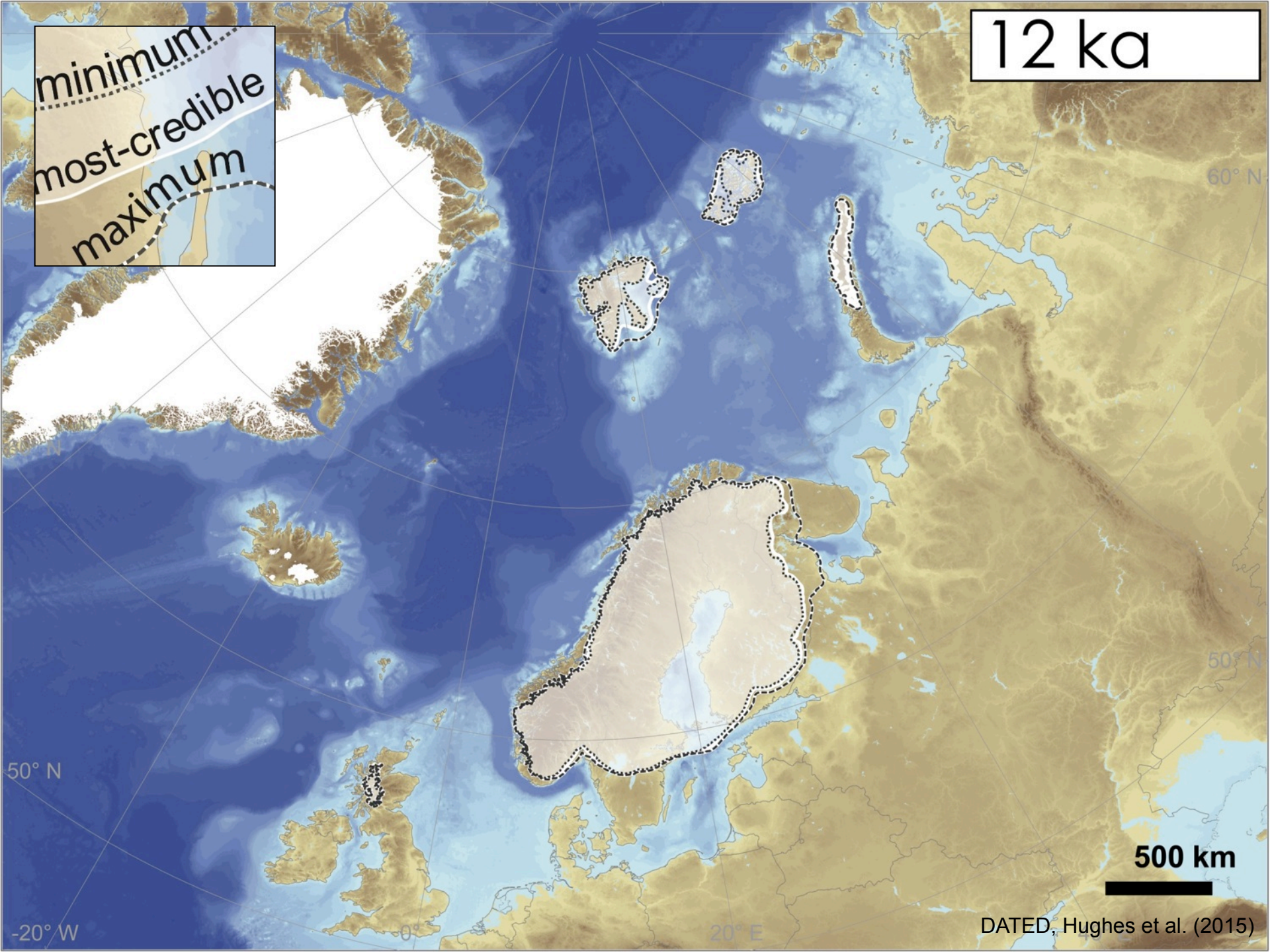


500 km

DATED, Hughes et al. (2015)

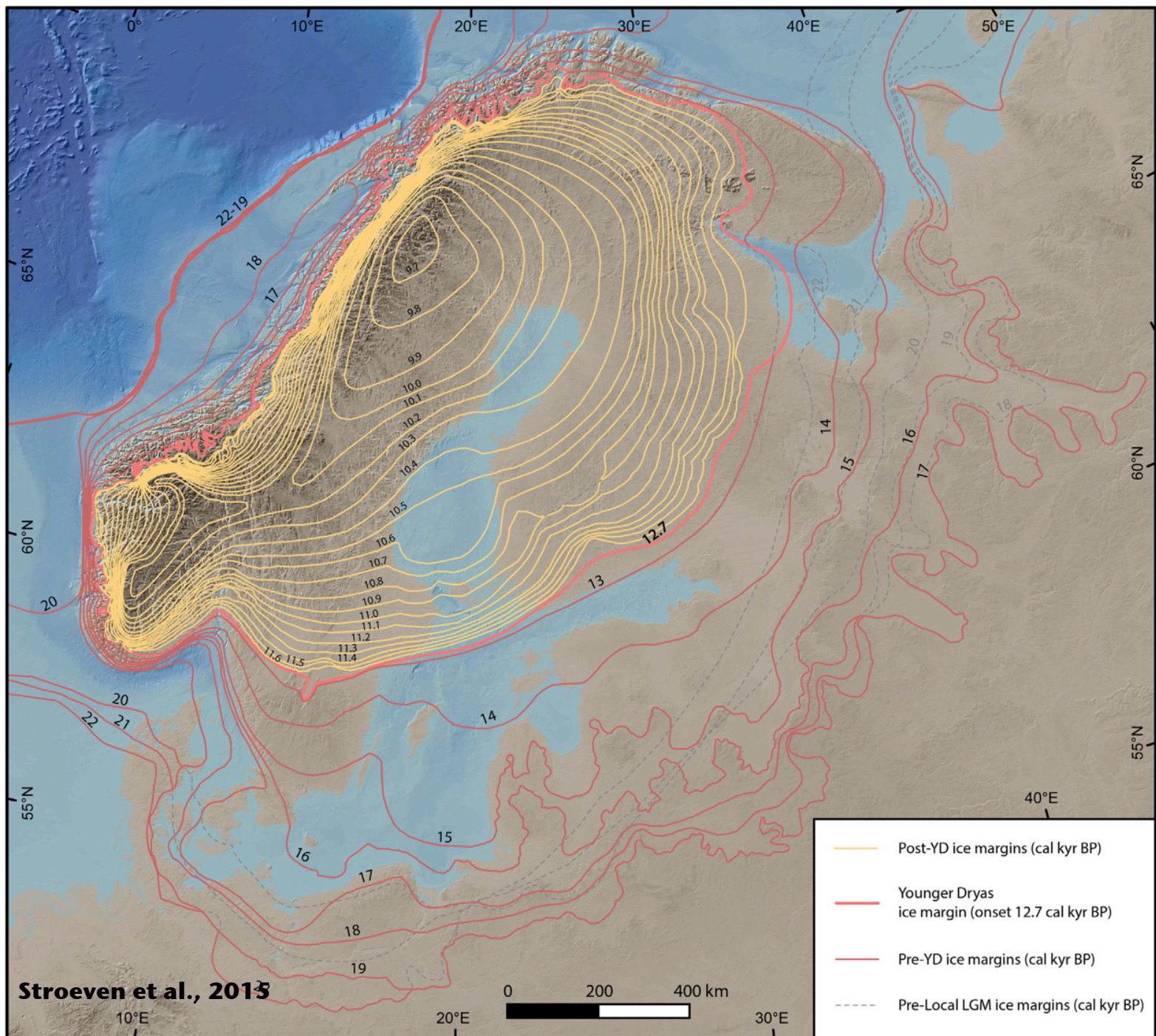
12 ka

minimum
most-credible
maximum



500 km

DATED, Hughes et al. (2015)



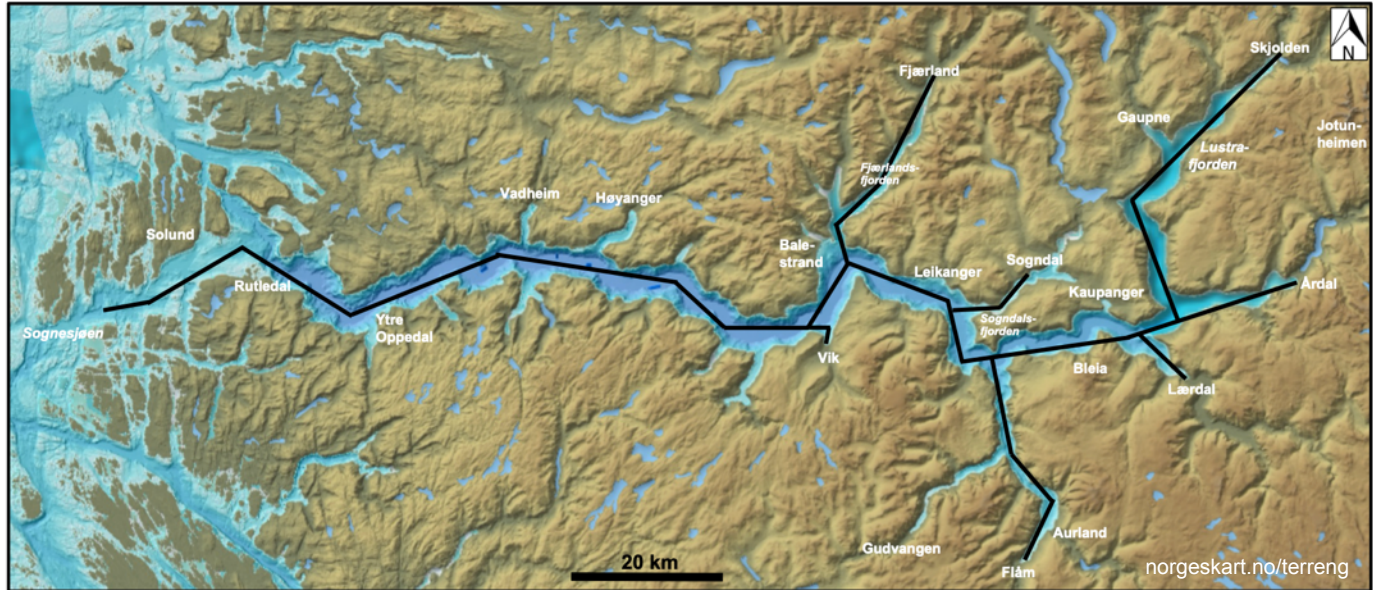
Moreneryggar avsette i Yngre dryas-perioden (12.900 – 11.700 år sidan)



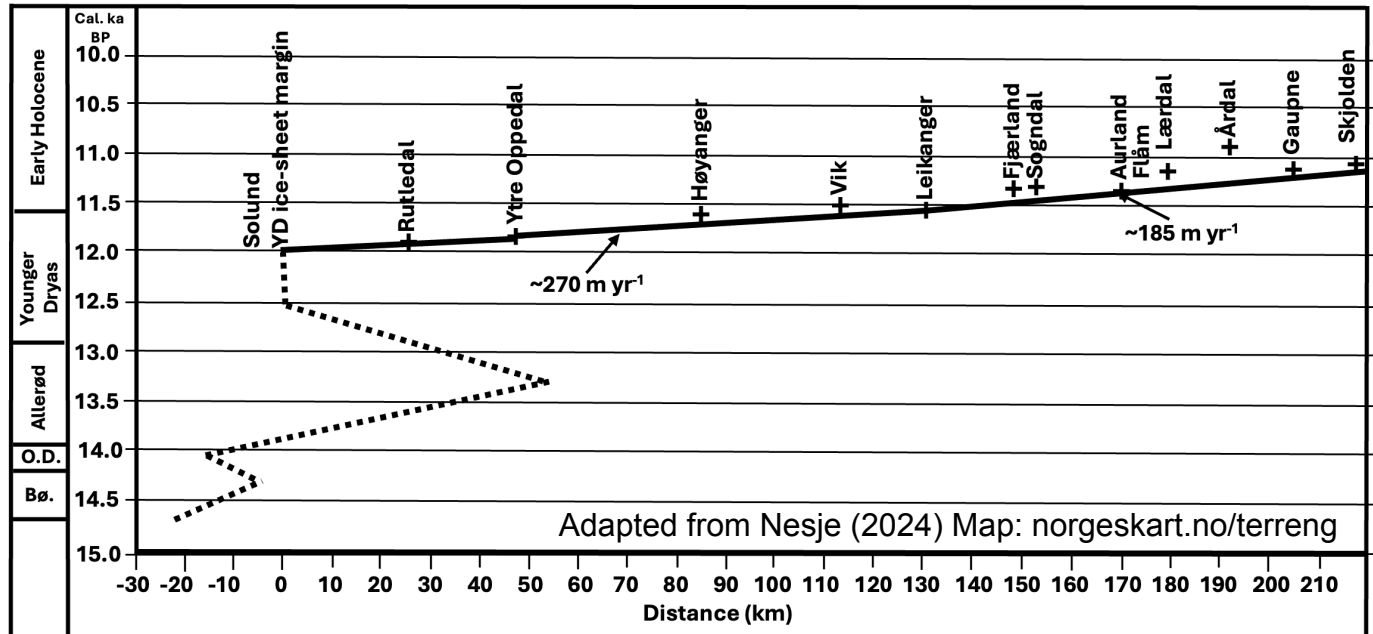


Tid/distance-diagram for Sognefjorden

A

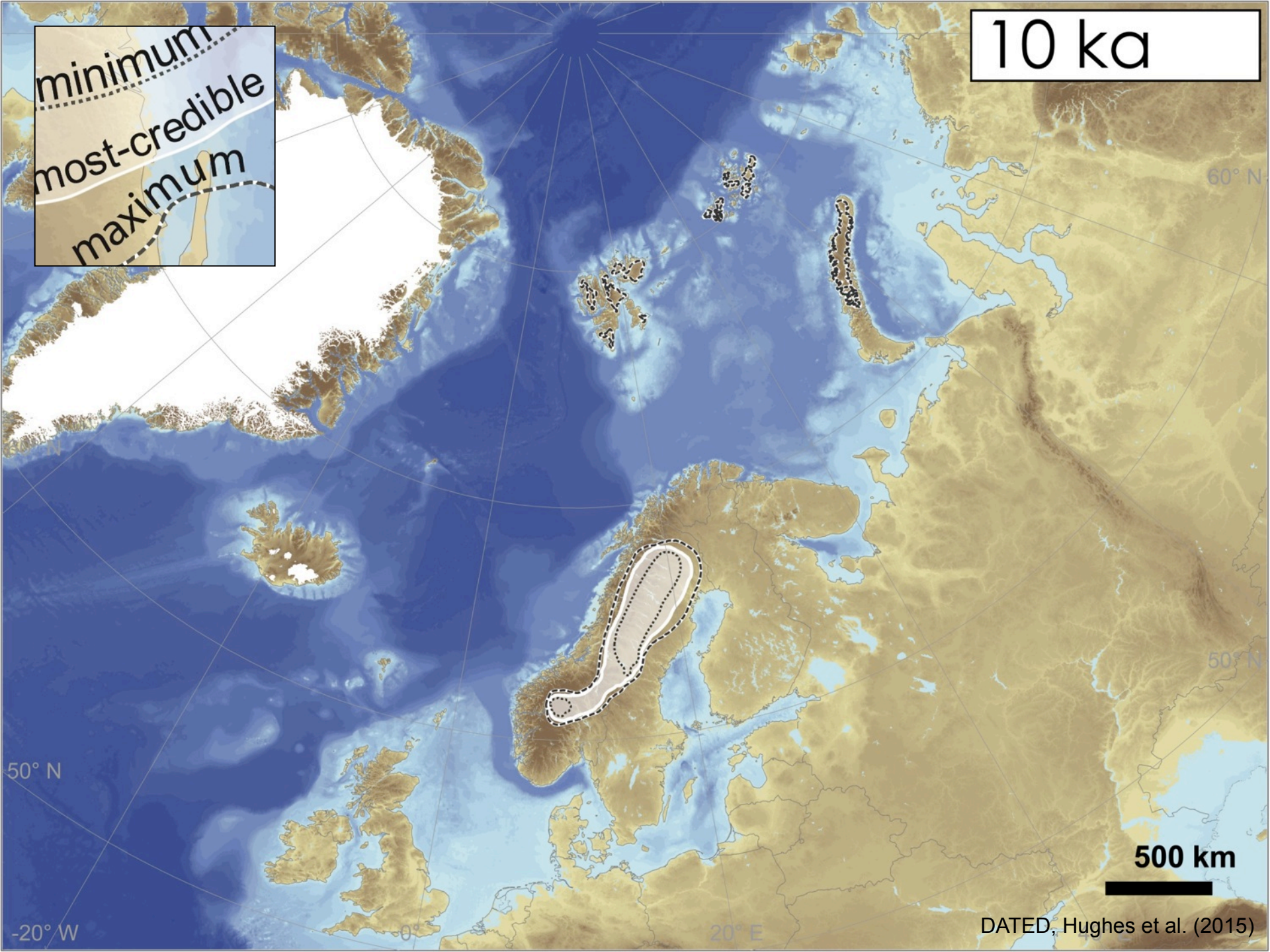


B



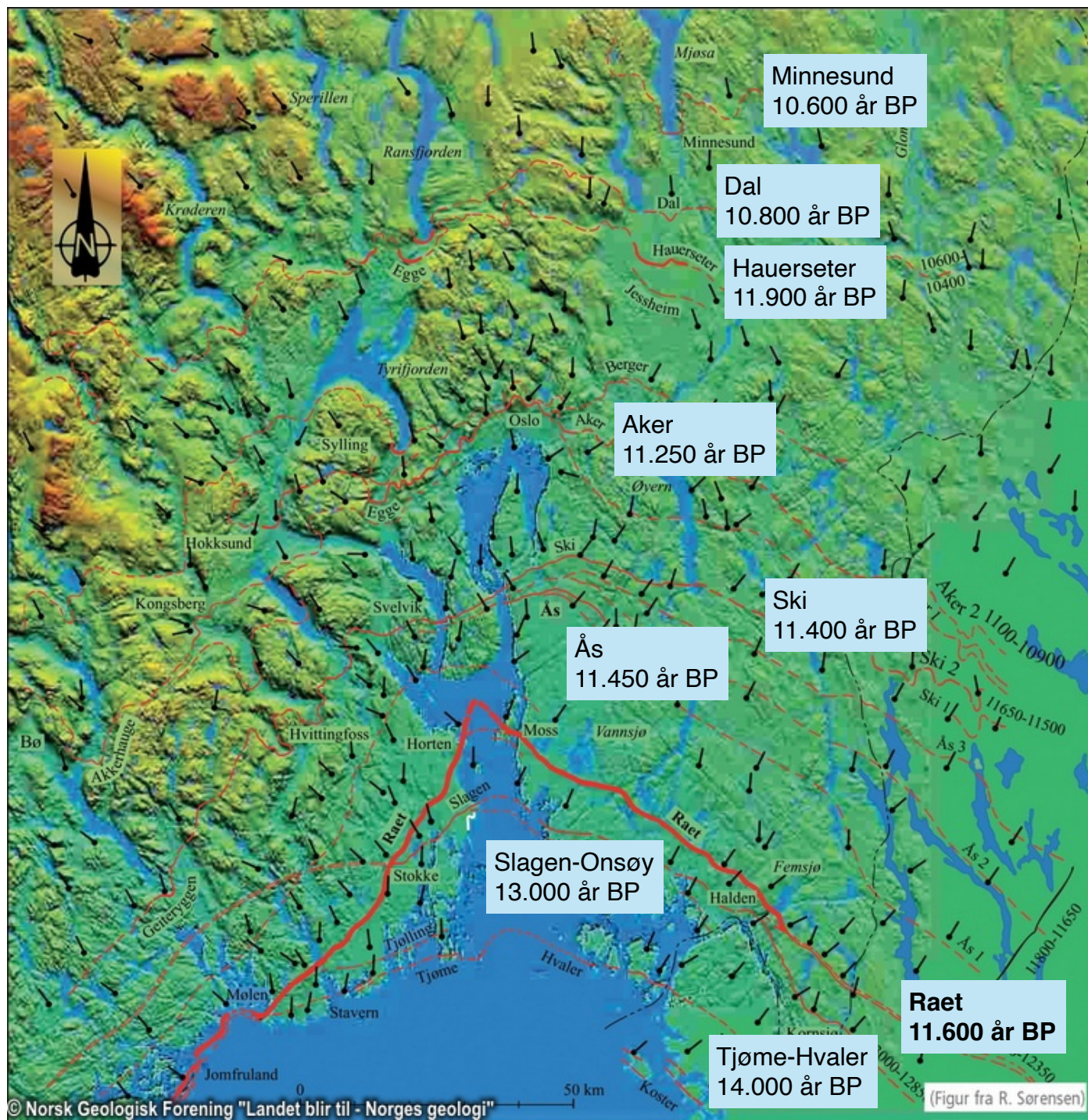
10 ka

minimum
most-credible
maximum



500 km

DATED, Hughes et al. (2015)



A 11 600 a BP
Ra substage



Oslo_x

x Larvik

0 10 20 km

B 11 400 a BP
Ski substage

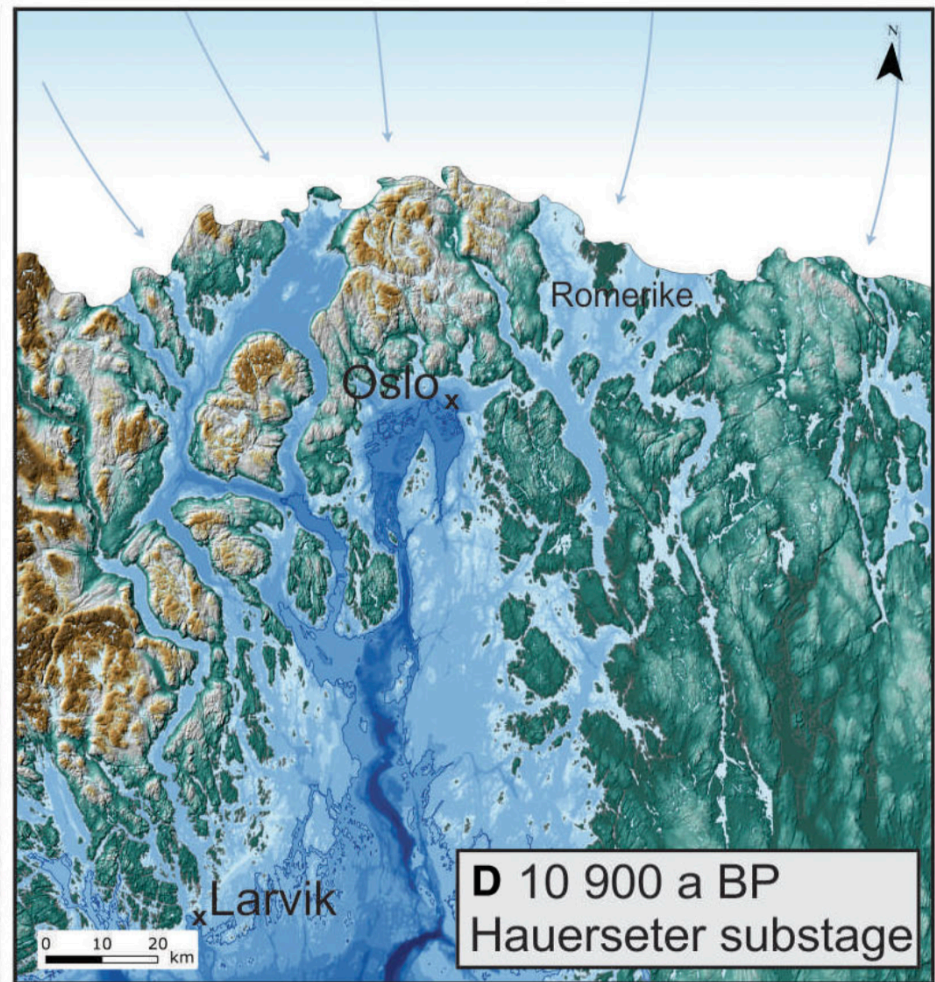
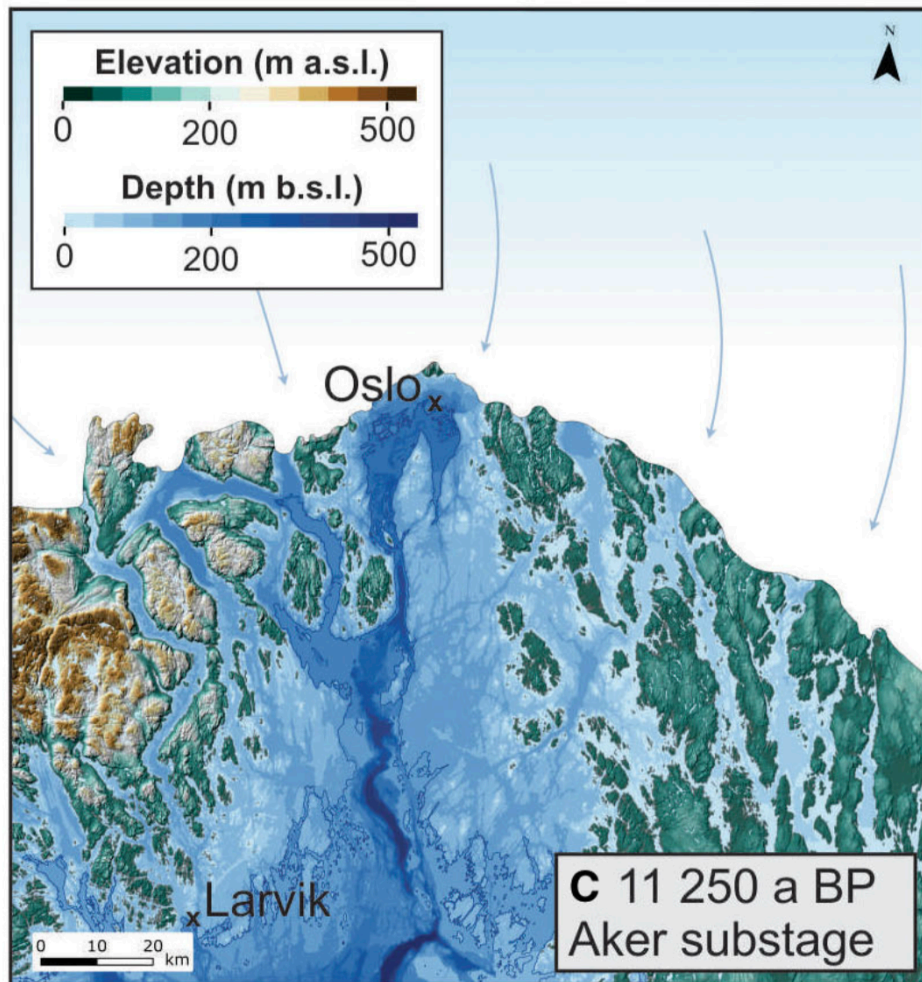


Oslo_x

x Larvik

0 10 20 km

Romundset et al.
(2025)



Romundset et al.
(2025)

Leirterreng, Romerike



Hauerseter

Gardermoen

6 672 064 N

278 925 Ø



Koordinatsystem: ETRS89/UTM sone 33N

0 1 850 m

1:40 000 (format: A3 liggende)

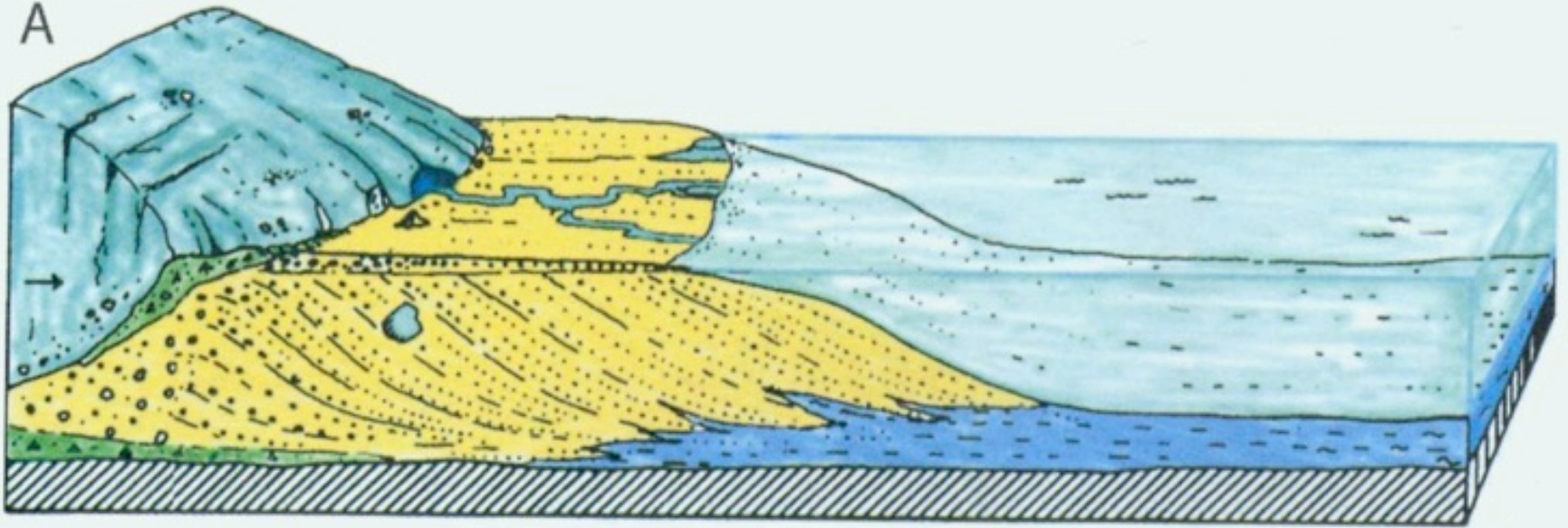
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Utskriftsdato: 28.03.2020

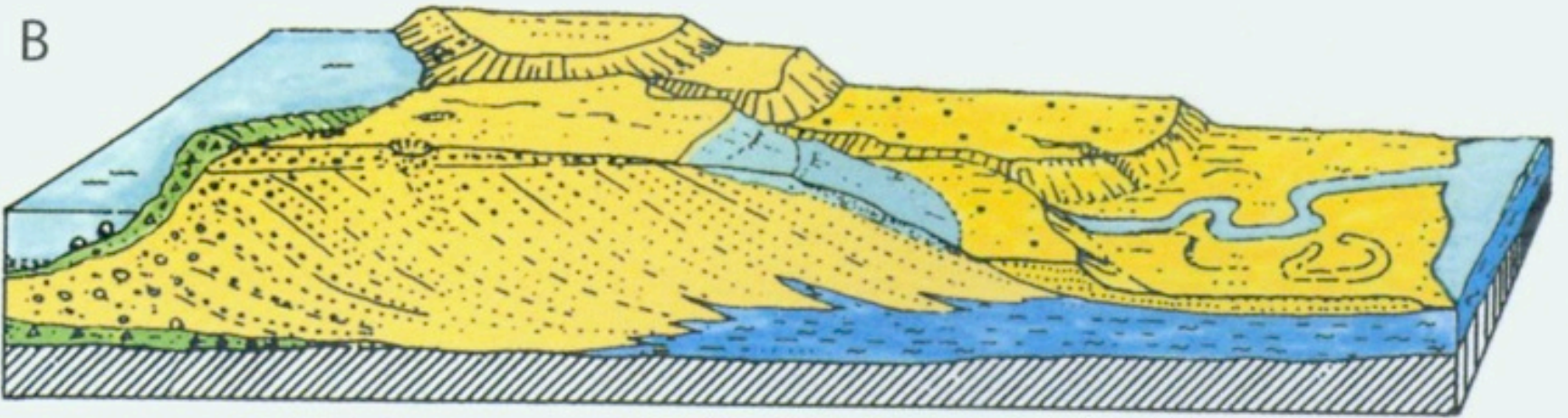
294 925 Ø

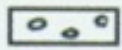
6 682 904 N

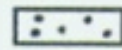
A

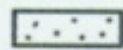


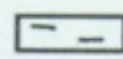
B

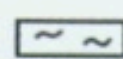


 Stein

 Grus

 Sand

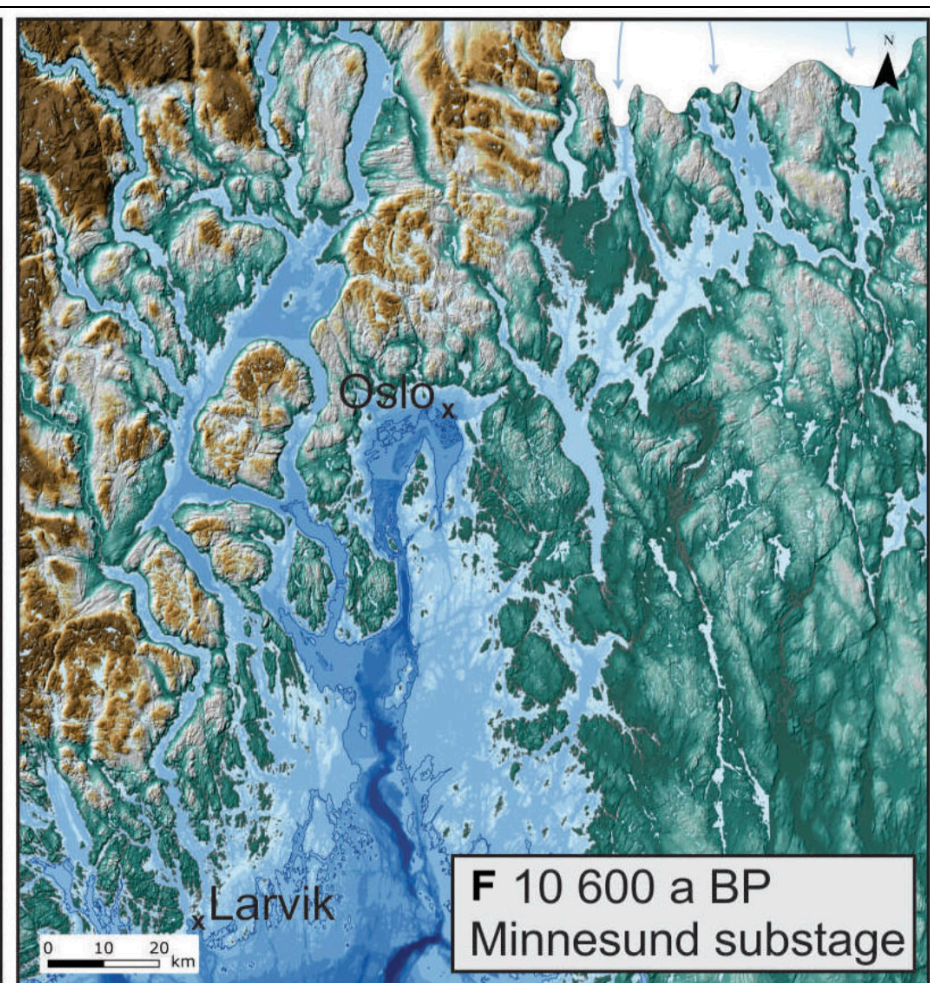
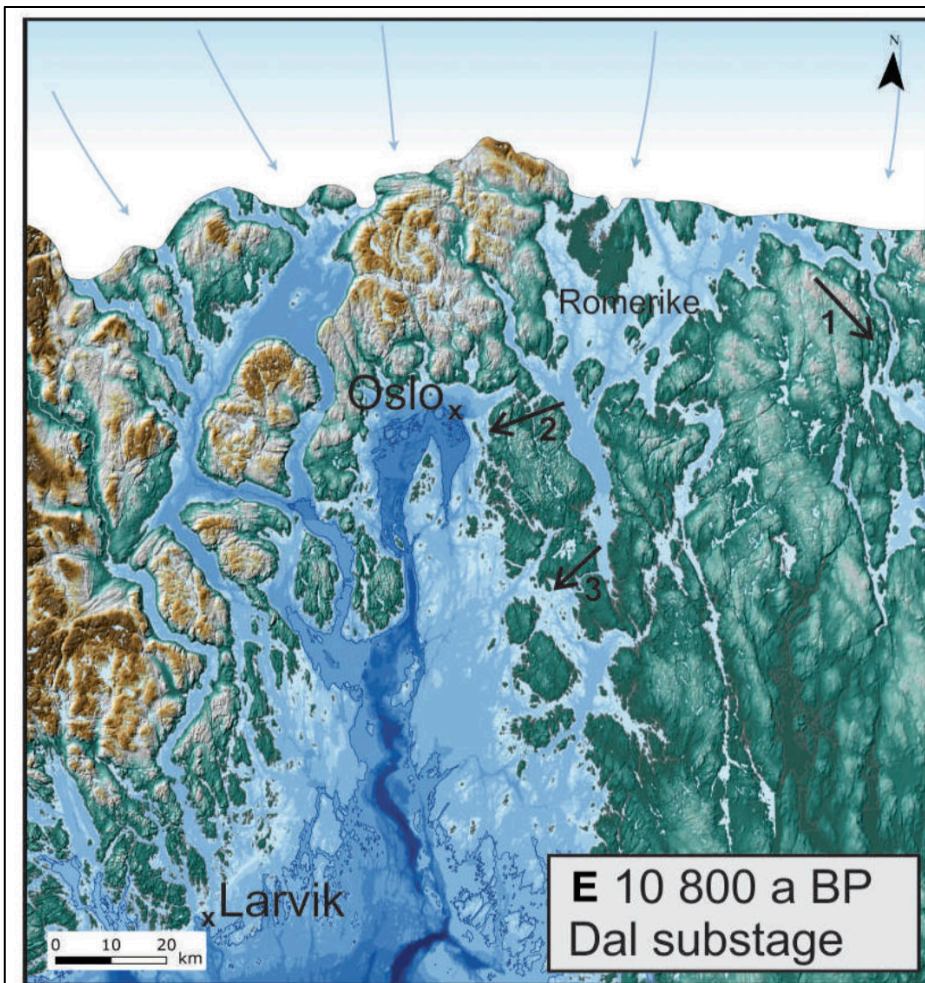
 Silt

 Leir

Hauerseter-deltaet

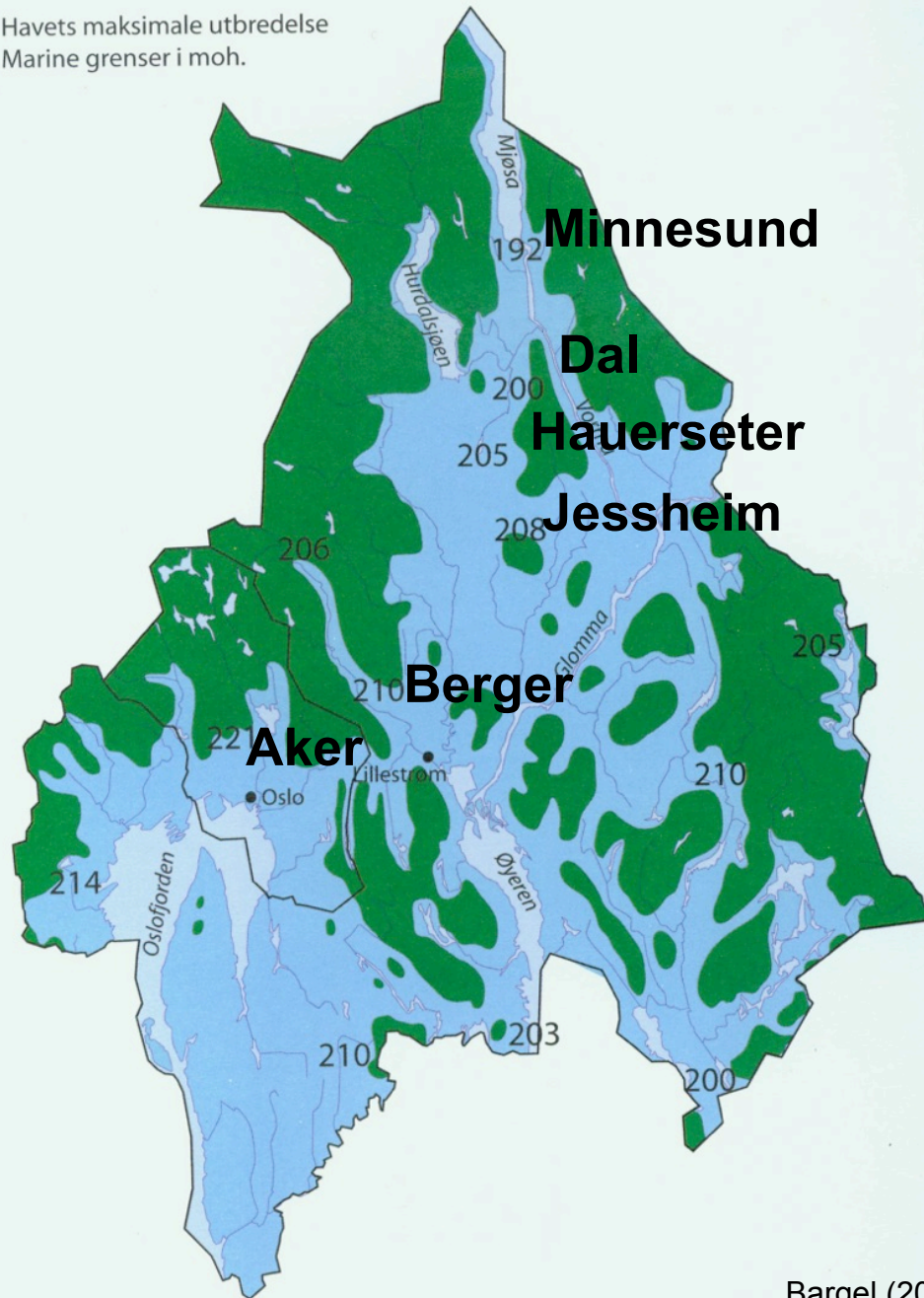


Bargel (2005)



Romundset et al.
(2025)

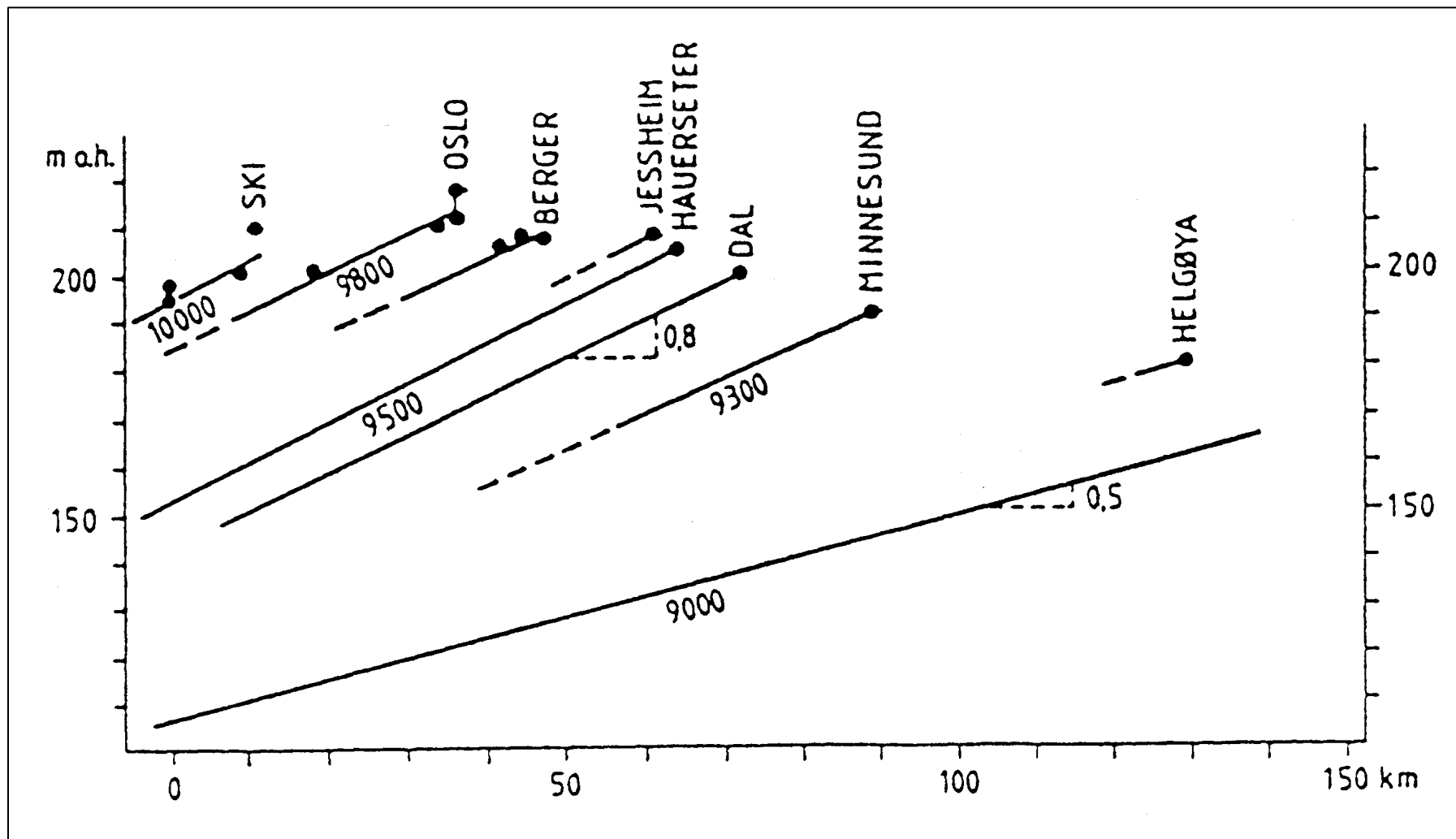
Havets maksimale utbredelse
Marine grenser i moh.



Bargel (2005)

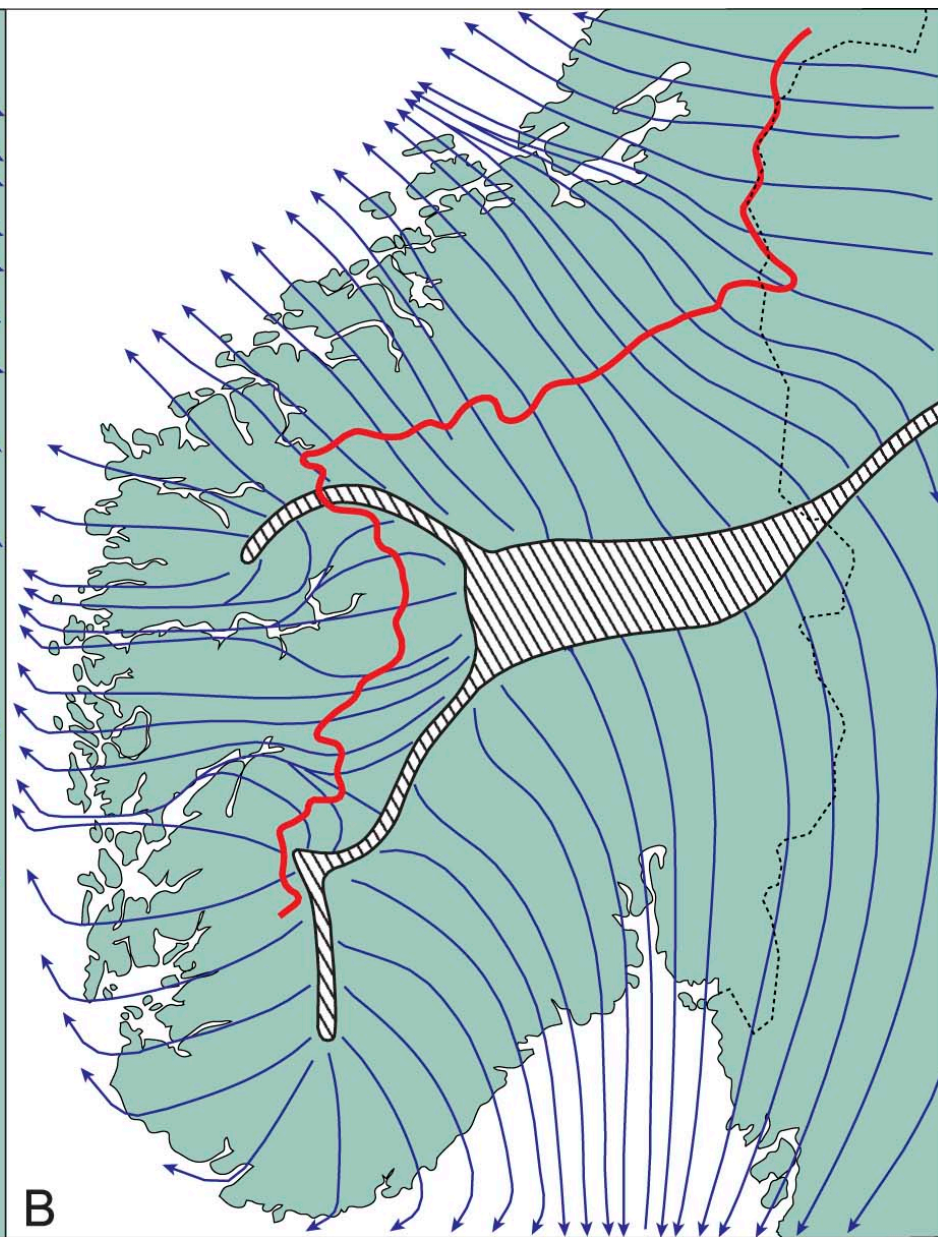
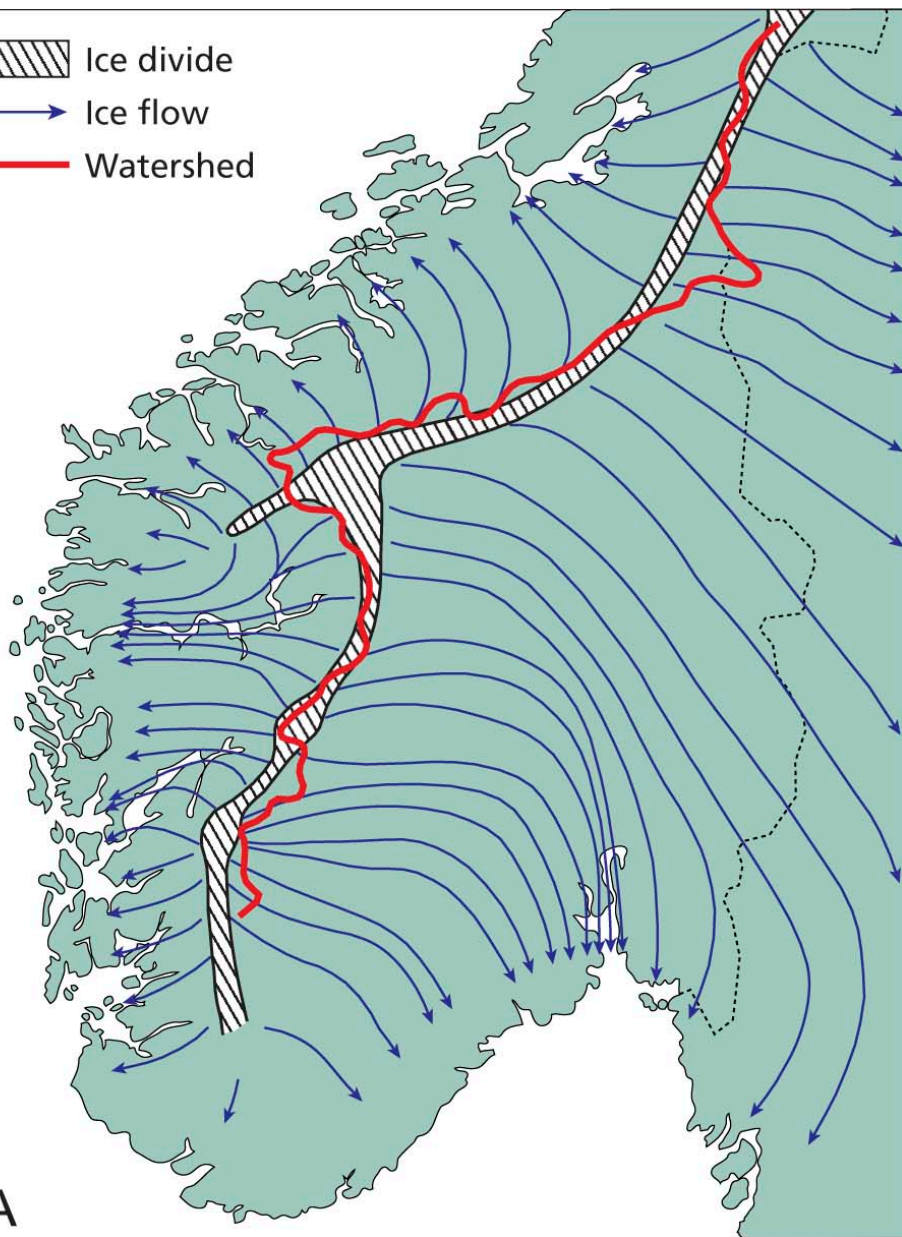
Ekvidistant strandlinjediagram for indre Oslofjord og Romerike

Etter Sørensen (1979)

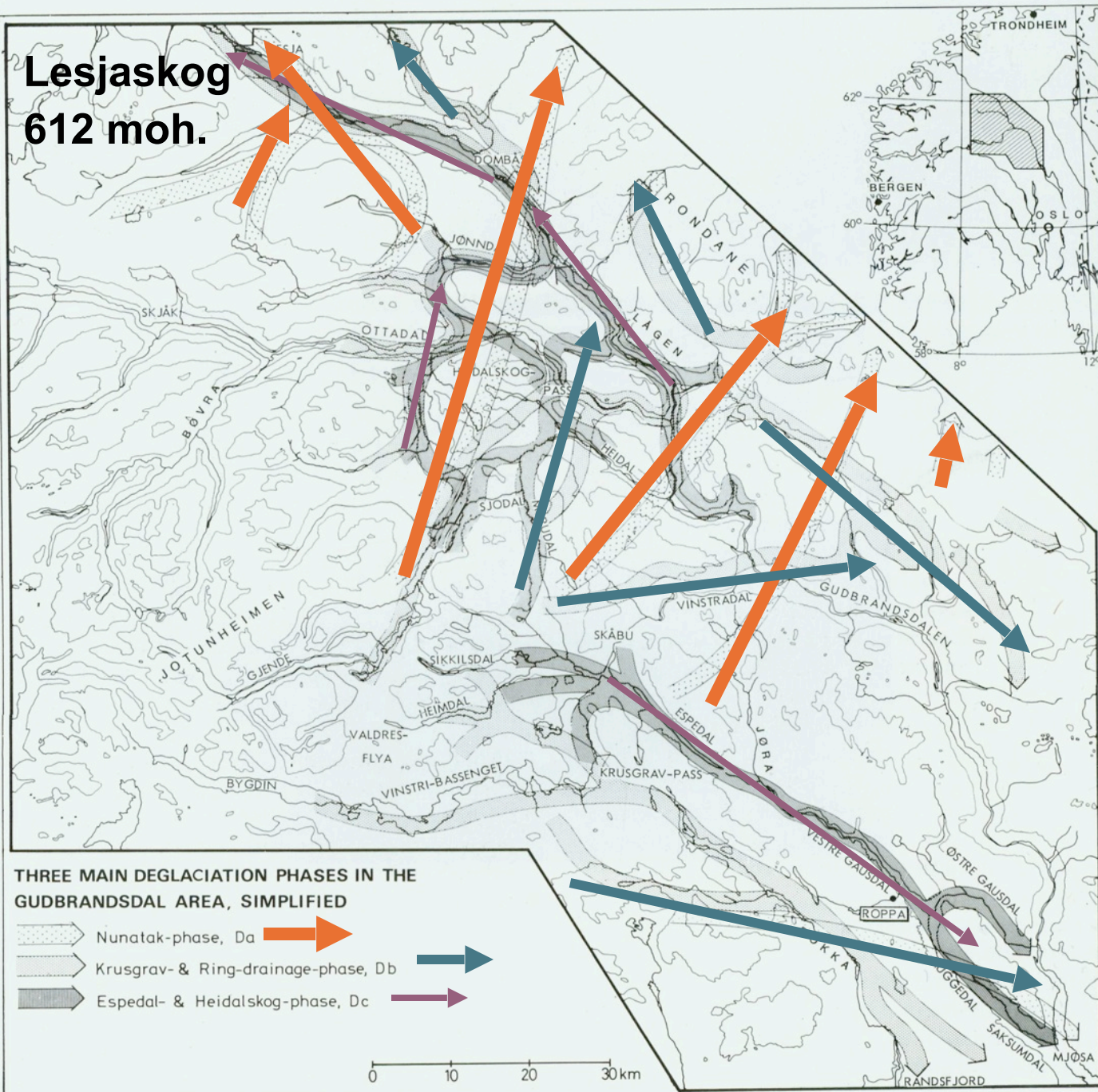


PAUSE

Ice divide
Ice flow
Watershed



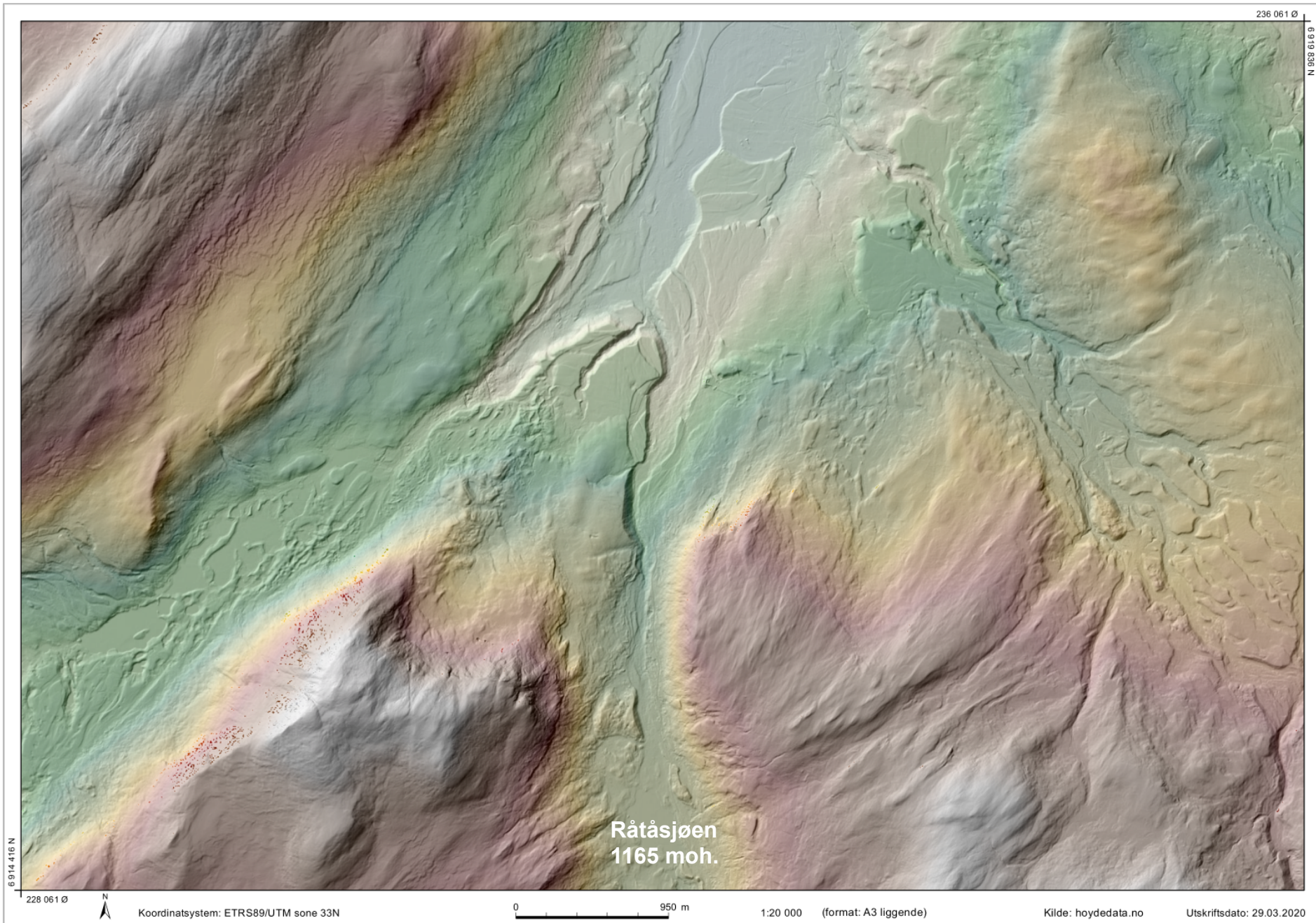
**Lesjaskog
612 moh.**



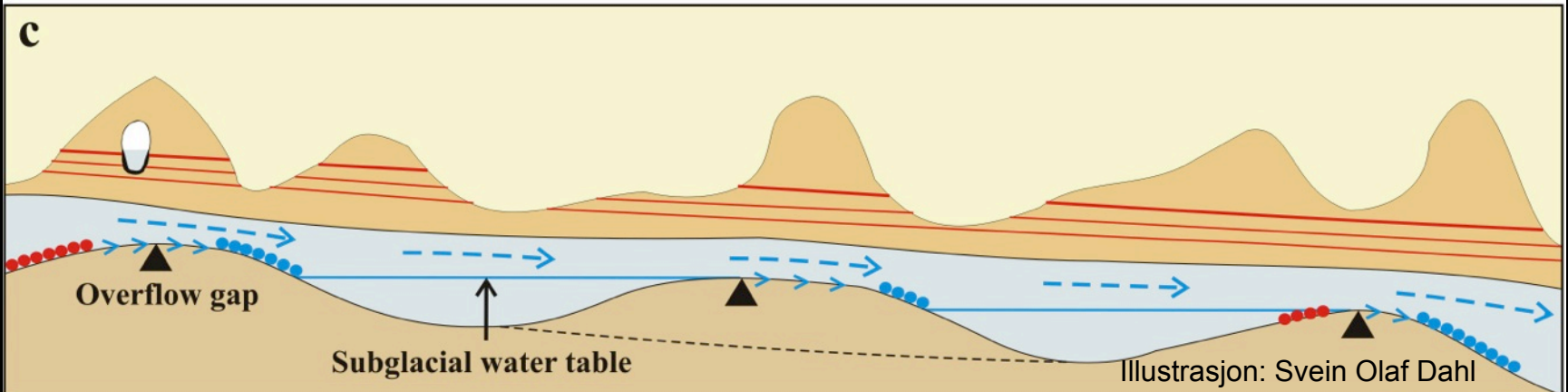
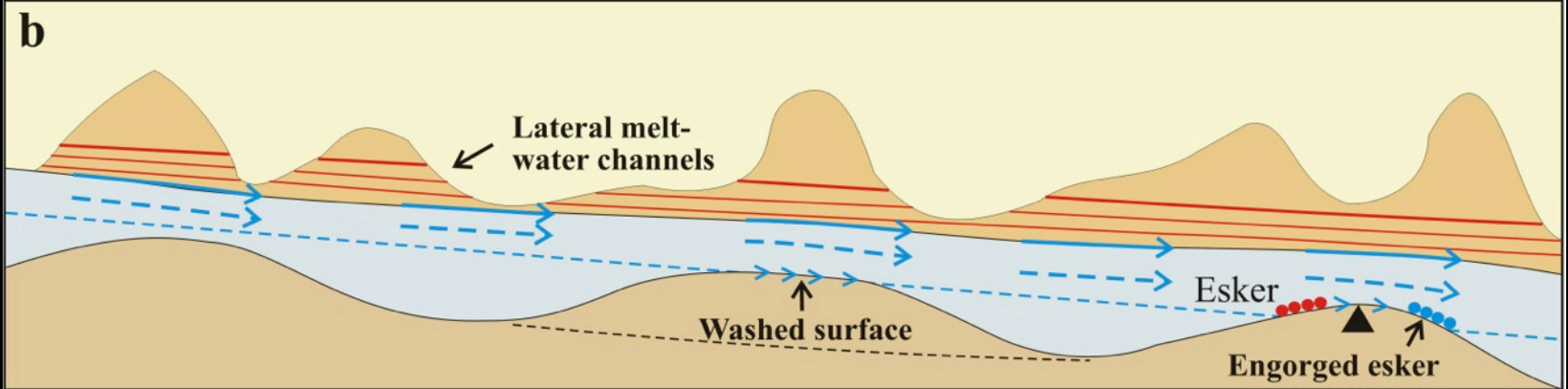
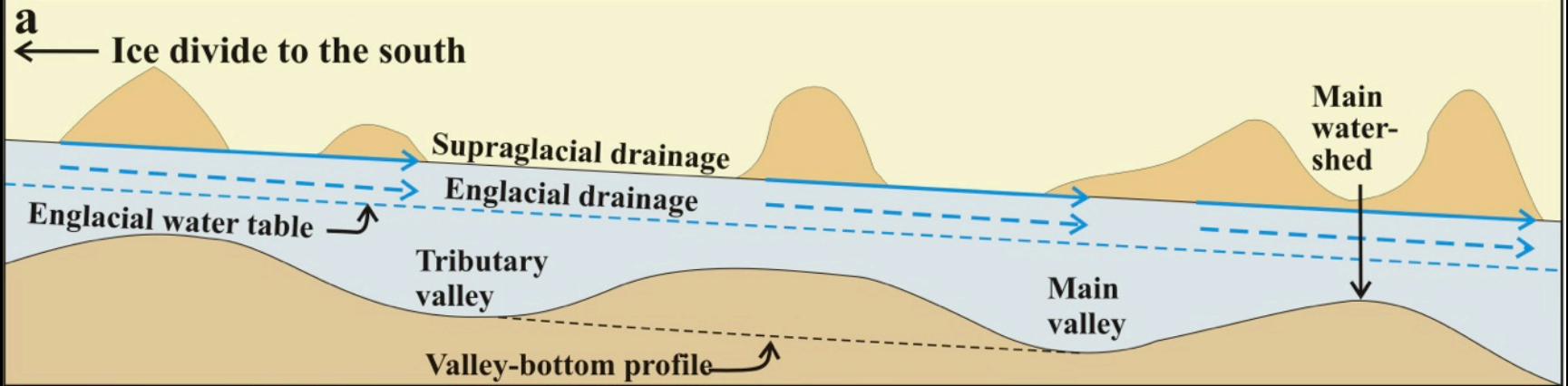
Spylerenner avsette under vertikal nedsmelting ved Hindseter i Sjødalen



Råtåsjø-passpunktet nord for Follal

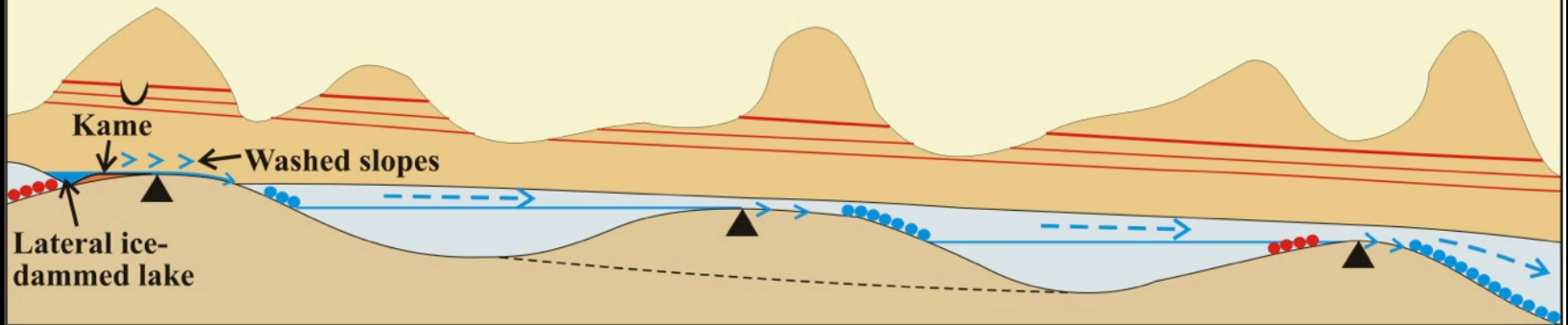


Vertical downwasting of cold-based ice sheets a-c

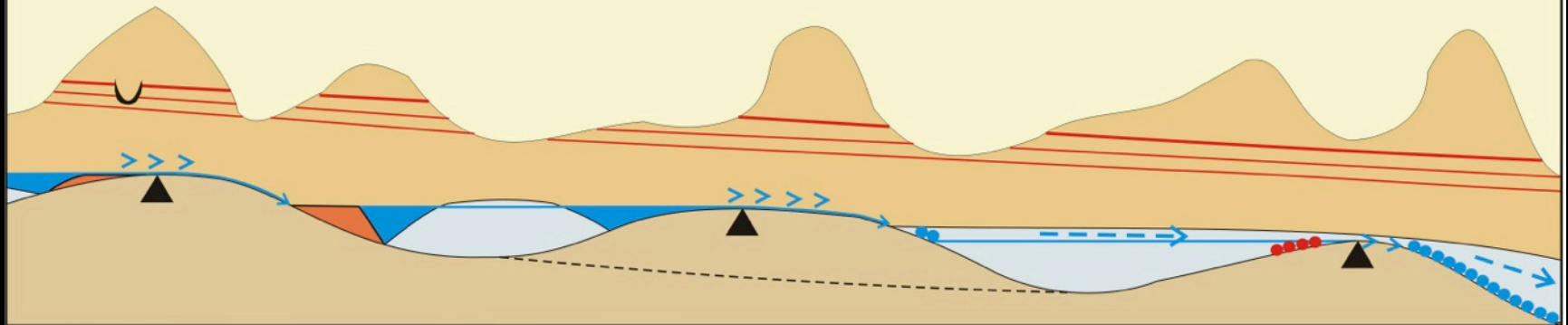


Vertical downwasting of cold-based ice sheets d-f

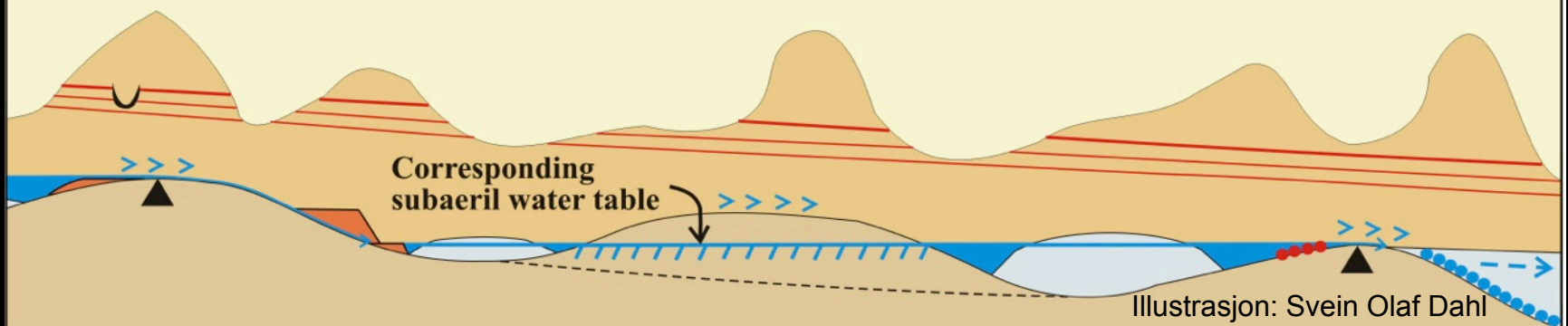
d



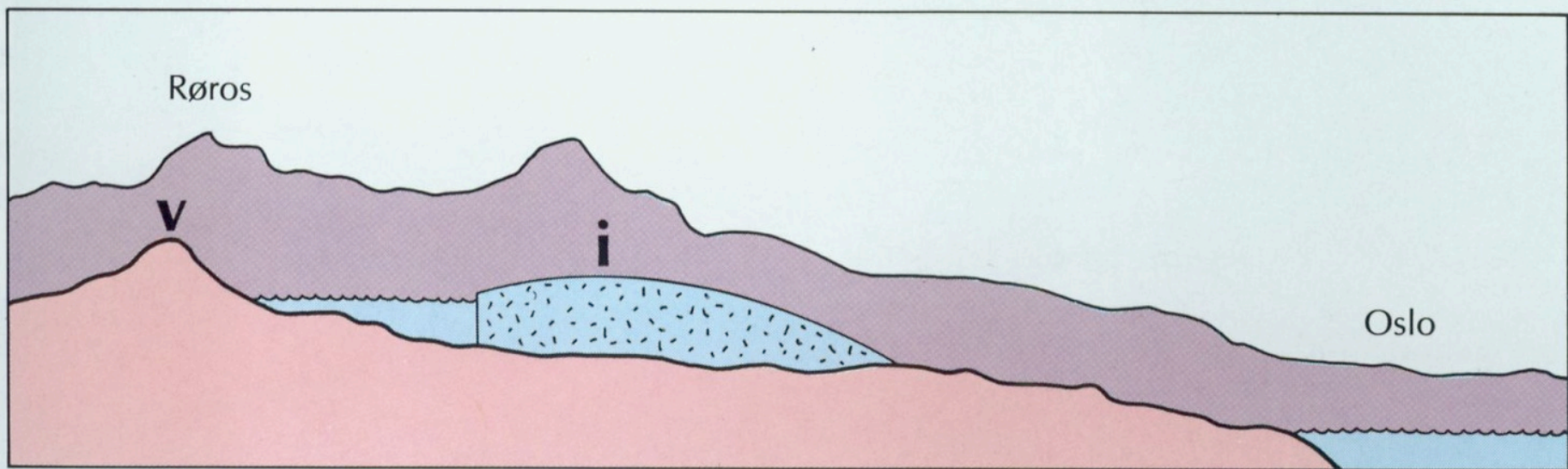
e



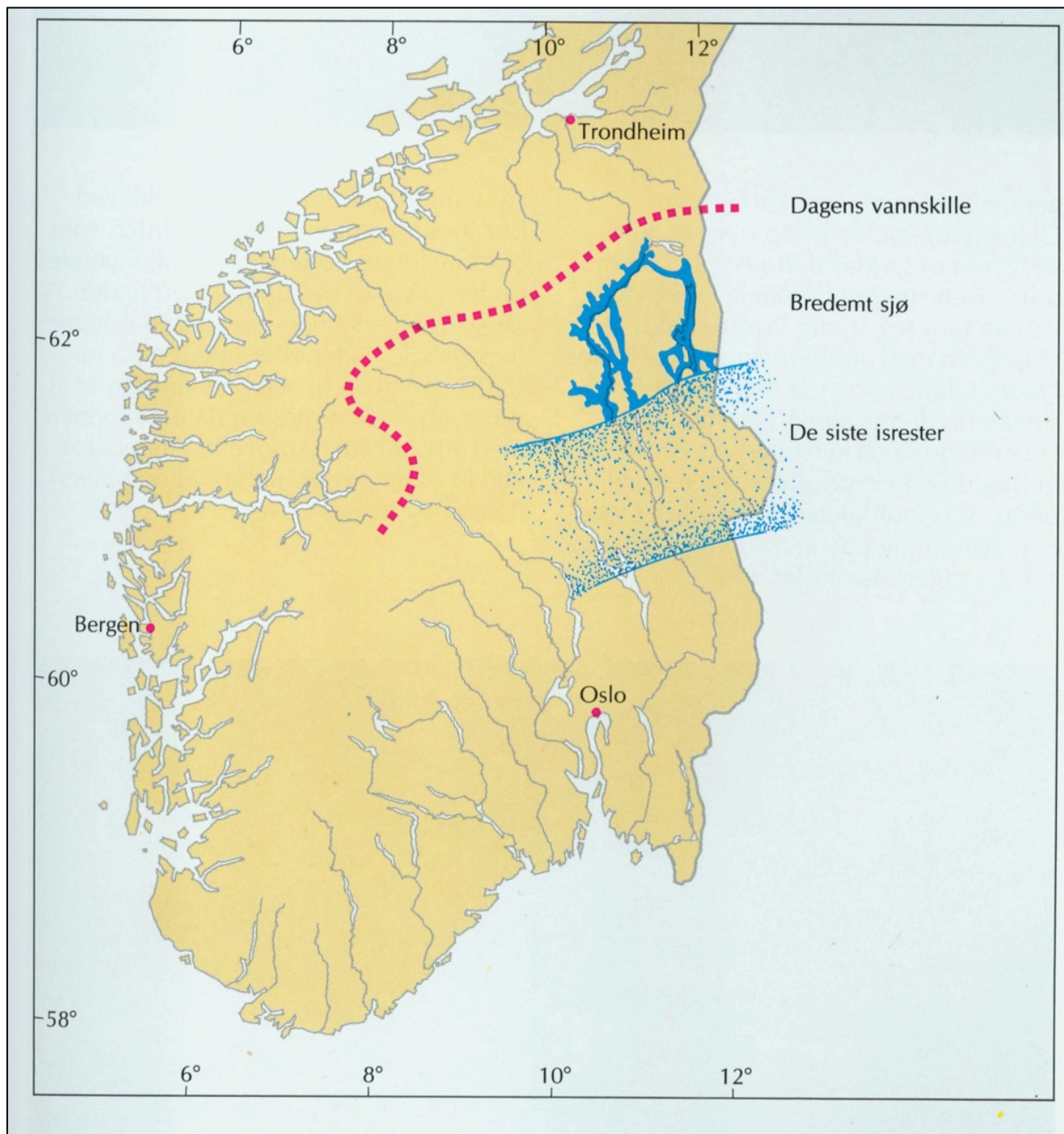
f



Bredemde innsjøar på indre Austlandet



Thoresen (1991)



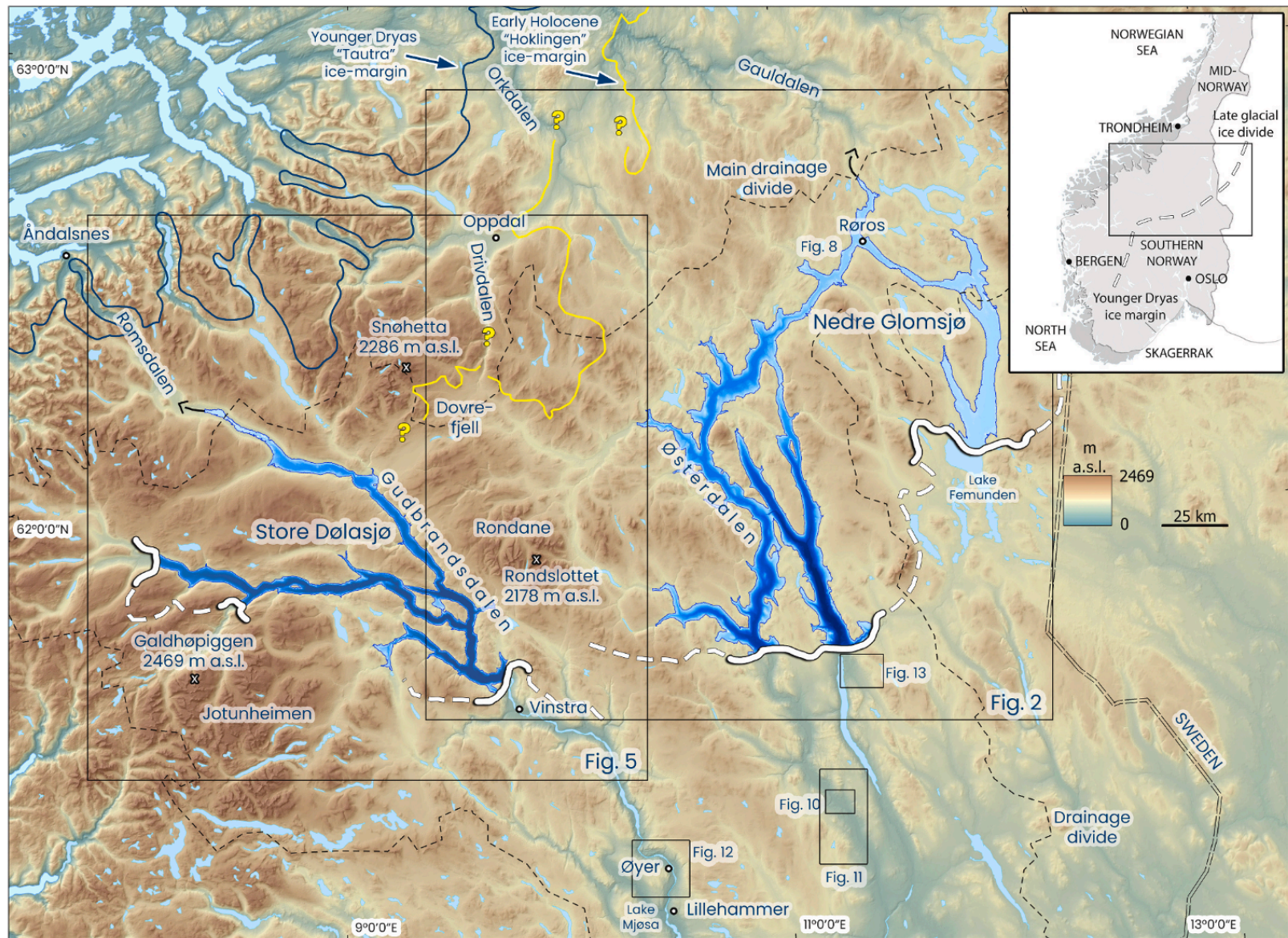


Fig. 1. Map of the study area given with the maximum extents of the Early Holocene IDLs Nedre Glomsjø (c. 10.4 ka; Høgaas et al., 2023) and Store Dølasjø (c. 10.0 ka; Romundset et al., 2023) with associated contemporary ice margins (white lines). The position of the maximum Younger Dryas “Tautra” ice sheet extent (blue line) is based on Hughes et al. (2016) most credible 13 ka reconstruction. The possible Early Holocene “Hoklingen” ice margin reconstruction (yellow line) is based on Olsen et al. (2015) and geological maps (Follestad, 2003, 2005; Olsen and Follestad, 2020). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)



Illustrasjon: Fredrik Høgaas, NGU

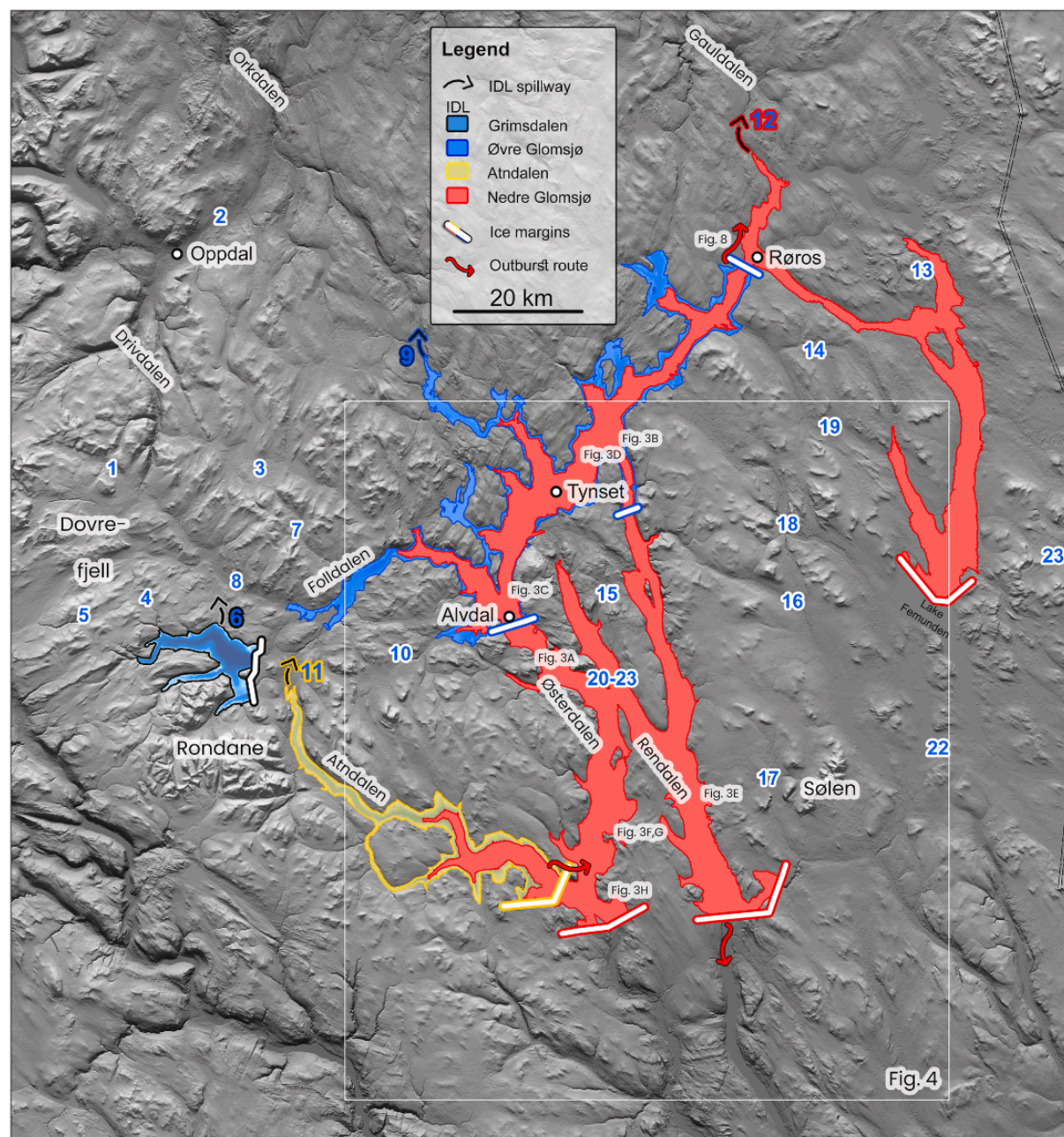


Fig. 2. Identified IDLs and associated ice margins in the Østerdalen region, depicted in different colours in overlapping areas. The numbers correspond to IDLs described in Table 1. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

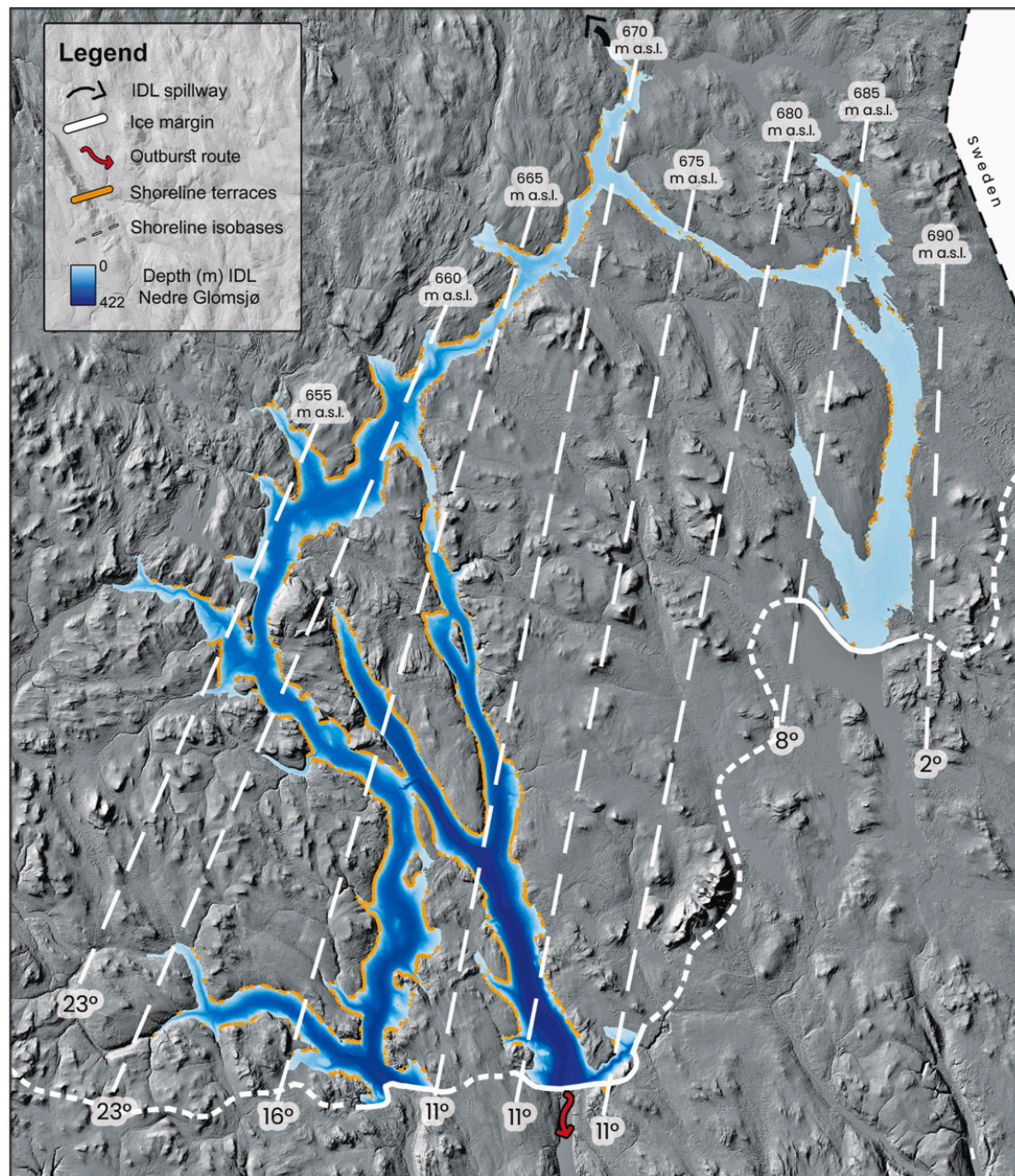
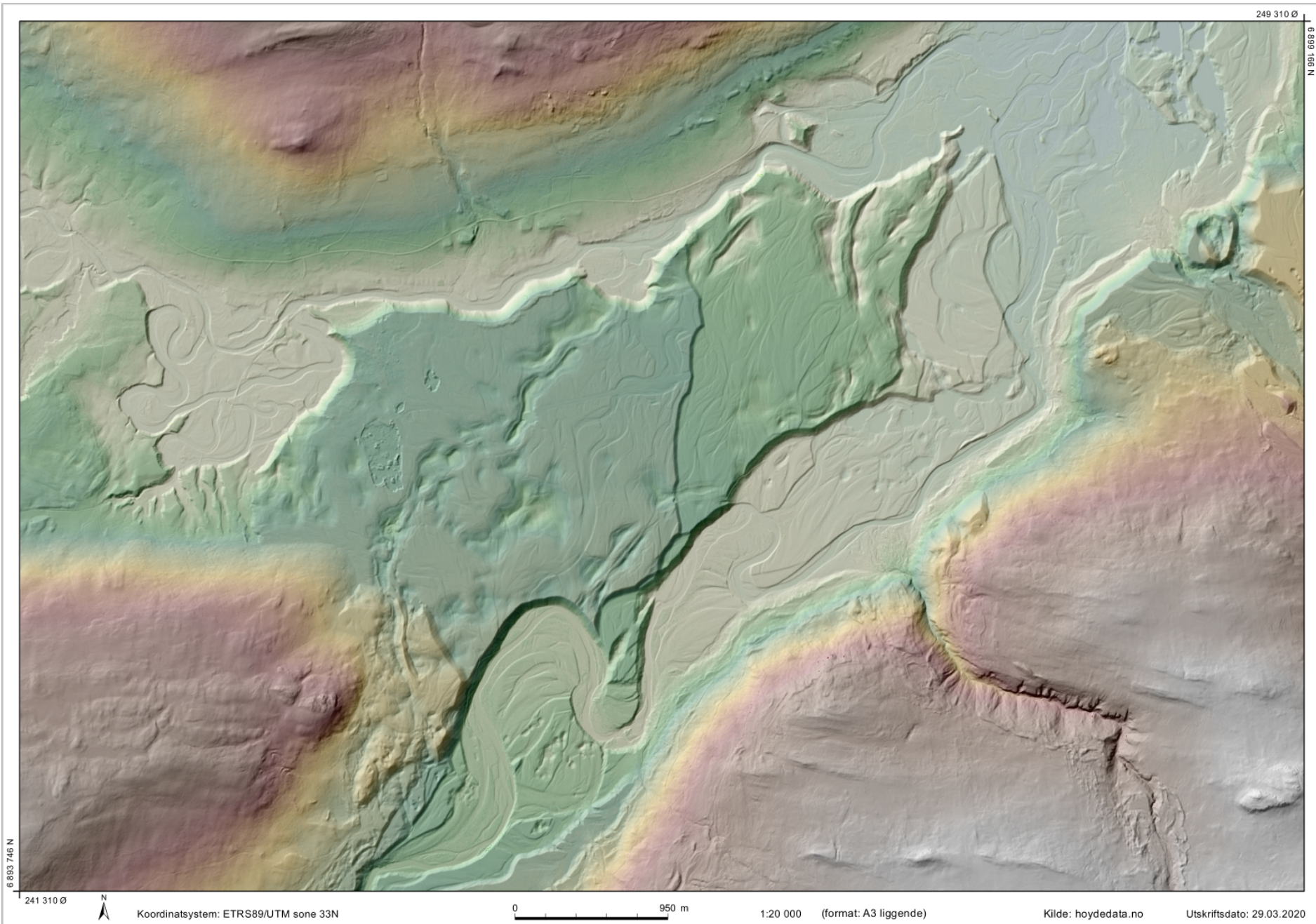


Fig. 6. IDL Nedre Glomsjø with mapped shoreline segments and elevations and directions of derived shoreline isobases.

Grimsmoen, Folldal





Figur 7.6: Bresjøavsetninger i Store Dølasjø nær Dovre. Lagfølgen viser velsorterte bresjøavsetninger (sand) over morene. Øverst er det et lite delta med grovt materiale.

Strandvoll på bresjøterrasse, Brennbakkmoen vest for Alvdal

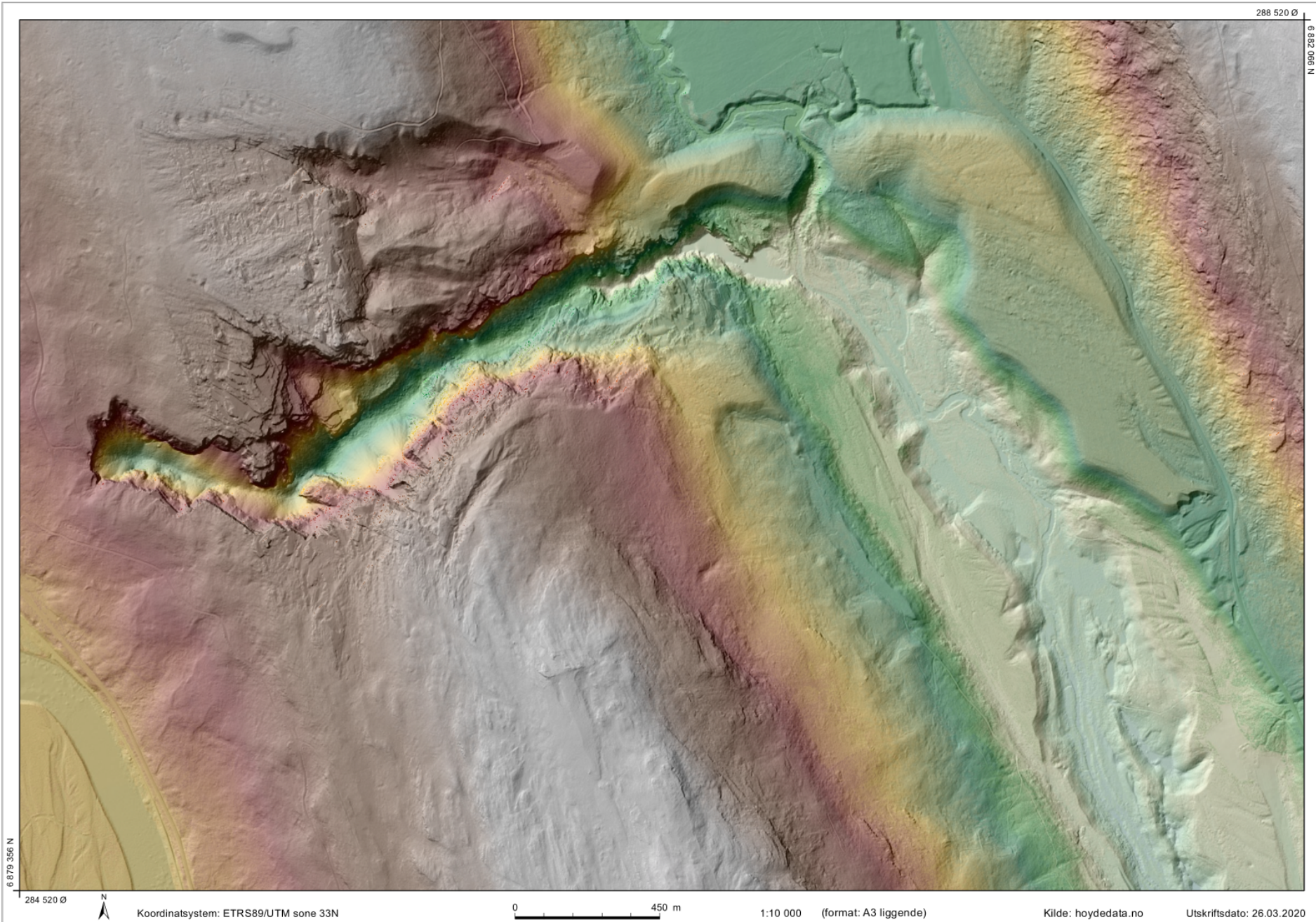


Foto: Atle Nesje



Fig. 9. A. Photo of Jutulhogget canyon. View towards west. B. Photo of the Fallegga deposit at the mouth of Jutulhogget canyon. White arrows show drainage directions. C. Hillshade image of Fallegga. X marks the spot for photo D. D. Flood transported mega boulder at the bar surface. Person for scale. The figure is modified from Høgaas (2023).

Jutulhogget mellom Østerdalen og Rendalen



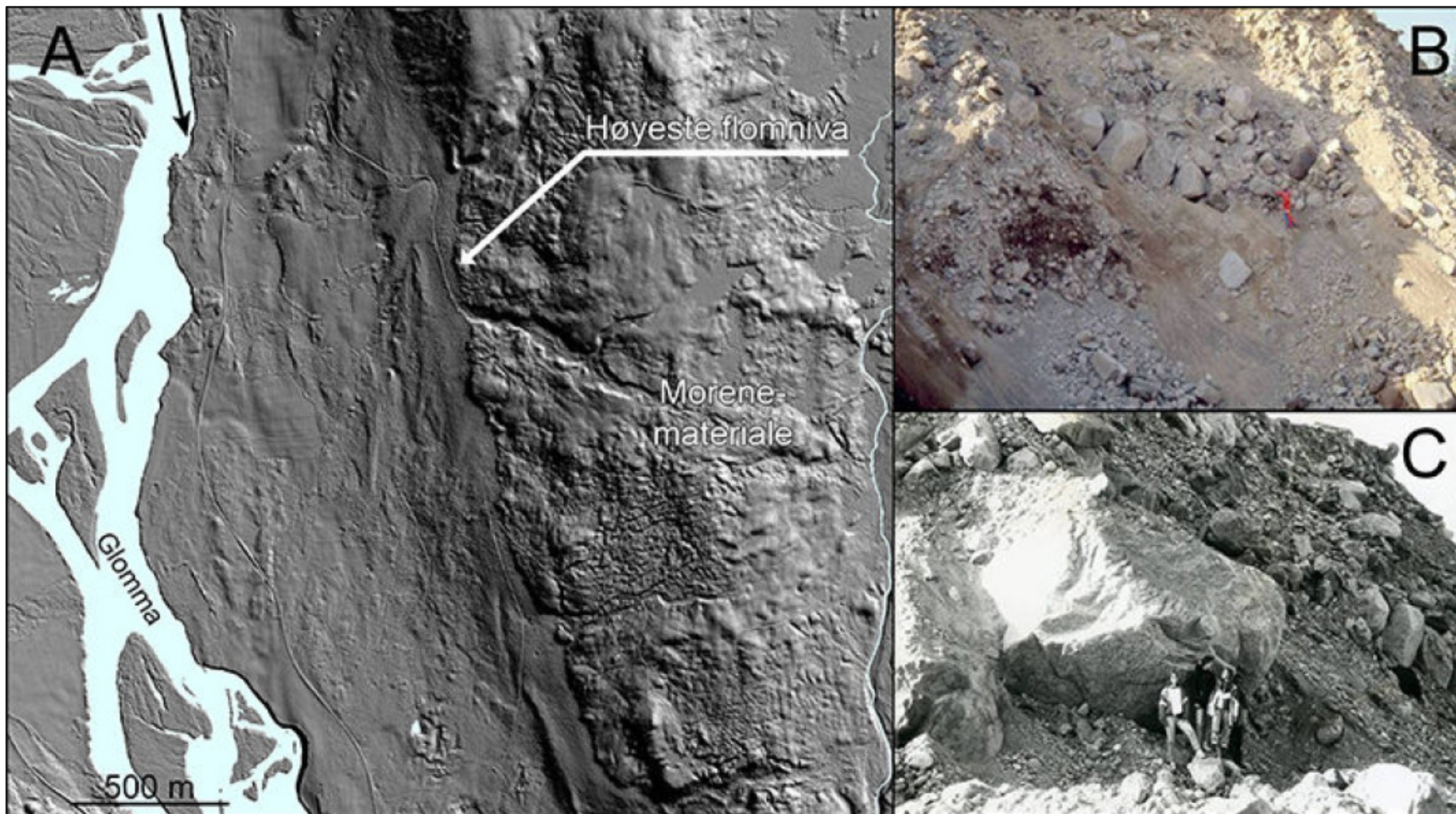
Jutulhogget

Glåmdalen/Østerdalen

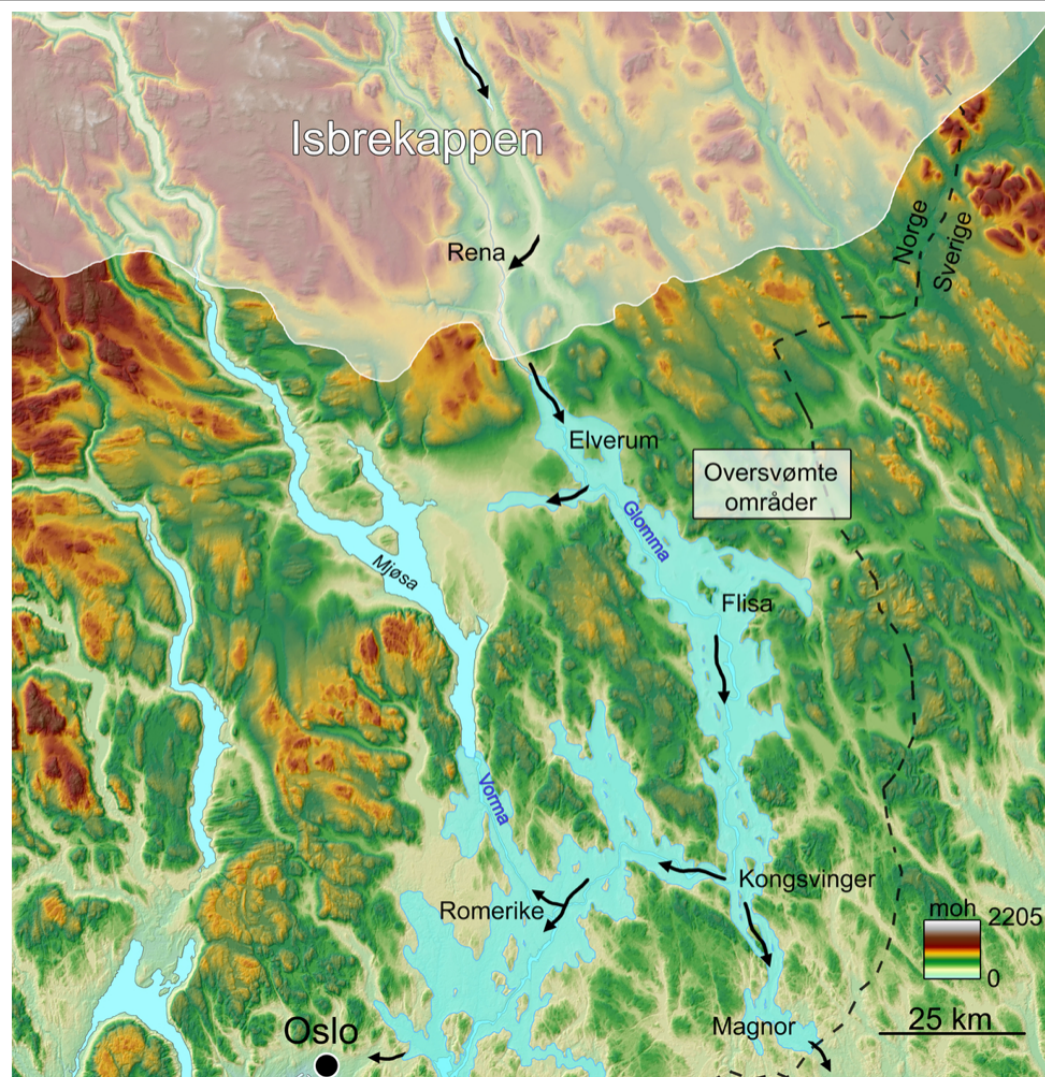
Rendalen/Tyldalen

norgebilder.no/3D



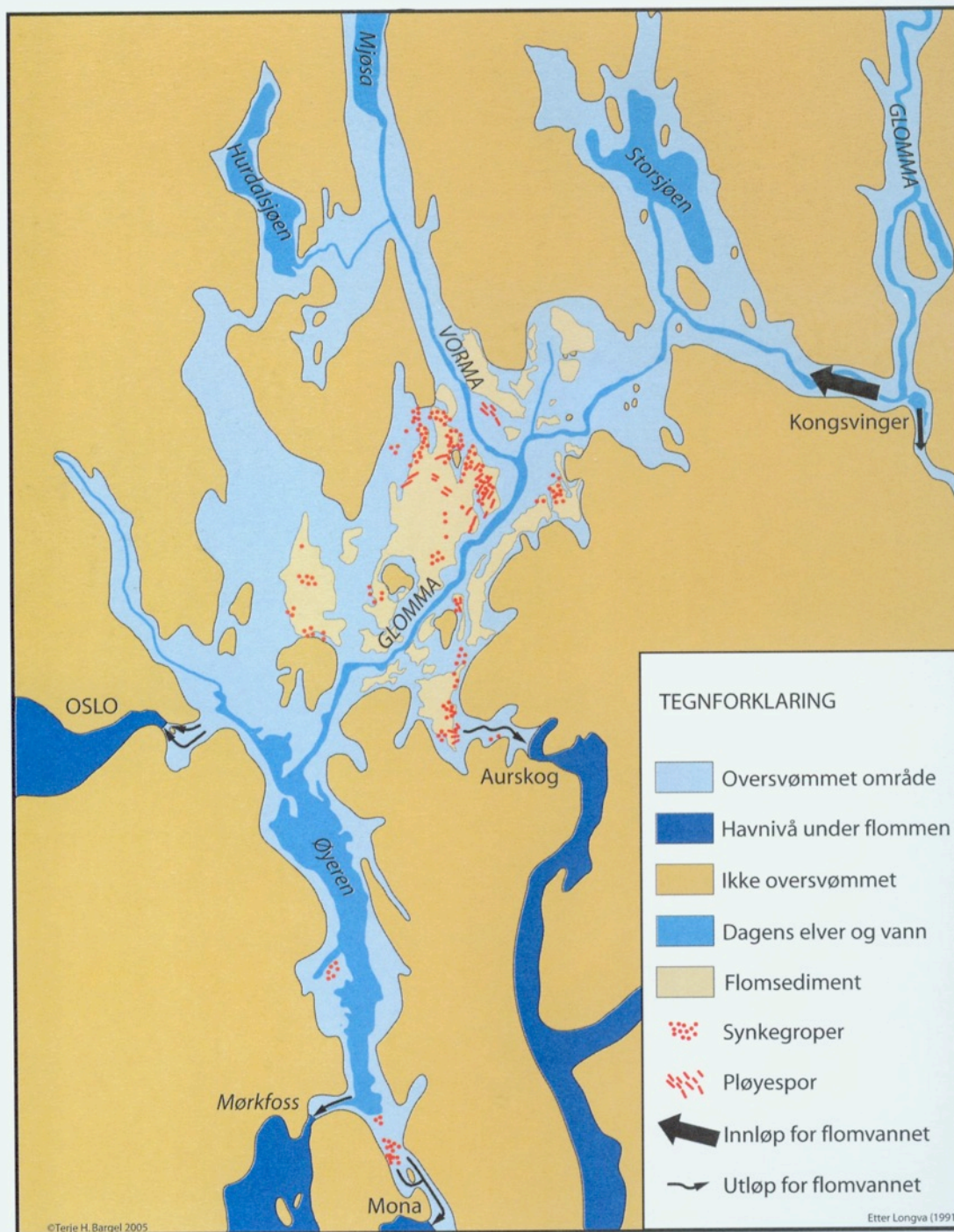


Eksempel på erosive linjer i terrenget (A) og blokkstørrelser (B, C), som er benyttet i forbindelse med den hydrauliske simuleringen. Merk forskjellen mellom terrenget over og under det høyeste flomnivået i LiDAR-figuren (A). Fotoene er fra Elverum, og er tatt av Arne Solli (B) og Oddvar Longva (C). (Illustrasjon: NGU).



Kart som viser den sydlige del av isbrekappen som demmet Nedre Glomsjø. Svarte piler viser vannstrømmen da sjøen ble tappet: Under breen i Rendalen, nedover langs Glomma til Kongsvinger hvor den delte seg. Noe rant over til Sverige, mens det meste flommet utover Romerike. Bl farge viser oversvømte områder.

Illustrasjon: Fredrik Høgaas og Oddvar Longva, NGU



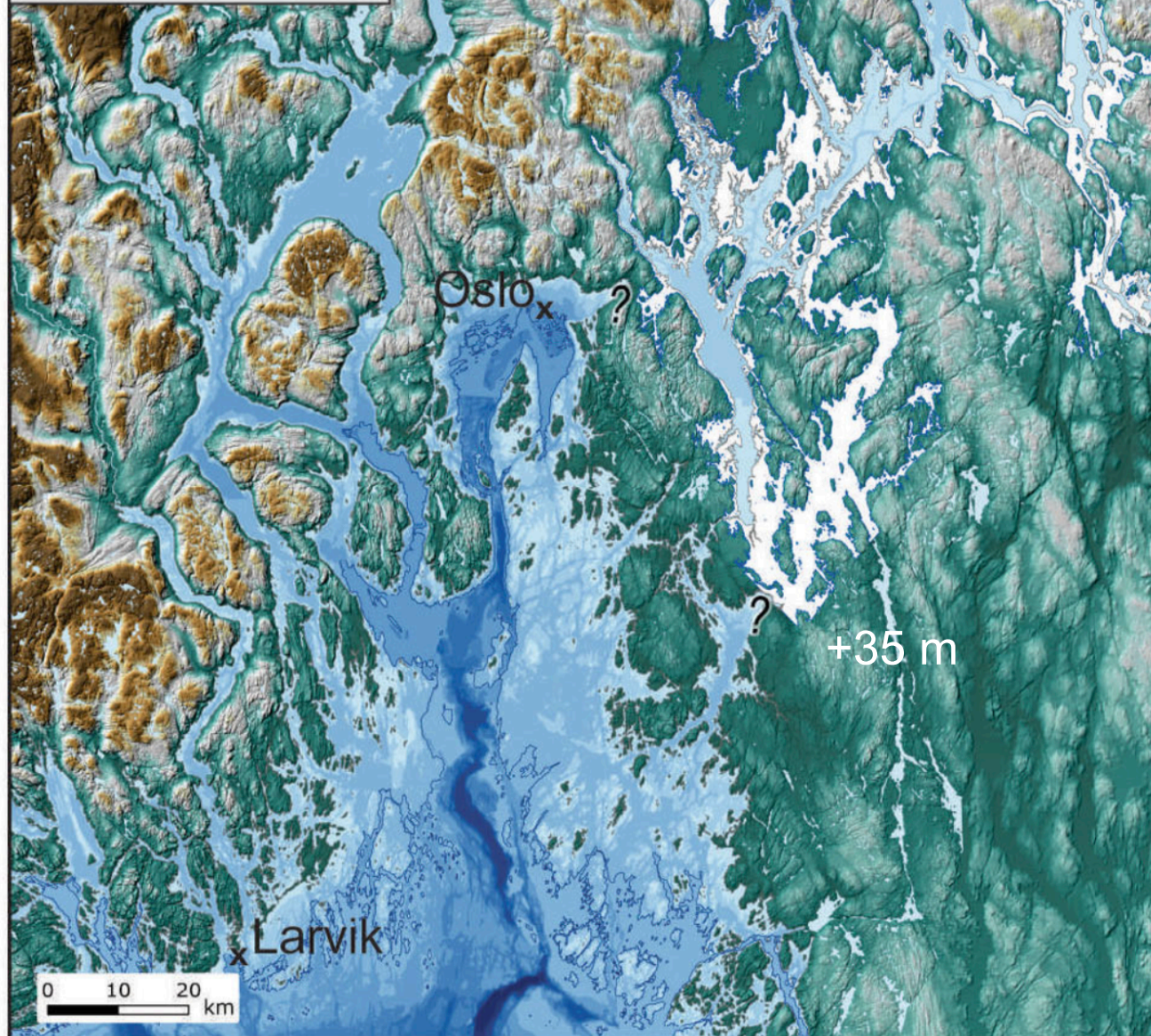
På Romerike
steig vatnet
35 m under
tappinga av
Nedre Glomsjø

Pløyespor etter isfjell på Romerike



Bargel (2005)

B 10 400 a BP
Nedre Glomsjø
flood highstand



Flommen fra Nedre Glomsjø var mer enn fem ganger større enn Amazonas målt i vannmasser, og langt mer enn tusen ganger større enn dagens Glomma. Illustrasjonen viser hvordan flomvannet strømmet gjennom Elverum-området. (Illustrasjon: NGU).





Romeriksmjelen

Planterestar datert til
10.400 kalenderår før notid

Jutulhoggsjøen i Østerdalen 506 moh.

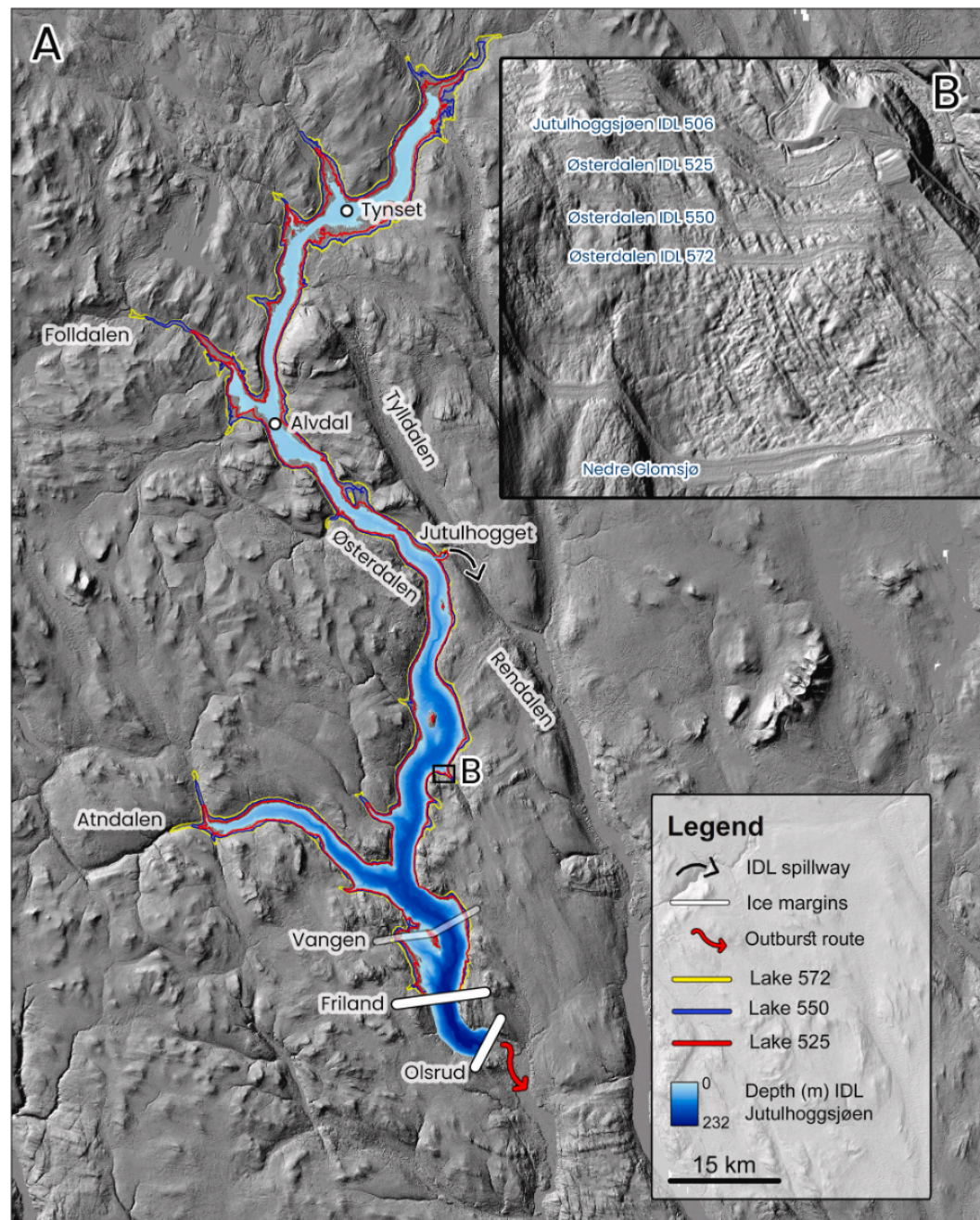


Fig. 4. A. Depth map is from IDL Jutulhoggsjøen (506 m a.s.l.), with the extent of Østerdalen IDLs 572, 550 and 525 (m a.s.l.) depicted as coloured lines. Nedre Glomsjø's ice dam is depicted as a transparent white line to indicate net retreat between the different IDL phases. B. Hillshade image of the Nedre Glomsjø and lower lying Østerdalen IDLs shorelines levels.

Store Dølasjø i Gudbrandsdalen Passpunkt Lesjaskog 612 moh.

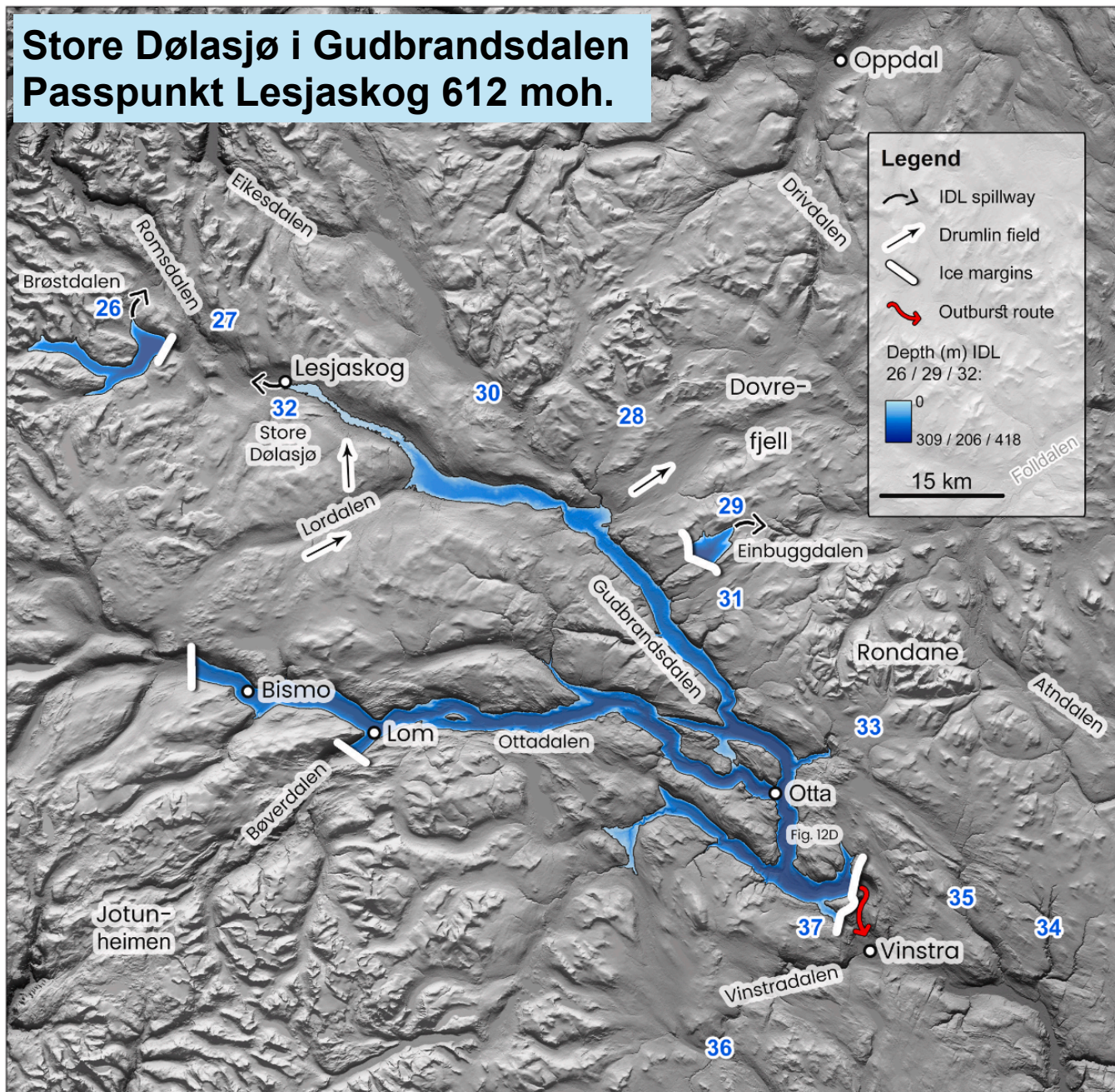
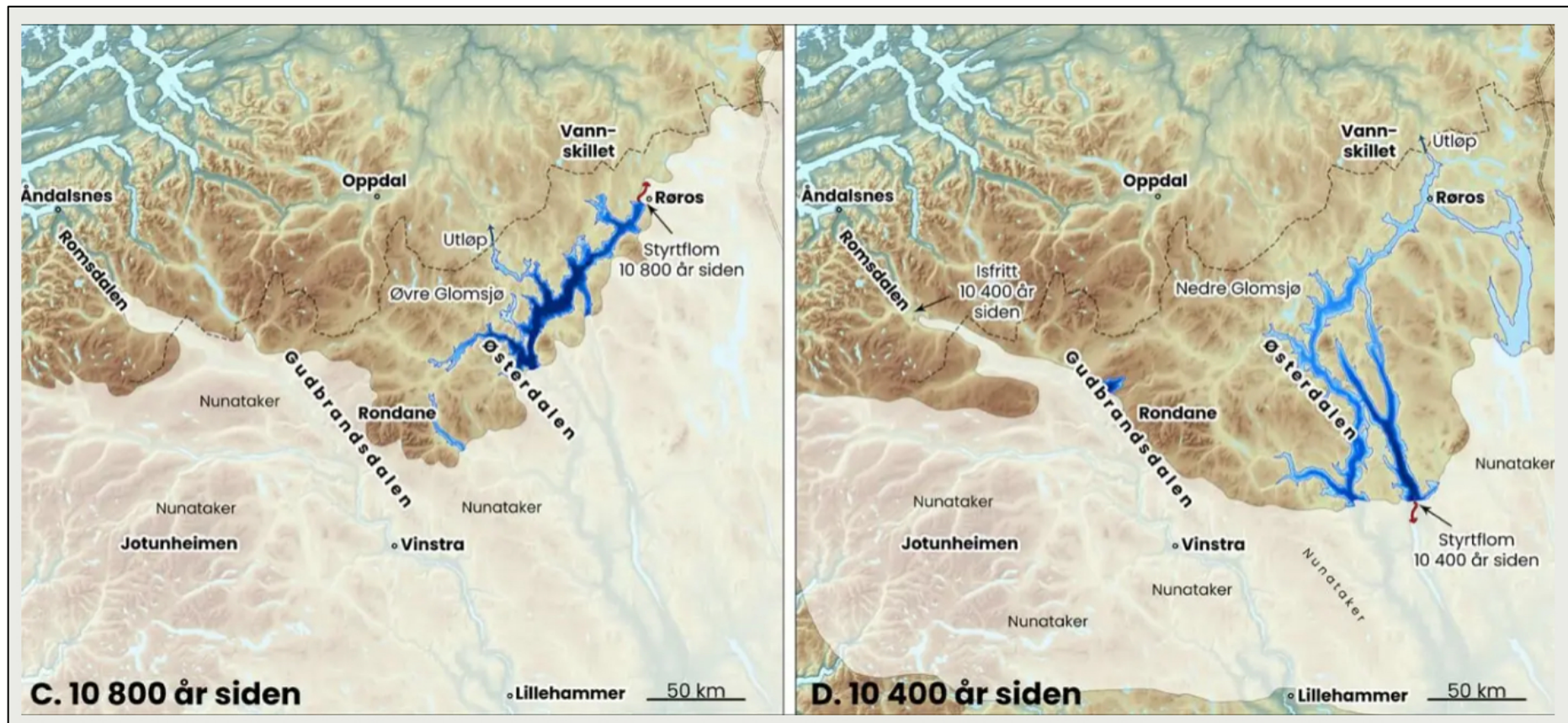


Fig. 5. Identified IDLs in the Gudbrandsdalen region with associated ice margins. The numbers correspond to IDLs described in Table 1.

Store Dølasjø i Gudbrandsdalen Passpunkt Lesjaskog 612 moh.





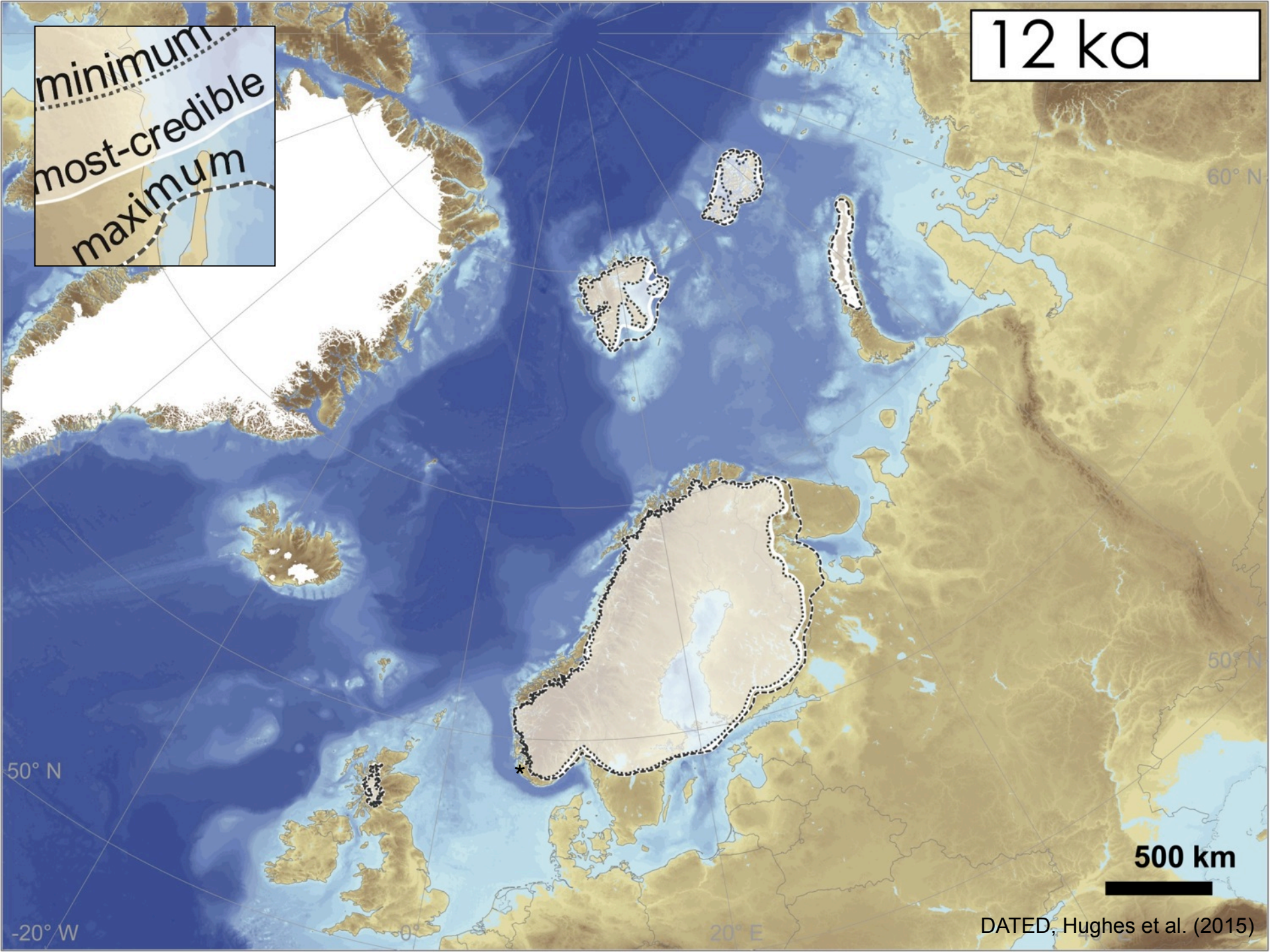


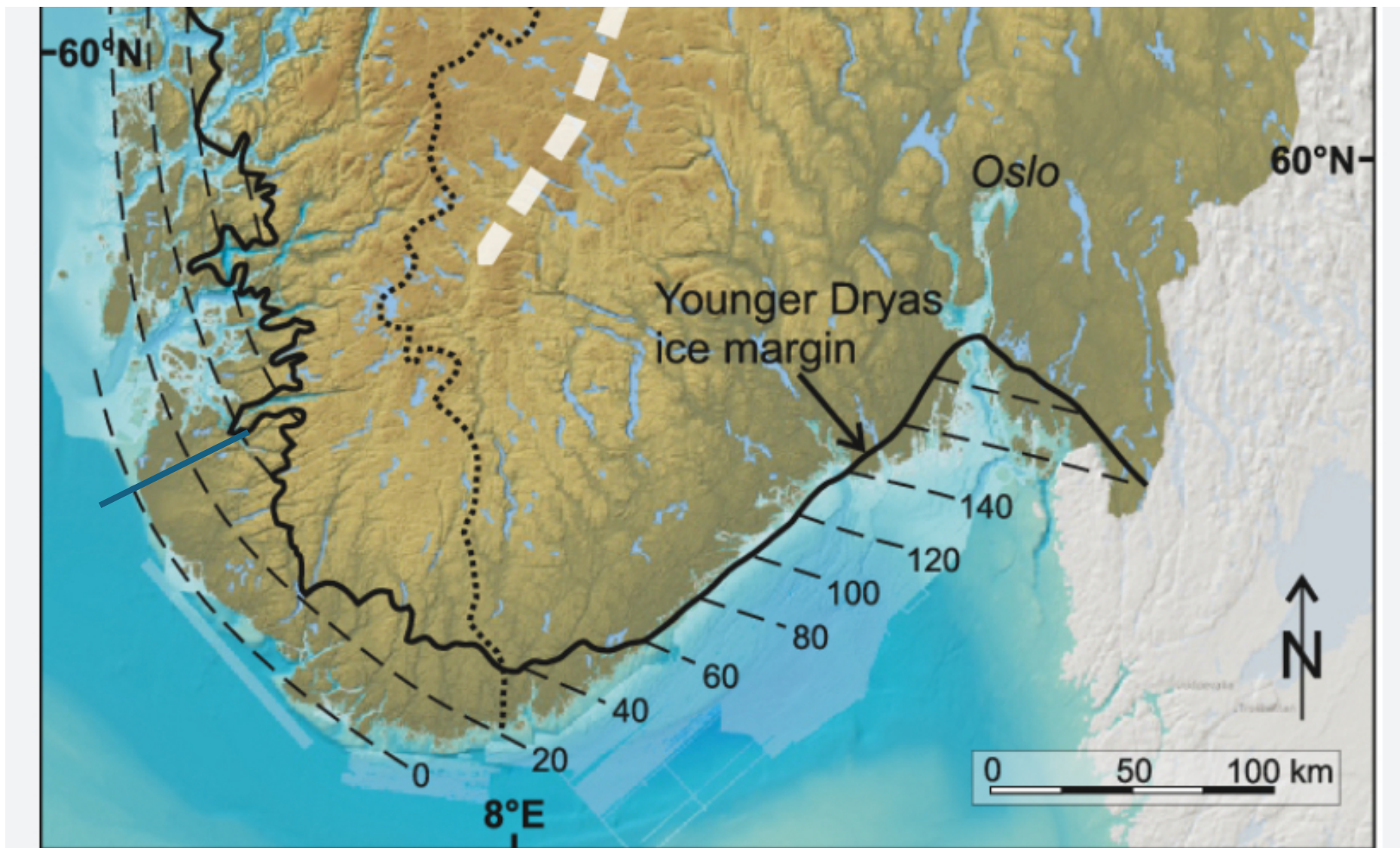
Høgaas m.fl. (2025)



12 ka

minimum
most-credible
maximum





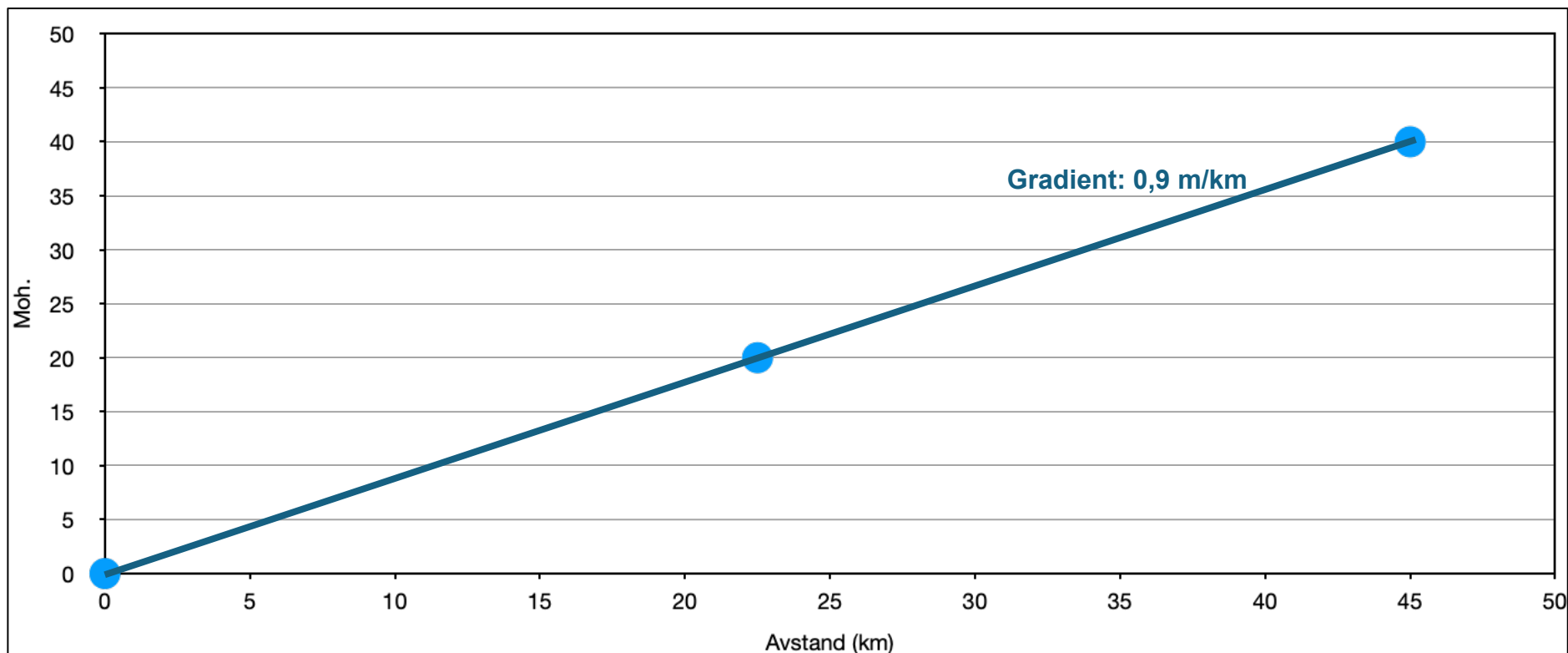
Modifisert etter Romundset m.fl. (2013)



Senterposisjon: -26178.92, 6551702.81
 Koordinatsystem: EPSG:25833
 Utskriftsdato: 25.02.2024



Yngre dryas (~12.000 år før notid) strandline på Jæren





-8 227 Ø

6 564 315 N

Haukalivatnet
51 moh.

Forsand

Ryggjen

Hestamoen

Vassryggen
(‘Esmarkmorenen’)

Breelvslette med
smeltevassløp

-12 227 Ø



Koordinatsystem: ETRS89/UTM sone 33N

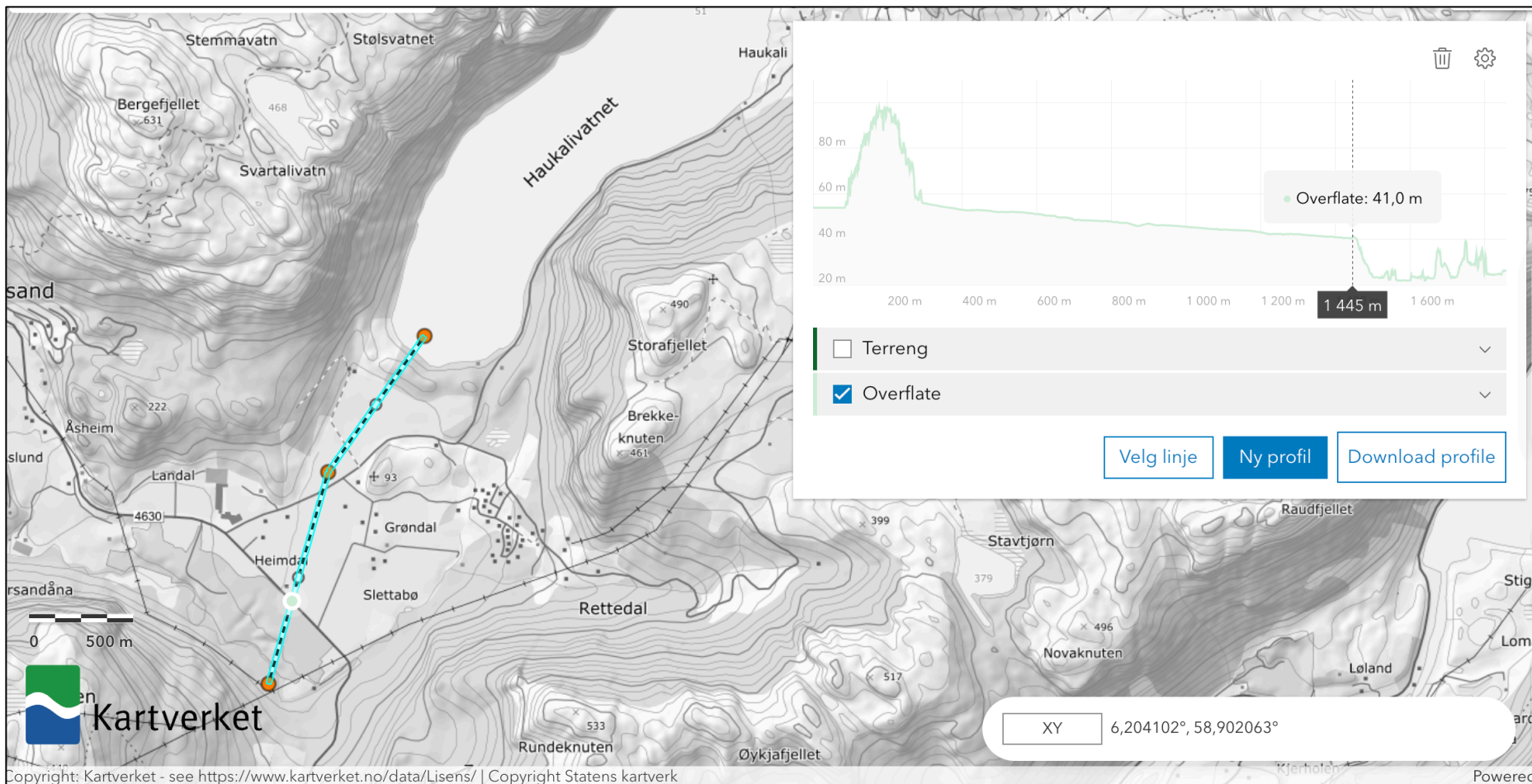
0 450 m

1:10 000 (format: A3 liggende)

Kilde: hoydedata.no

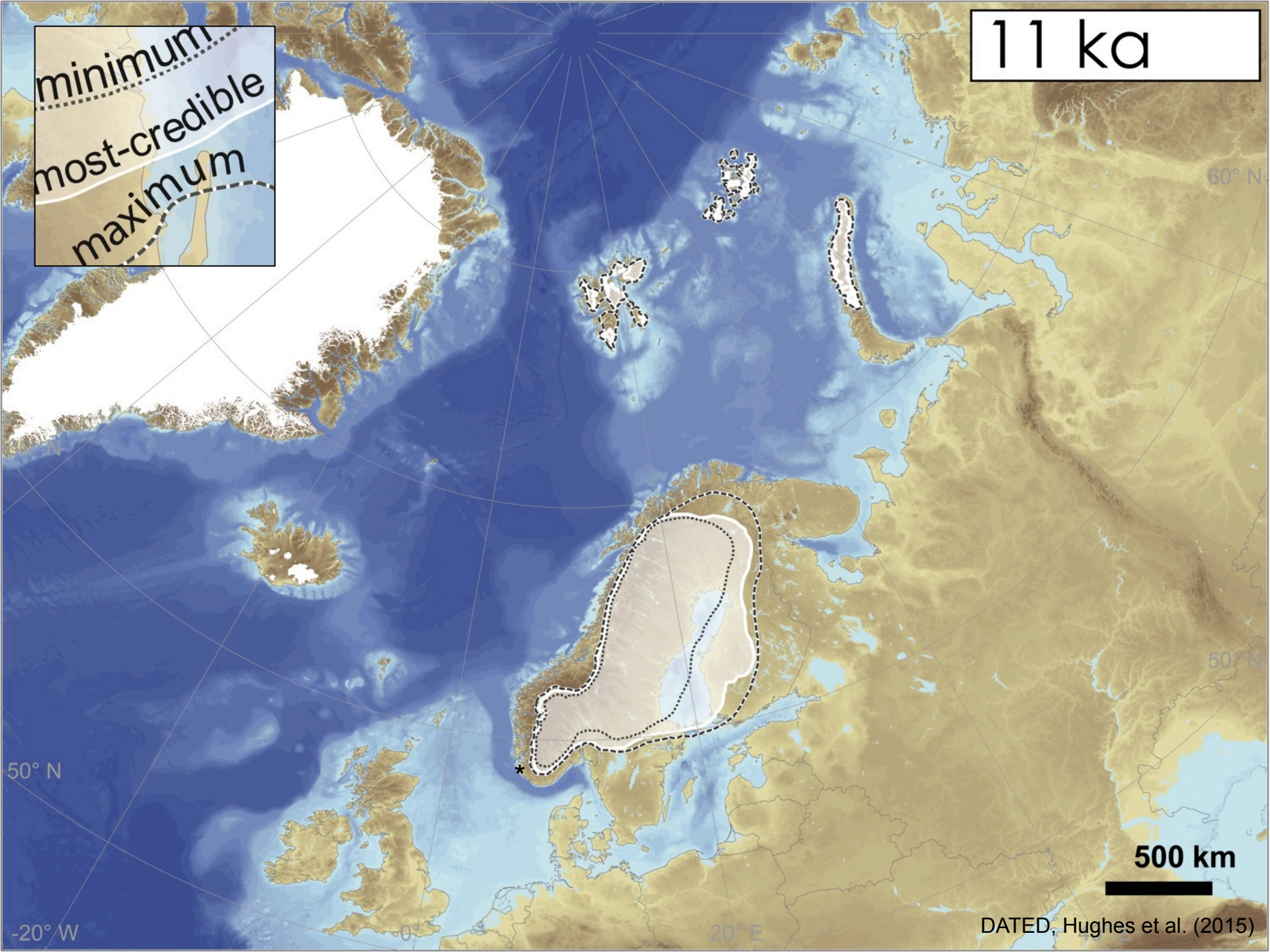
Utskriftsdato: 12.03.2021

hoydedata.no



11 ka

minimum
most-credible
maximum

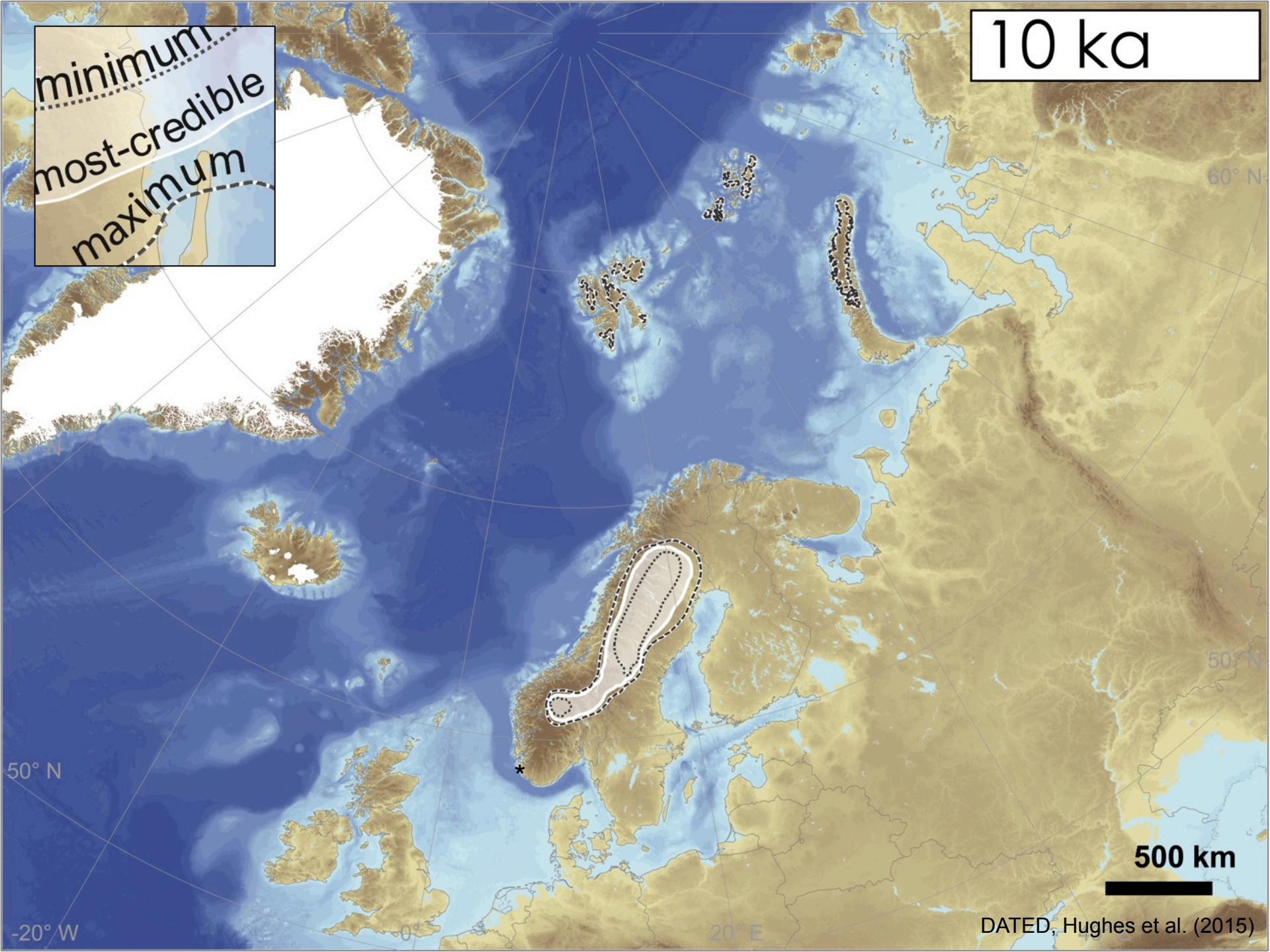


500 km

DATED, Hughes et al. (2015)

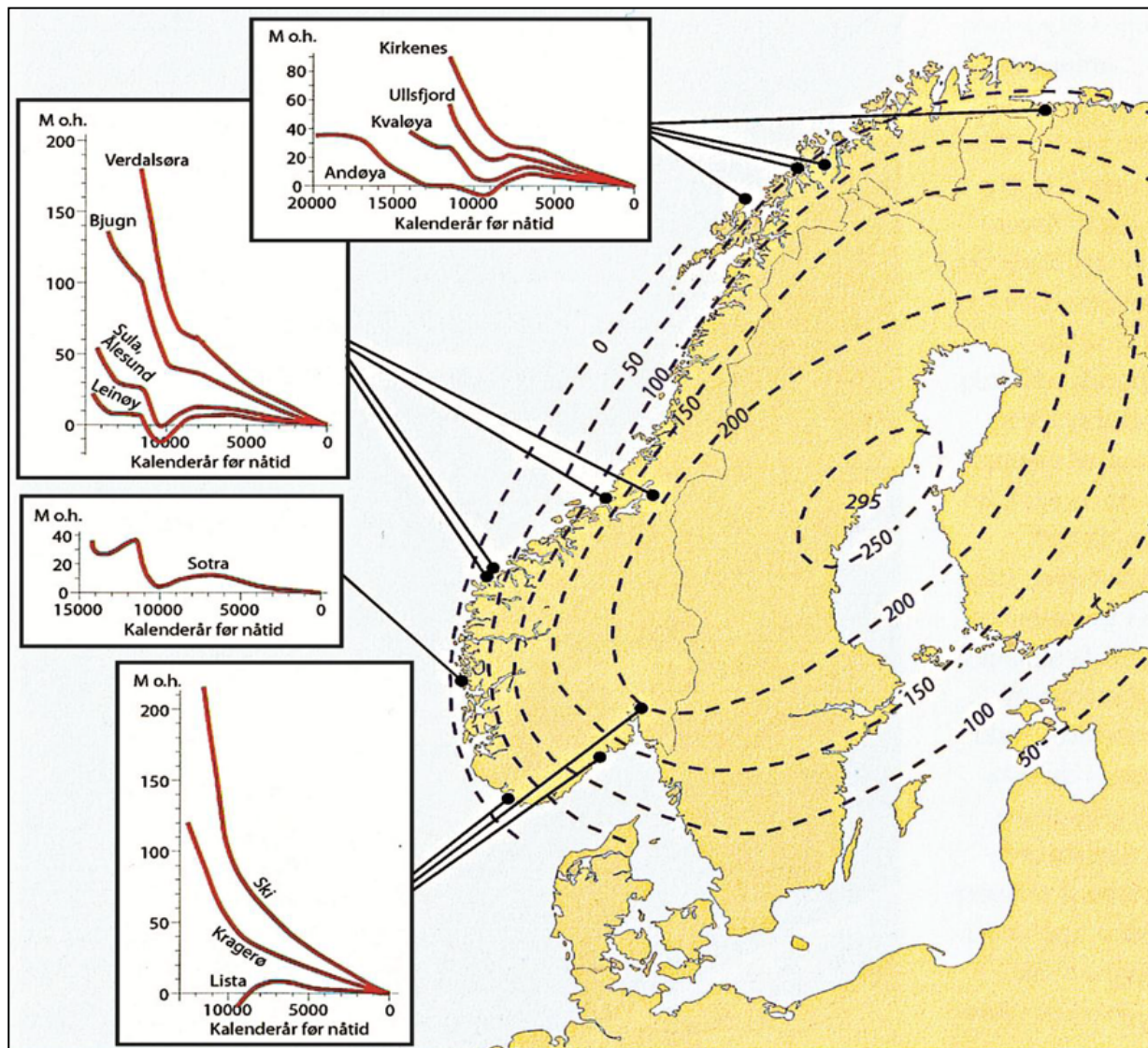
10 ka

minimum
most-credible
maximum



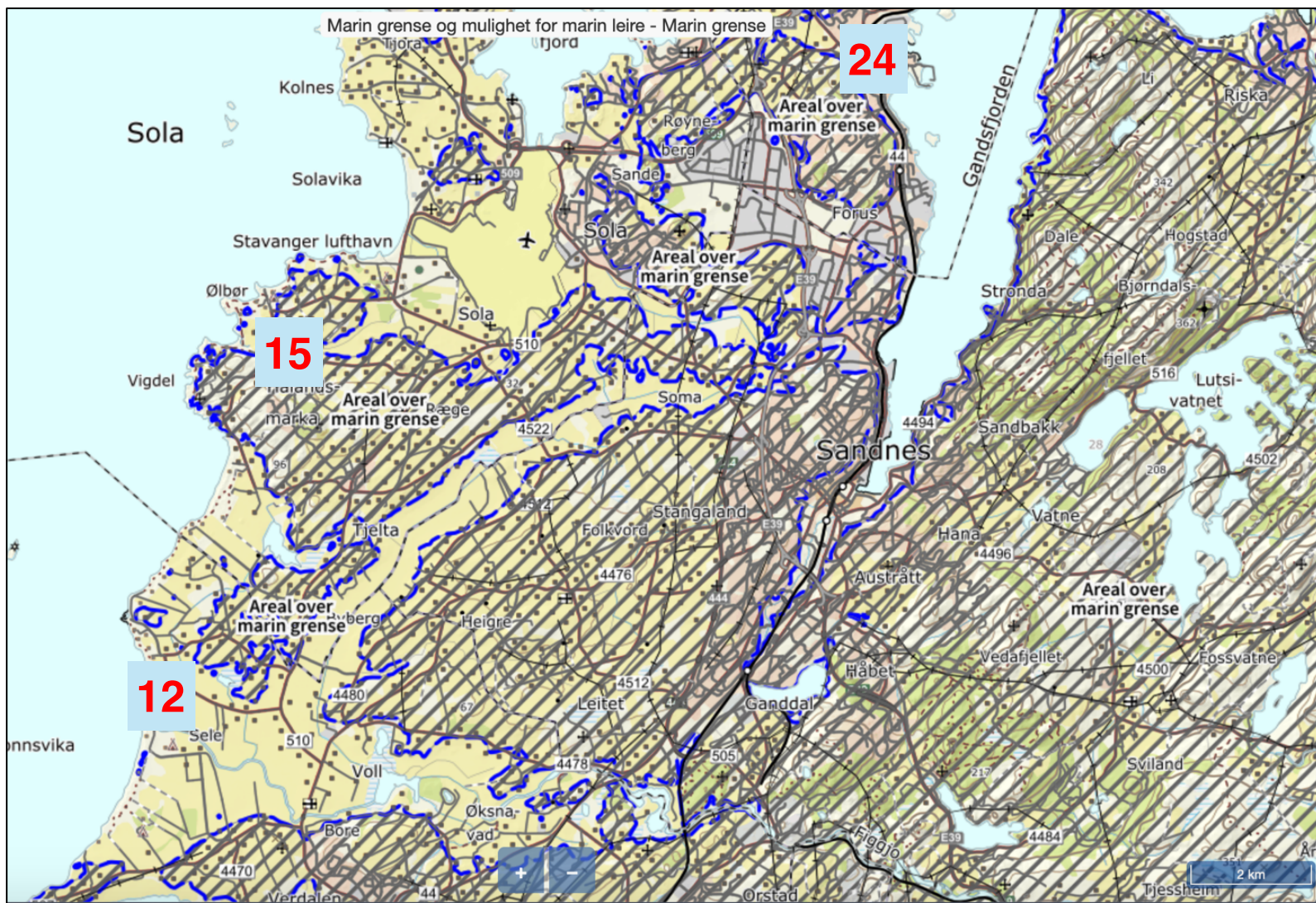
500 km

DATED, Hughes et al. (2015)



Dei stipla linene syner marine grenser i Noreg. Den høgaste marine grensa i Noreg er i Oslo (221 moh.), medan på Jæren har vi mellom dei lågaste marine grensene i Noreg.

Til venstre på figuren er det strandforskyvingskurvar (variasjonar i havnivå over tid) frå slutten av siste istid til i dag for ulike delar av landet. Figur: NGU (2012).



Utsnitt av digitalt kart (https://geo.ngu.no/kart/losmasse_mobil/?lang=Norsk&Box=-268657:6427000:1299257:7965000&map=Marin.grense) som syner areal under og over marin grense frå slutten av siste istid på Jæren.

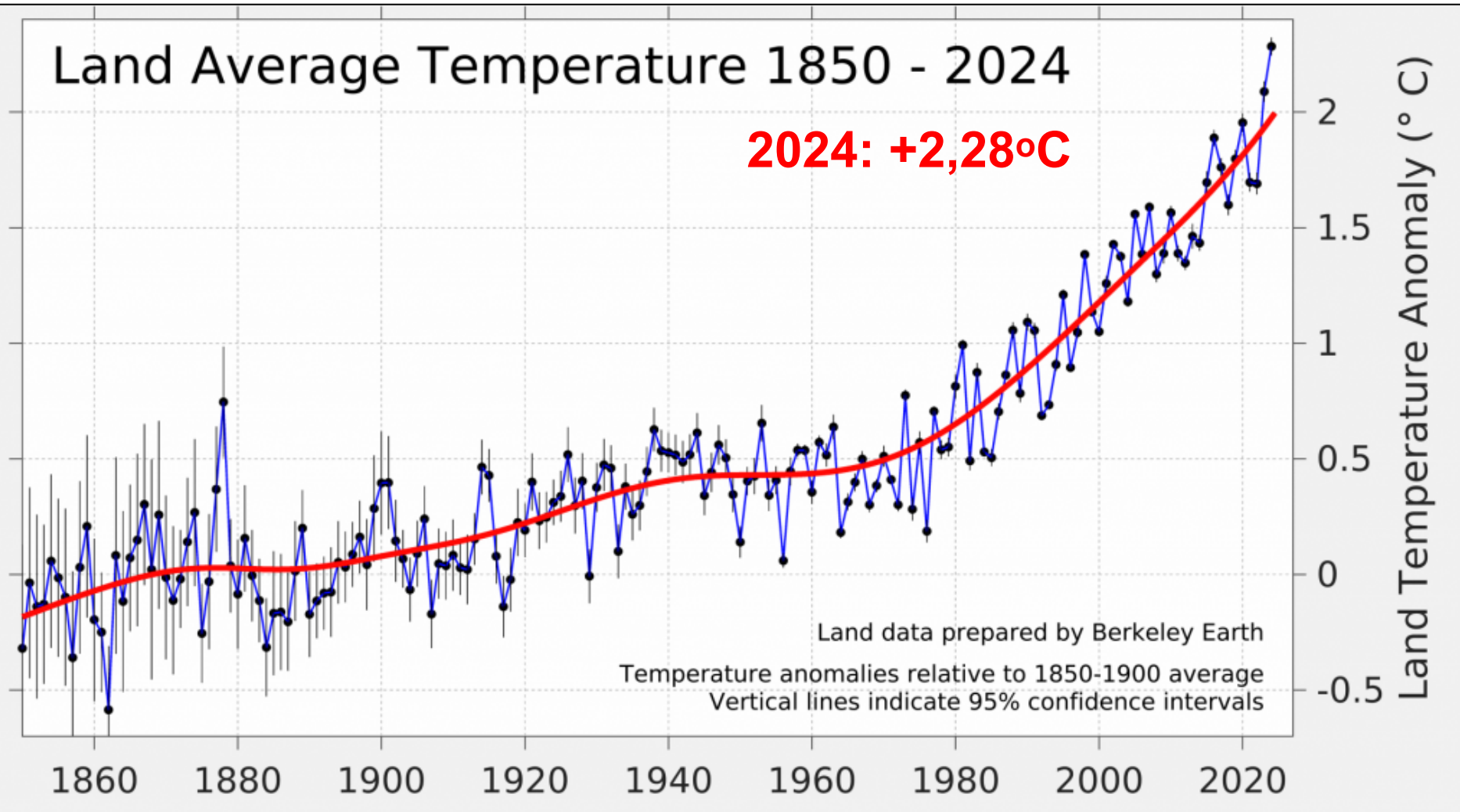
Ved Sele i sørvest er marin grense sett til 12 moh., ved Ølbør (sørvest for Stavanger Lufthamn Sola) til 15 moh., og til 24 moh. ved Jåttåvågen langs nordvestsida til Gandsfjorden.

Global (land) gjennomsnittstemperatur 1850 – 2024

Avvik fra gjennomsnittstemperaturen 1850 - 1900

Land Average Temperature 1850 - 2024

2024: +2,28°C



Atmospheric CO₂ at Mauna Loa Observatory

1958-2025

Scripps Institution of Oceanography

NOAA Global Monitoring Laboratory

CO₂ mole fraction (ppm)

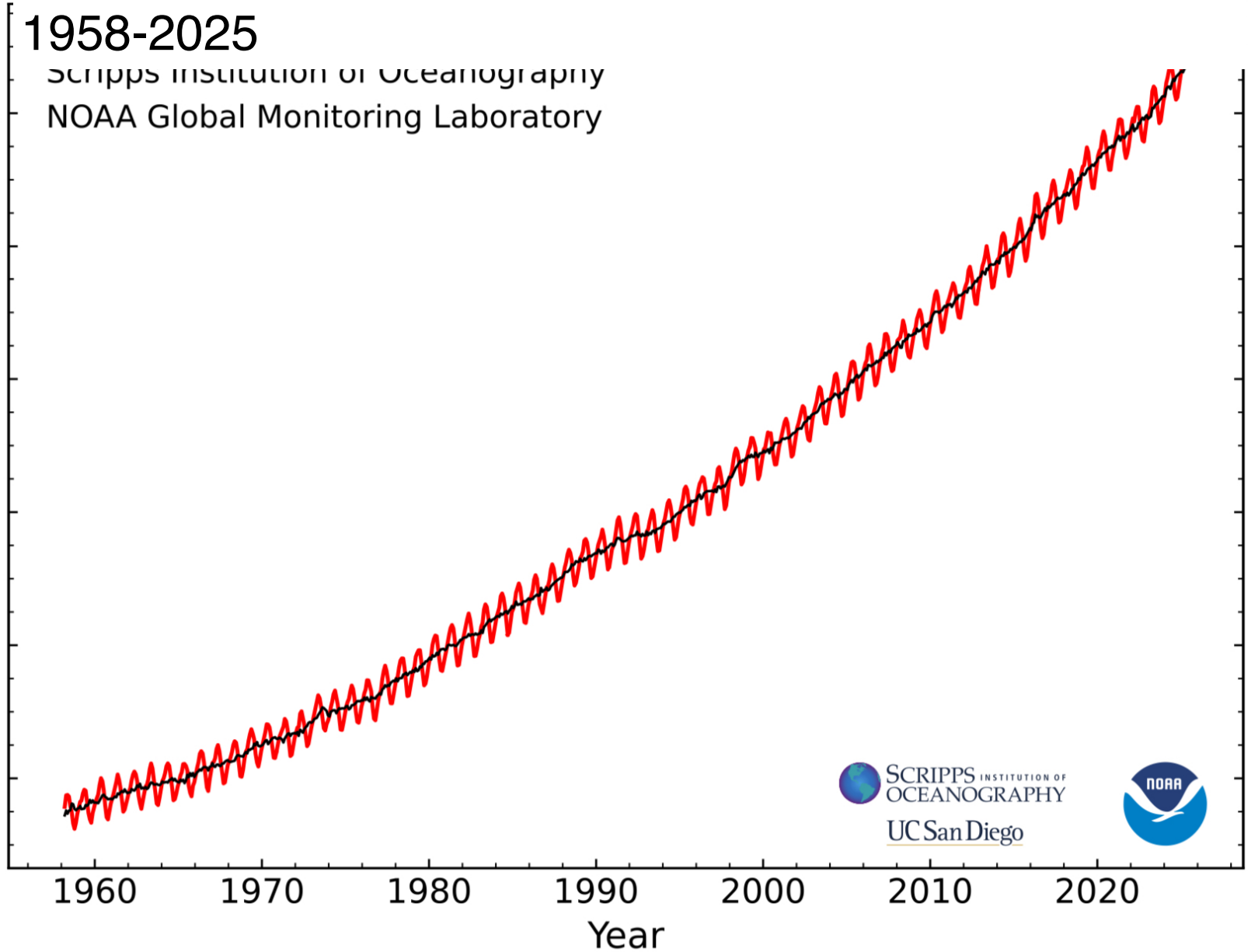
420
400
380
360
340
320

1960 1970 1980 1990 2000 2010 2020

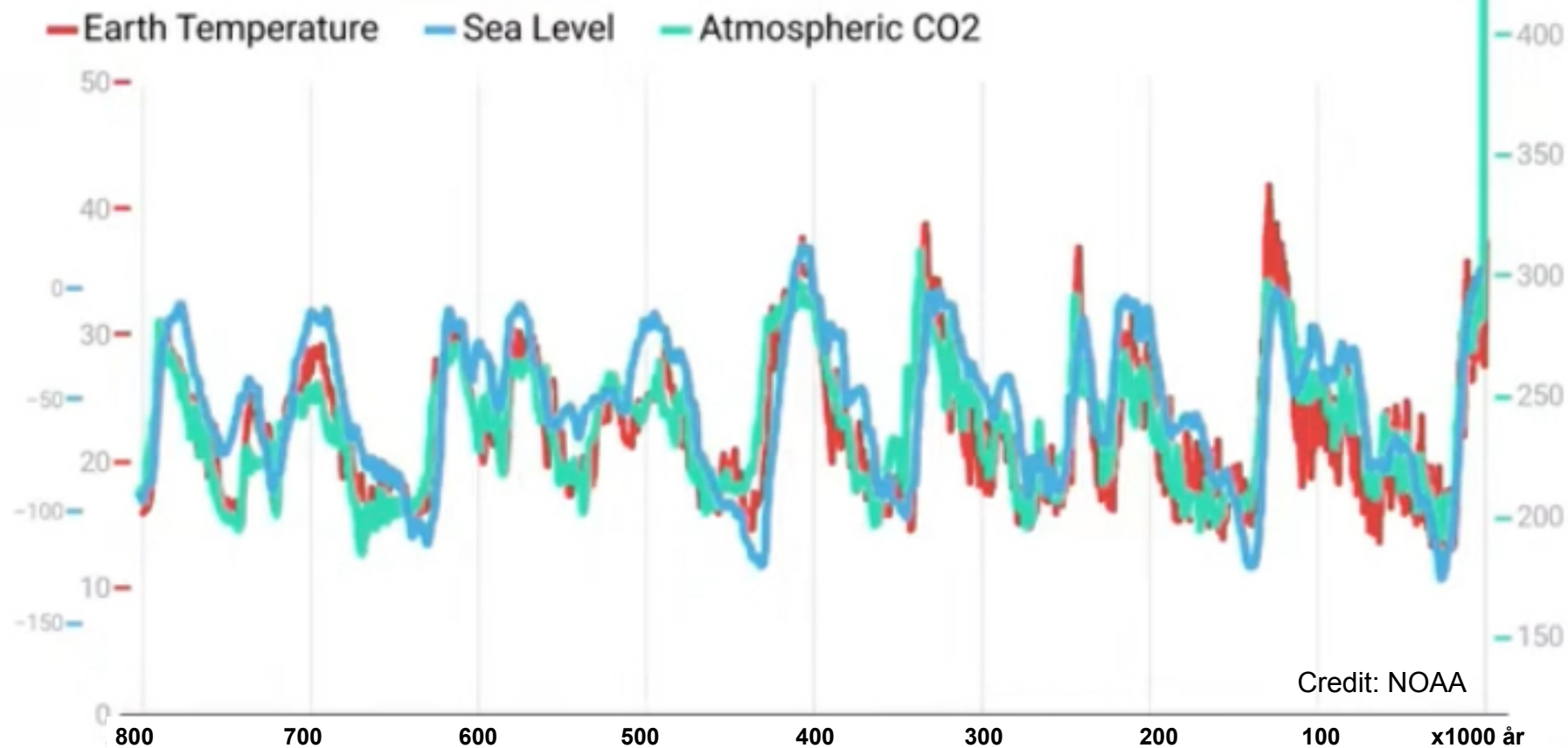
Year



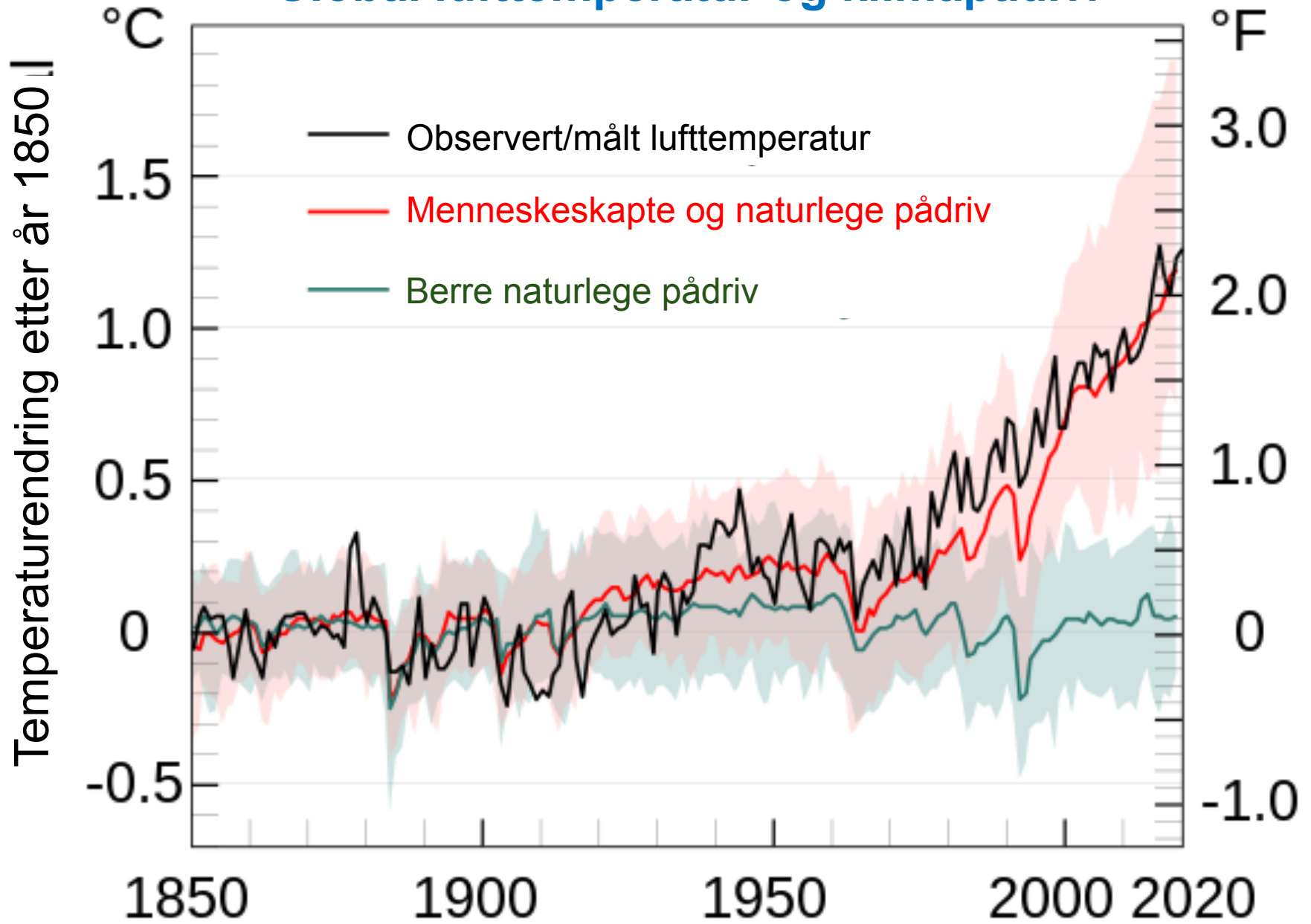
2025-June-05



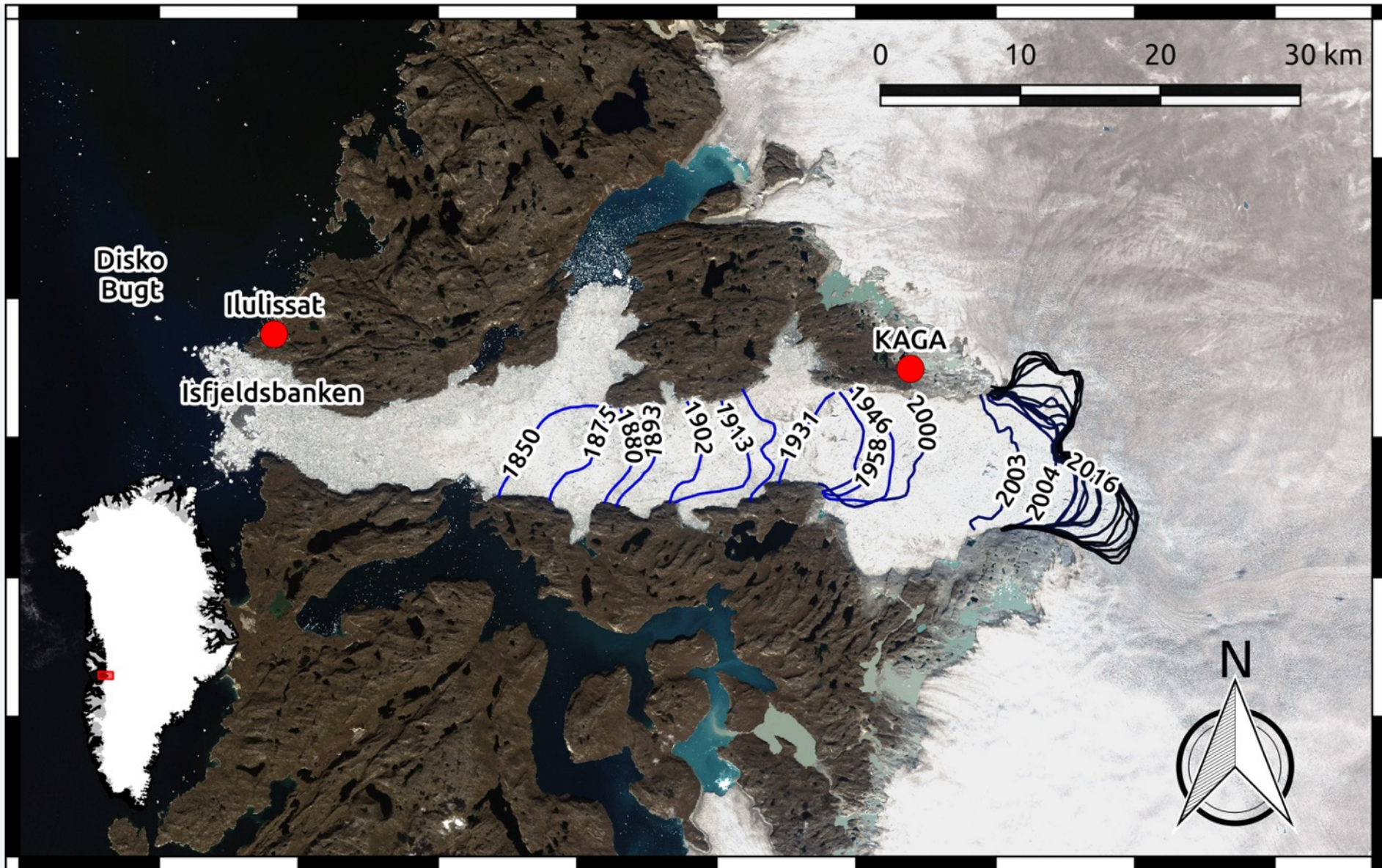
Temperatur, havnivå and karbondioksid (CO₂) gjennom dei siste 800.000 år



Global lufttemperatur og klimapådriv



Jakobshavn Isbre, Grønland – Frontposisjon 1850 - 2016

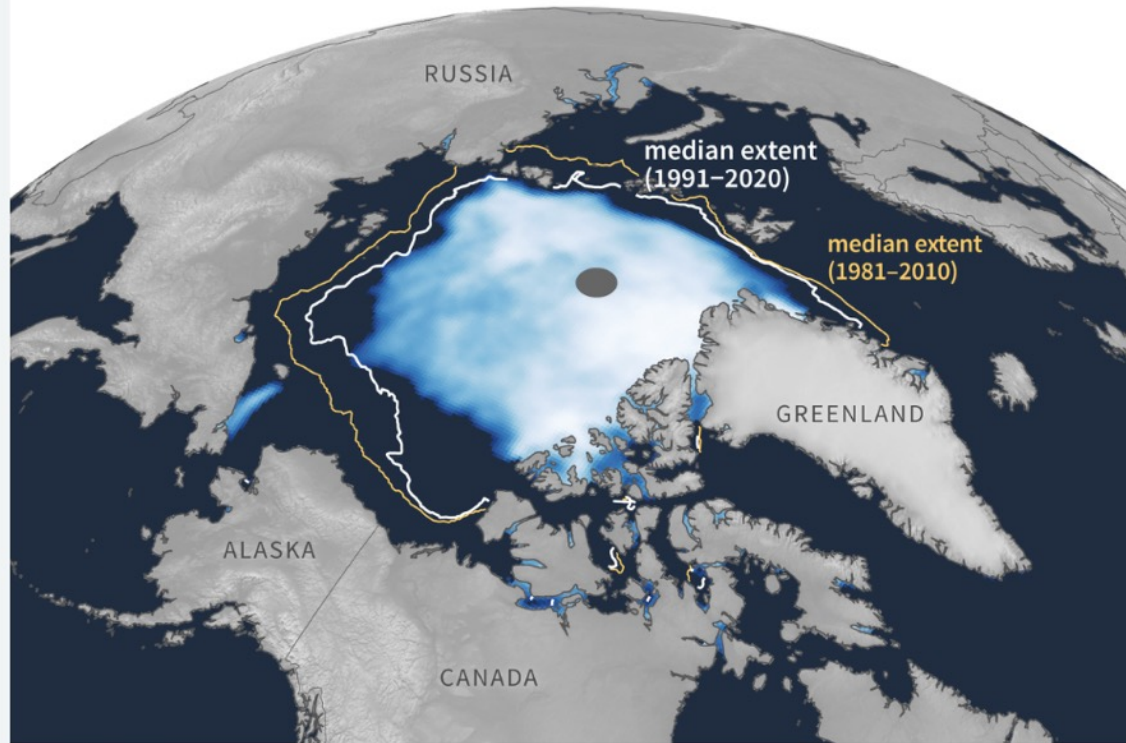


An aerial photograph showing a vast, flat expanse of ice and snow, likely a glacier or ice sheet. The surface is highly textured with numerous small, irregular ice floes and patches of snow. In the foreground, there are some small, dark, circular depressions or meltwater pools. The horizon is marked by a range of dark, low mountains under a clear, pale blue sky. The overall scene conveys a sense of immense scale and cold, desolate beauty.

Jakobshavn/Ilulissat Isfjord

Foto: Atle Nesje 2008

Arctic sea ice summer minimum (September 2024)



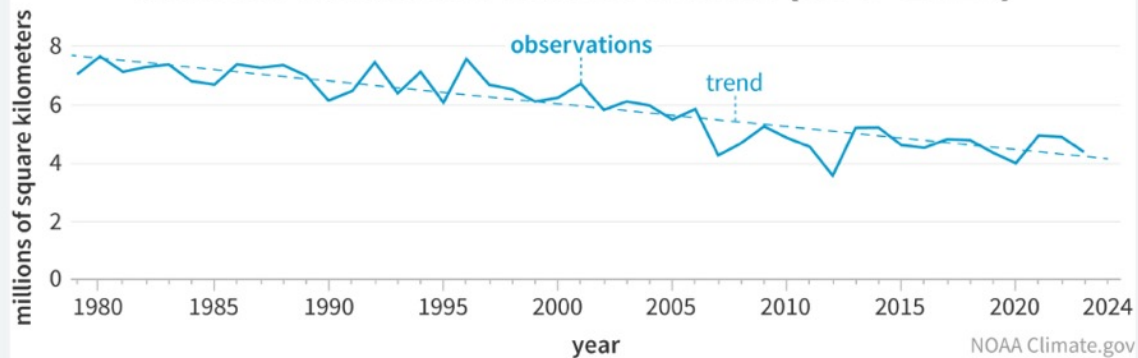
September 2024

Sea ice concentration (%)

NOAA Climate.gov
Data: NSIDC

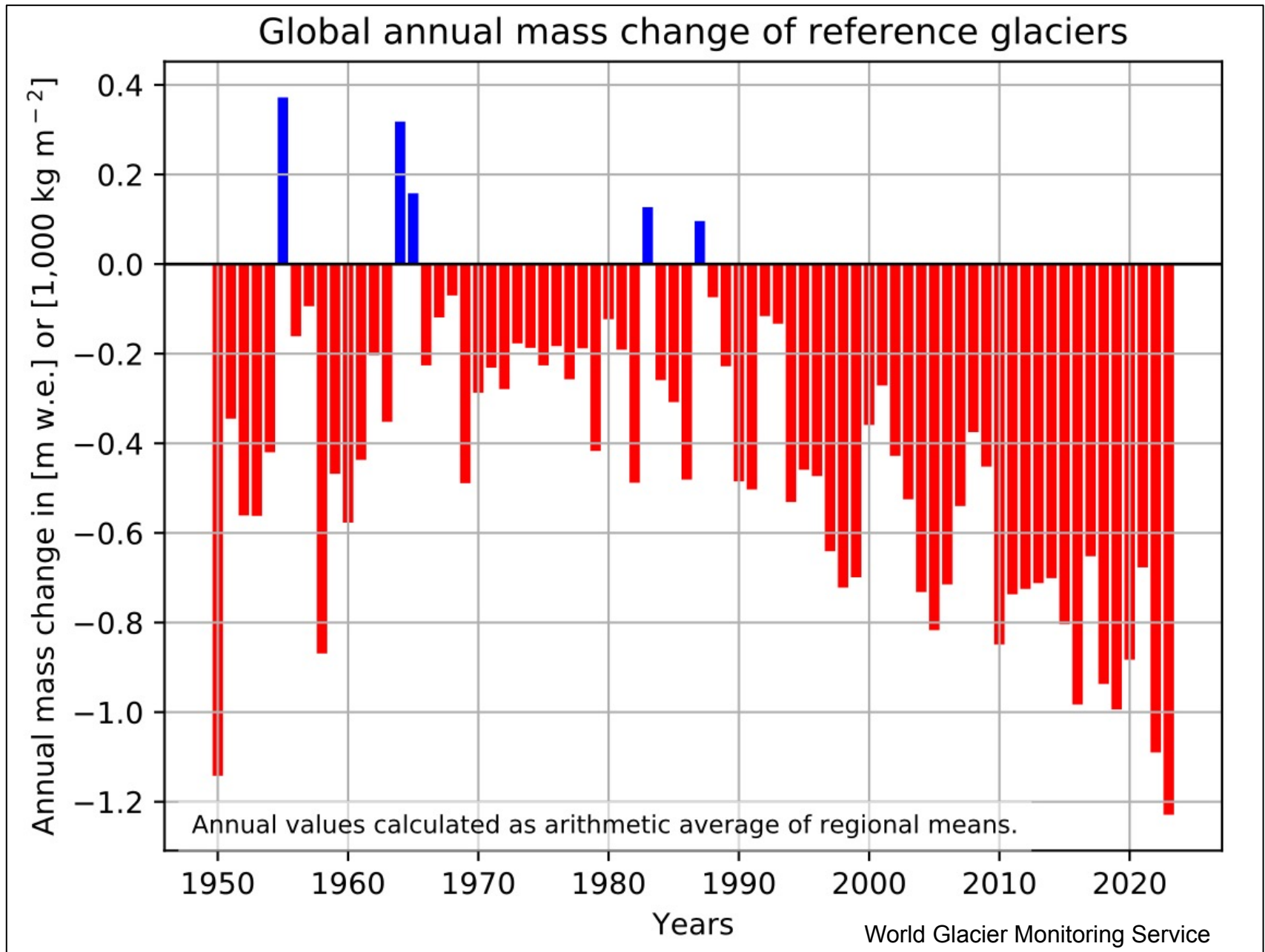
15 100

Summer minimum sea ice extent (1979-2024)



NOAA Climate.gov
Data: ARC 2024

Global árleg (netto) massebalanse på referansebrear 1950-2023



Global kumulativ massebalanse på referansebrear 1950-2023

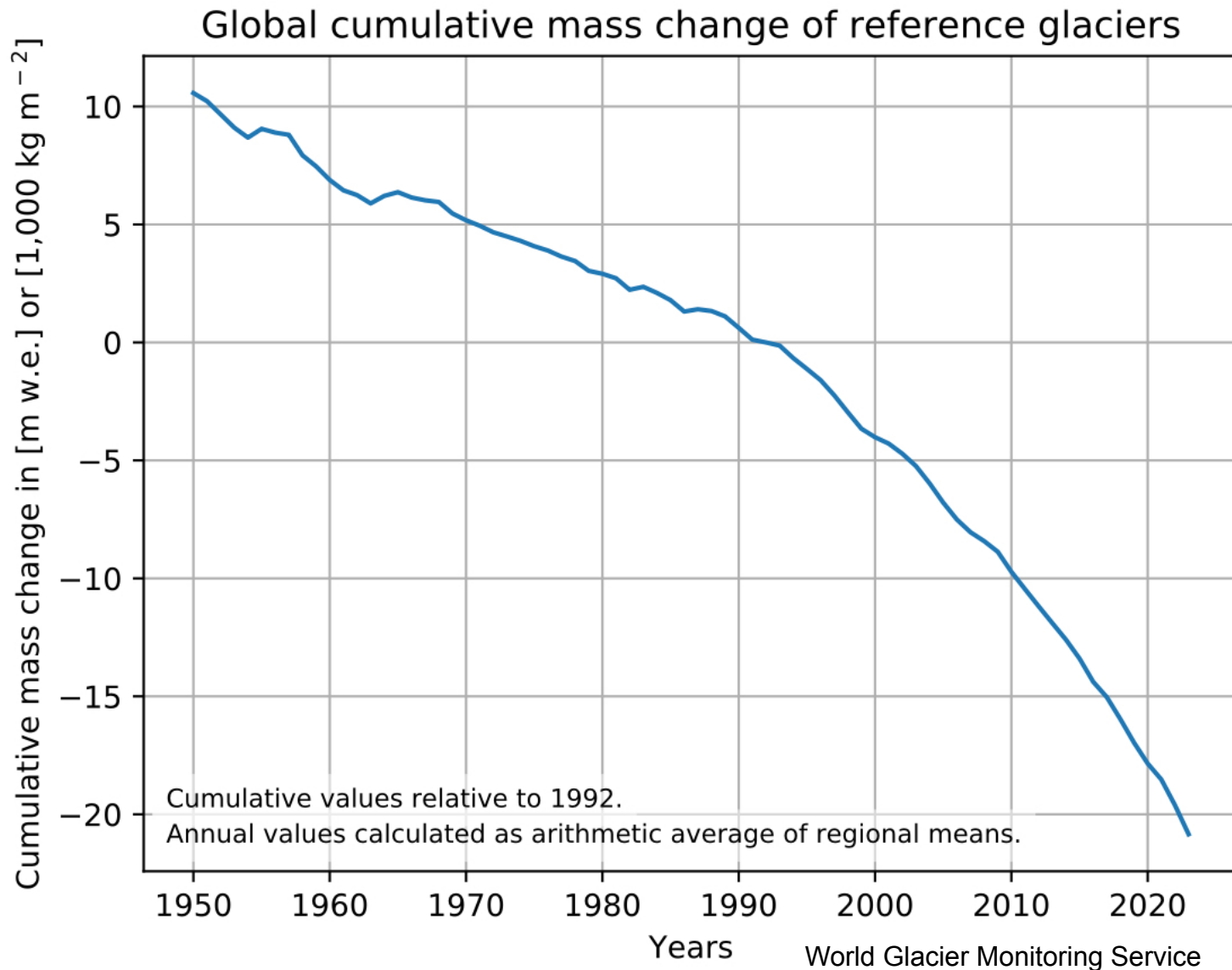
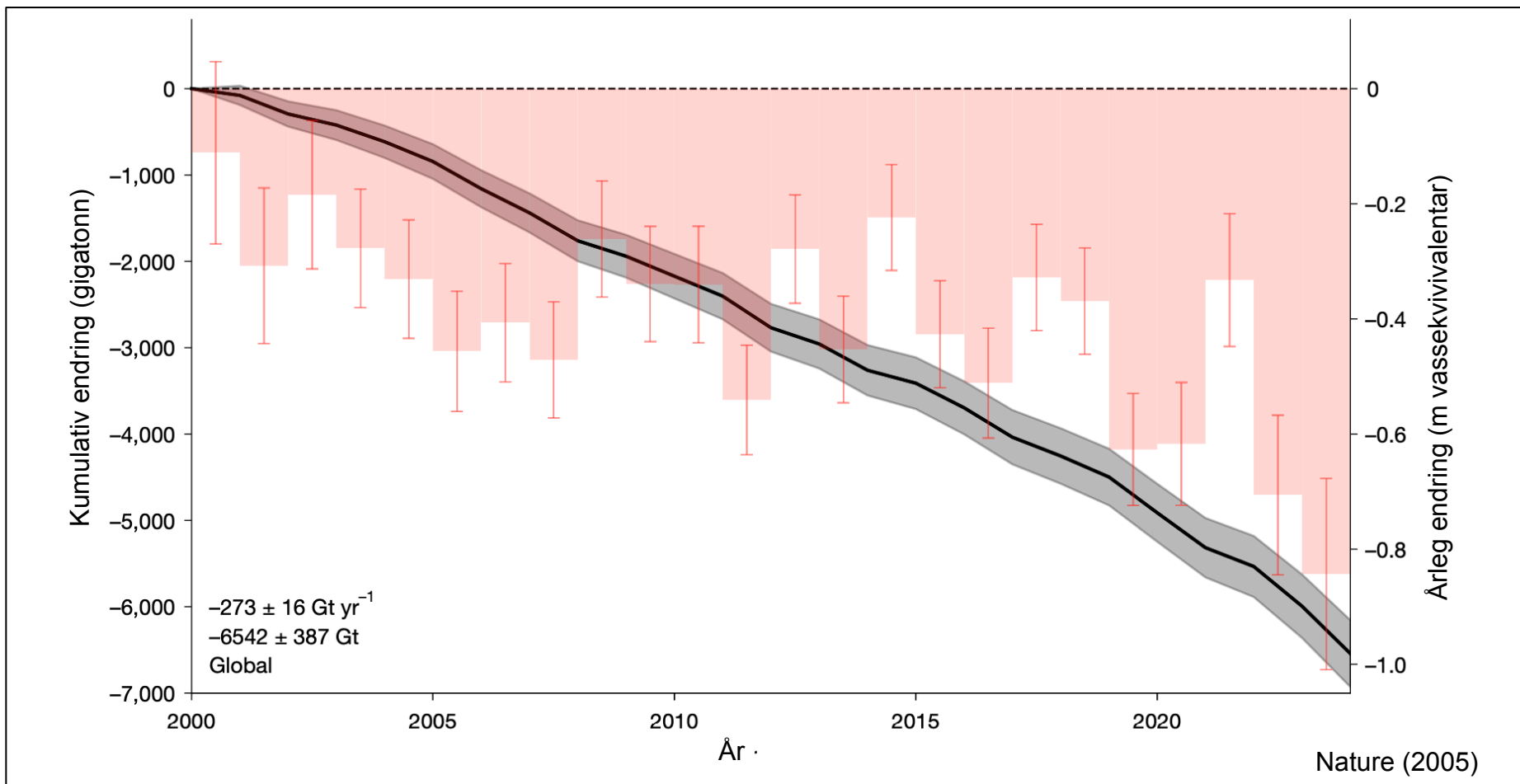


Figure 2: Cumulative mass change of reference glaciers. Cumulative values relative to 1992 are given on the y-axis in the unit meter water equivalent (m w.e.).

Kumulativ og årleg endring i massebalansen på mindre brear 2000-2023



Regionale kumulative endringer i masse på referansebrear 1950-2023

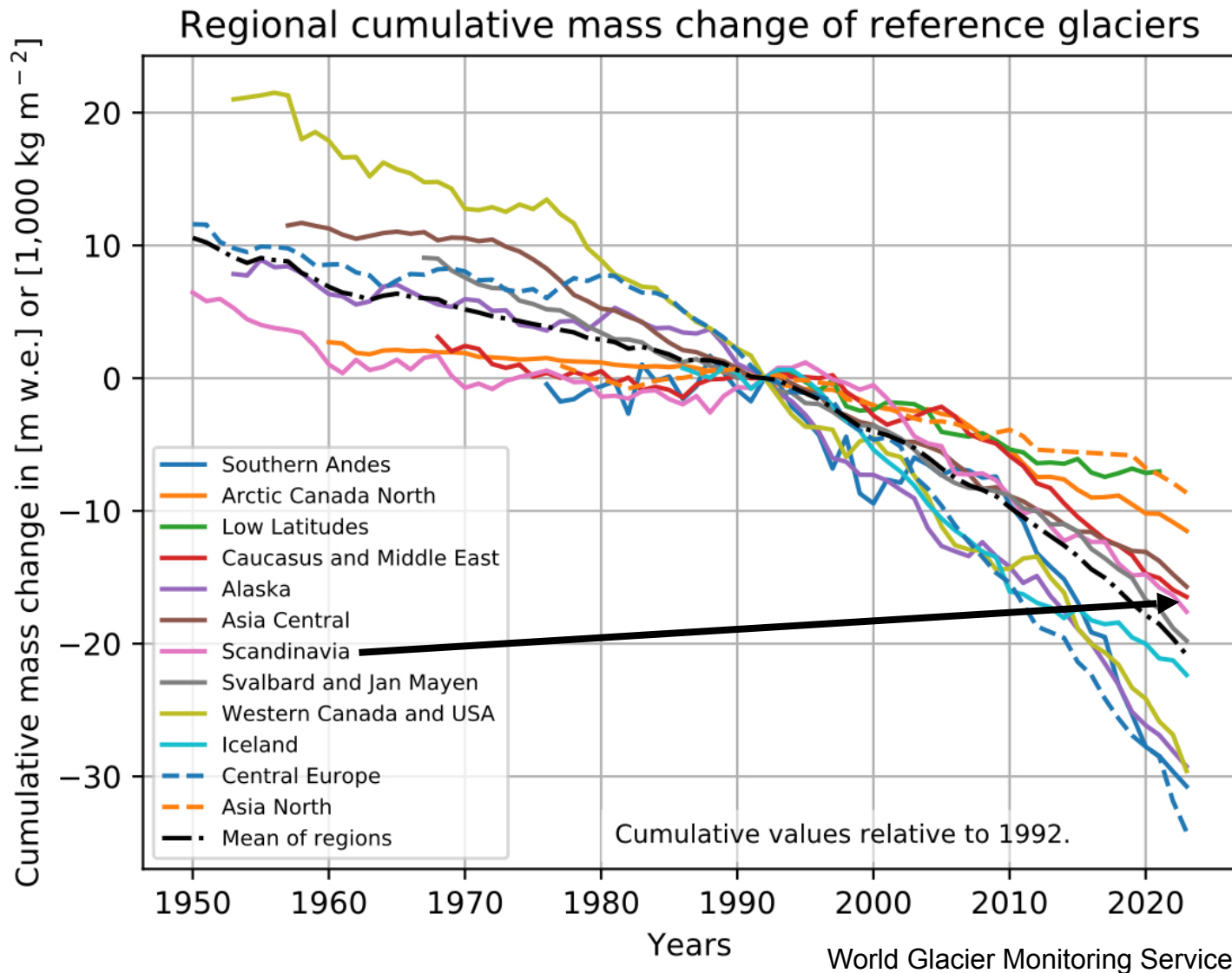
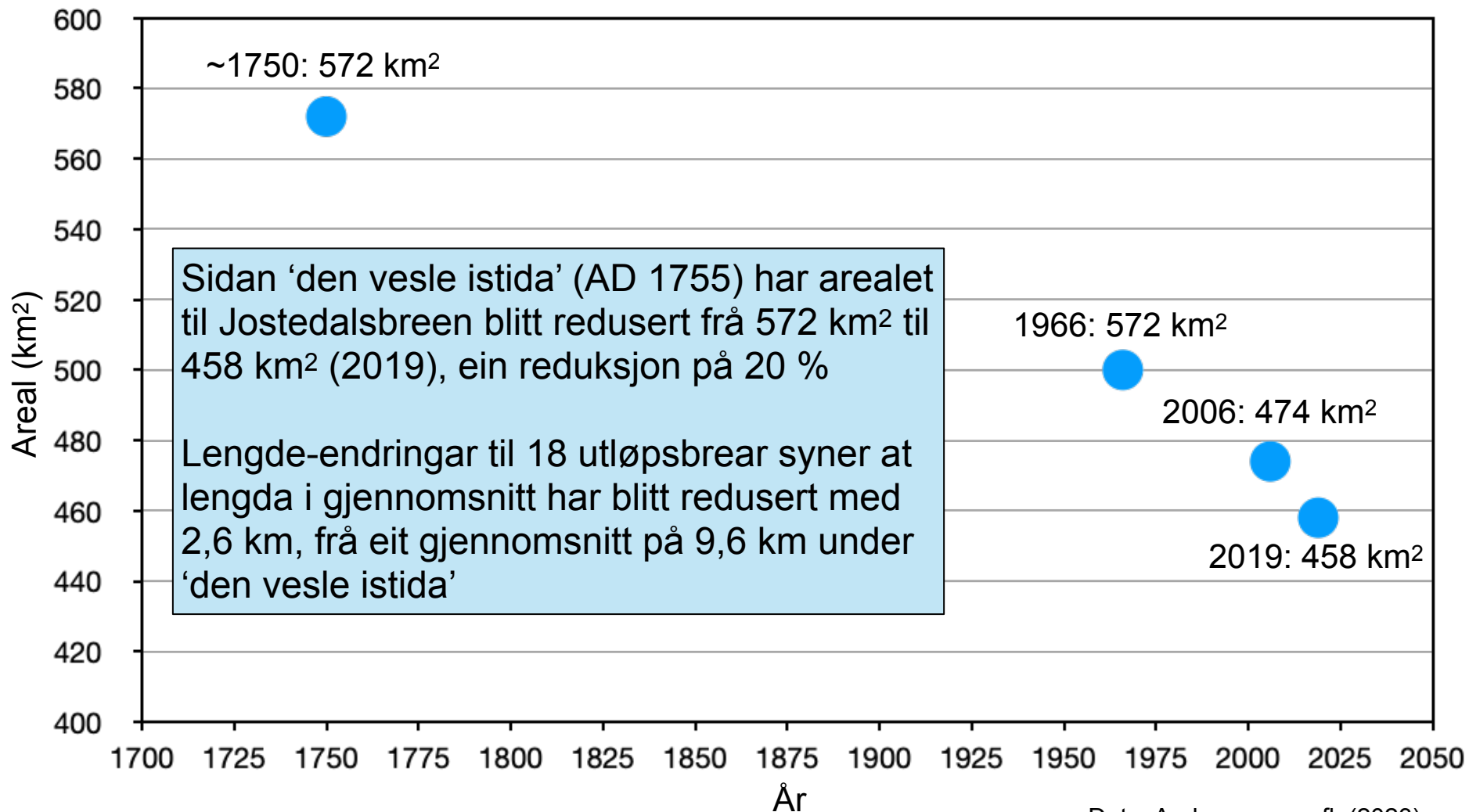


Fig. 3: Cumulative mass change relative to 1992 for regional and global means based on data from reference glaciers. Cumulative values are given on the y-axis in the unit meter water equivalent (m w.e.).

Jostedalsbreen – Arealreduksjon frå 'den vesle istids' maksimum til år 2019



Data: Andreassen m.fl. (2023)

Briksdalsbreen

Photos: Rune Rustøen (1997), Atle Nesje (2004, 2006-2017, 2021-2023), Kurt Erik Nesje (2005), Andreas Nesje (2018-2020, 2024), Ingeborg Sol Fure (2025)



**Natt til 10. oktober 2025 delte brefronten
til Briksdalsbreen seg i to**



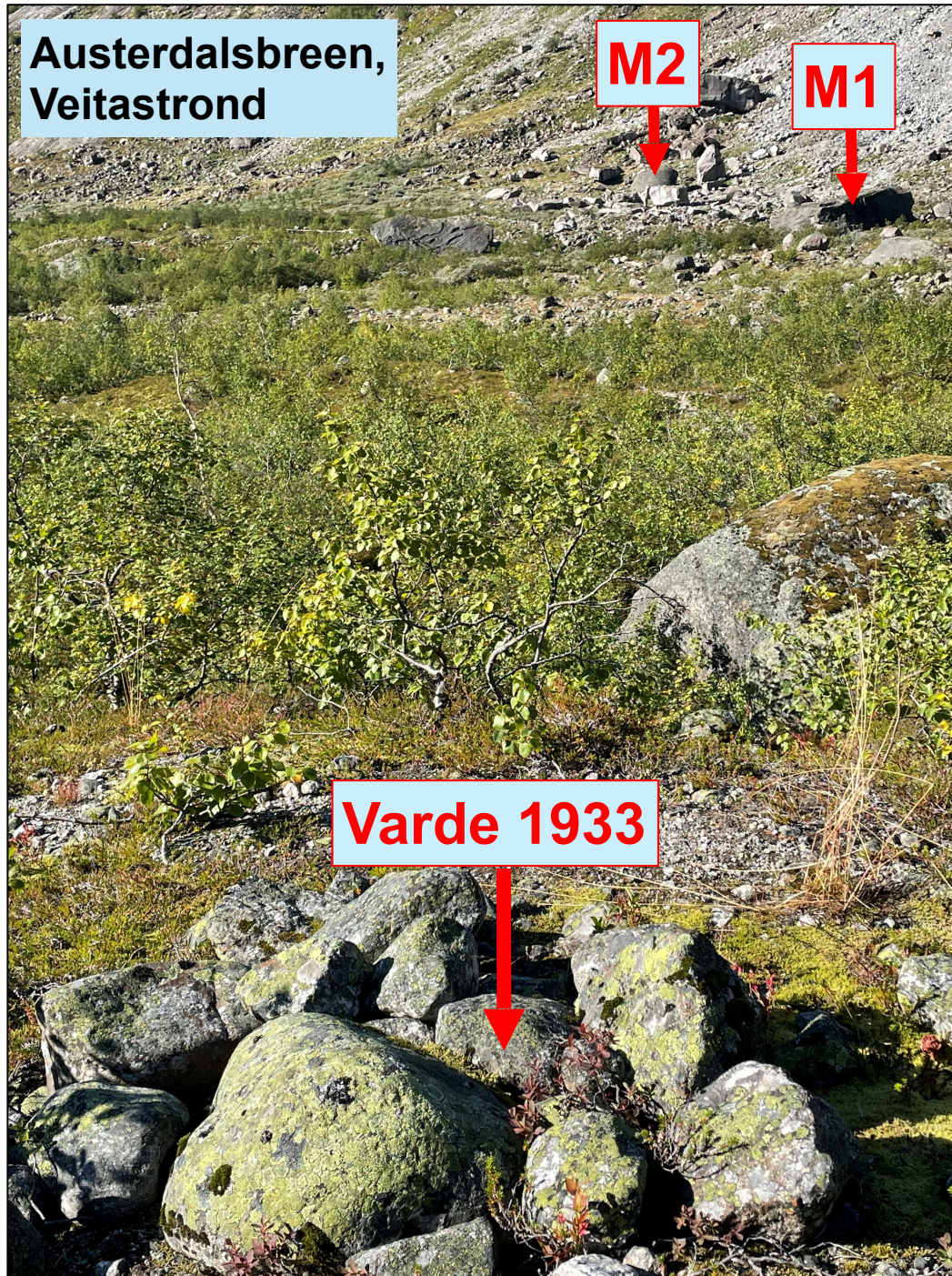
Foto: Jon Olav Kvame

**Austerdalsbreen,
Veitastrond**

M2

M1

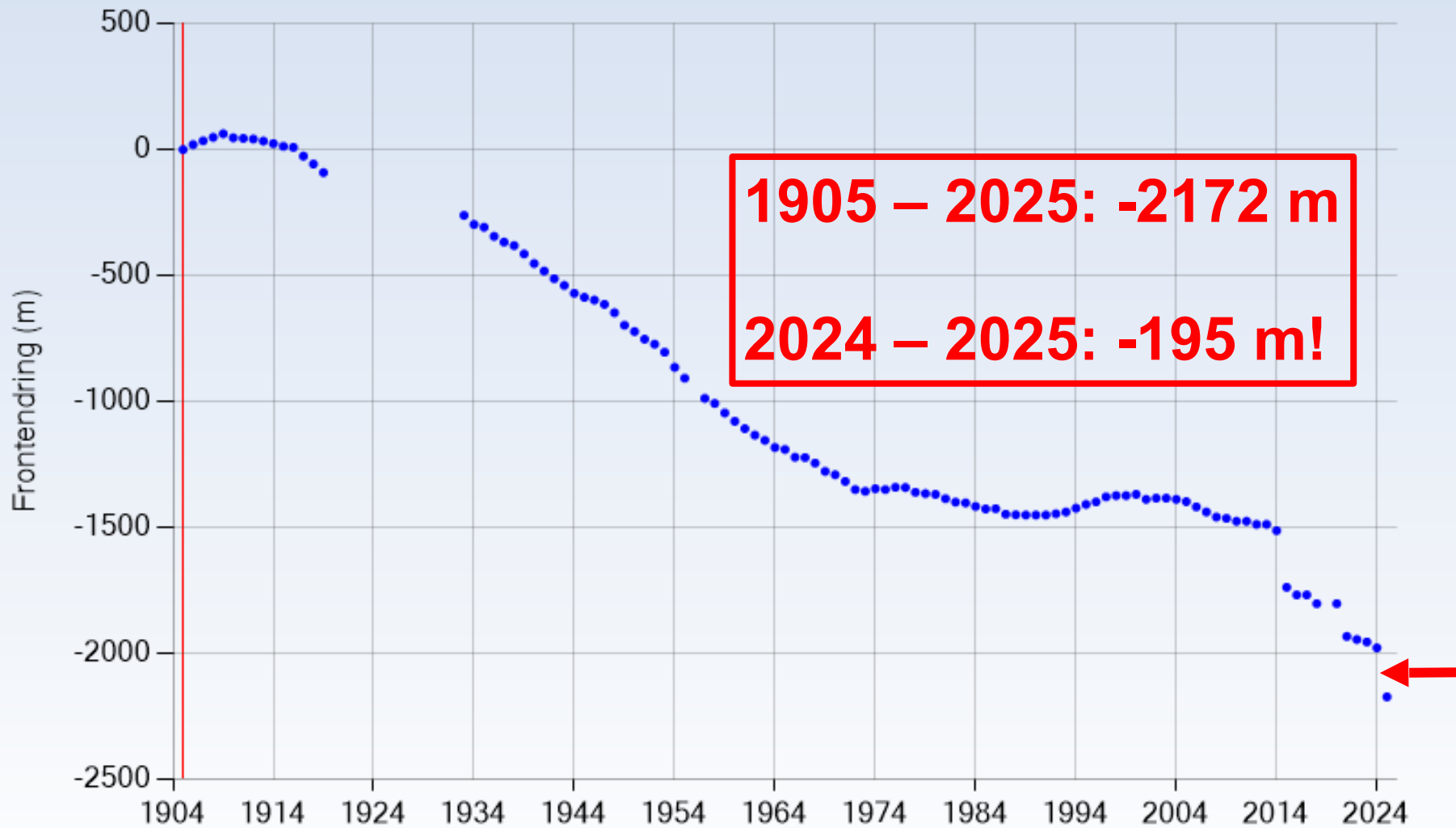
Varde 1933





**Austerdals-
breen**

Austerdalsbreen kumulativ frontendring 1905-2025



Breiar i Alpene

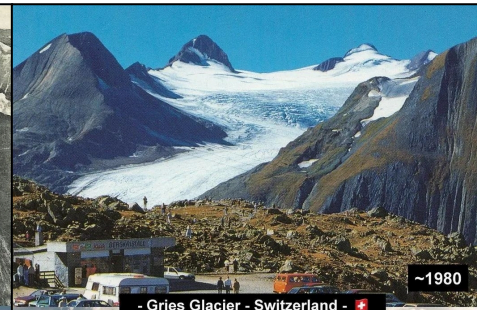
Glaciers in the European Alps



~1935



~1900



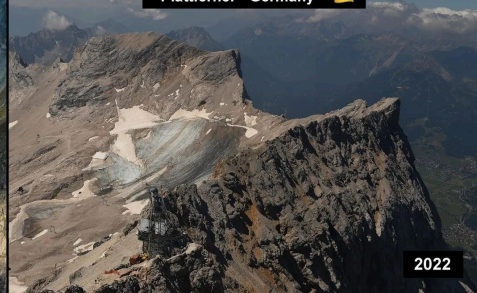
~1980



1906



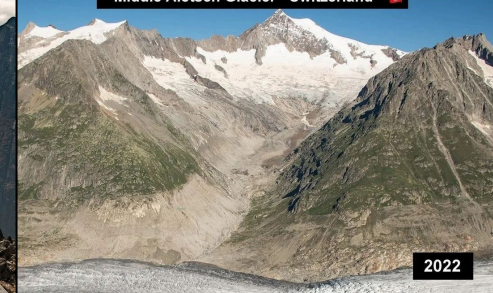
2022



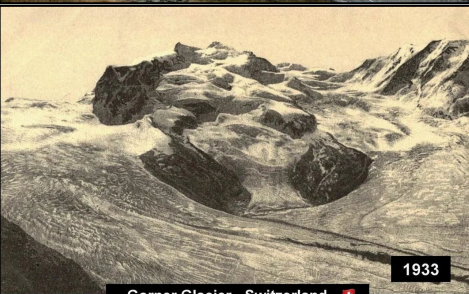
2022



2022



2022



1933



~1930



1948



1924



2022



2022

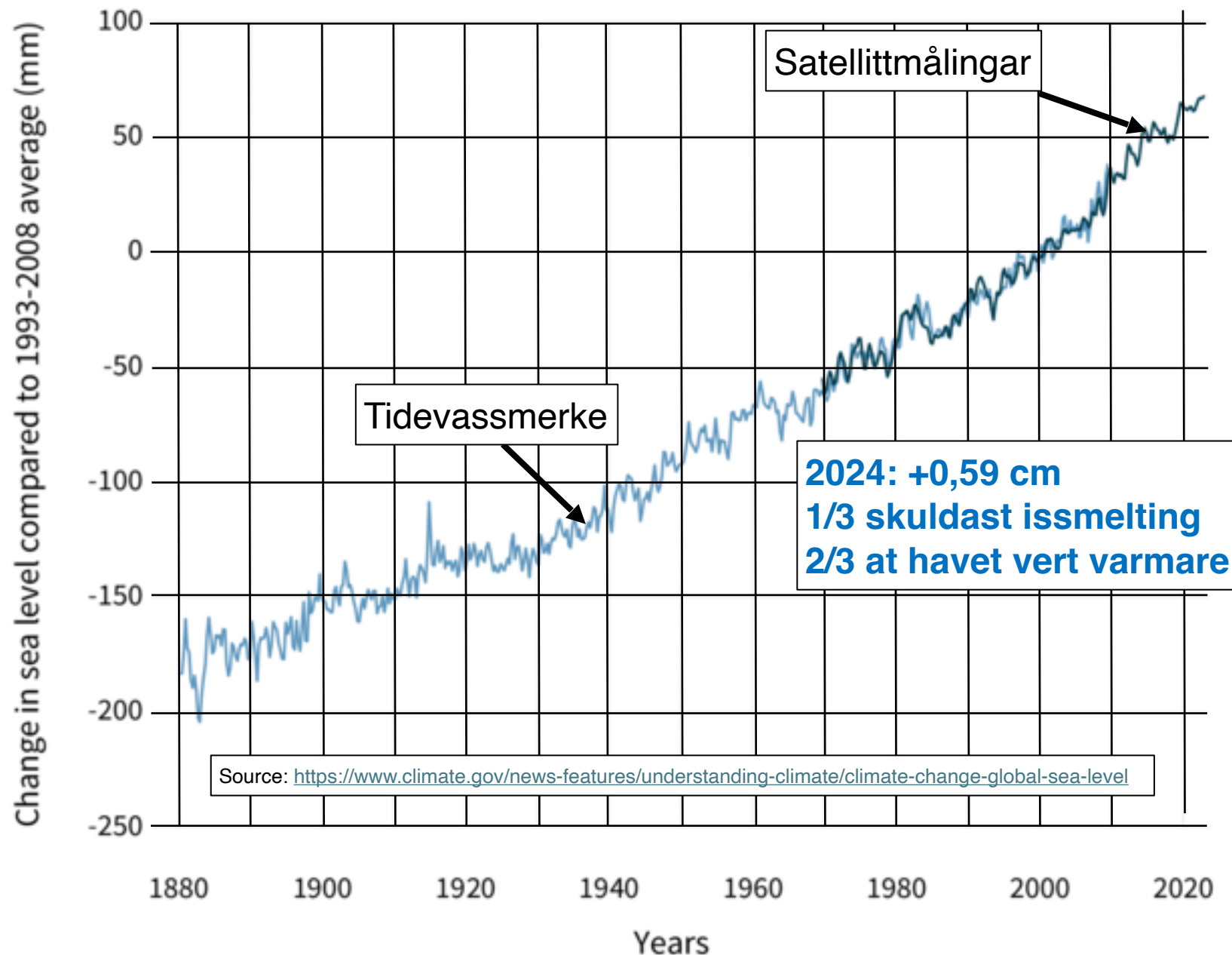


2022



2022

GLOBAL SEA LEVEL Globale havnivåendringer





I FULL FYR: Om lag 200 aktive skogbranner herjer for øyeblikket i Canada. Her fra en av brannene i provinsen Manitoba, 27. mai. Foto: Reuters / NTB

Briksdalsbreen

Finnar: Olav Kvame

Seljestokk
~8520 år gamal

Foto: Inge Fænn, Fjordingen

Morenerygg danna
under breframstøyt 1996/97

Foto: Atle Nesje

Omnsbreen, Finse,
14. september 2014

Takk!

Reinsdyrgevir
~4100 år gammalt!

Foto: Ingvild Nesje