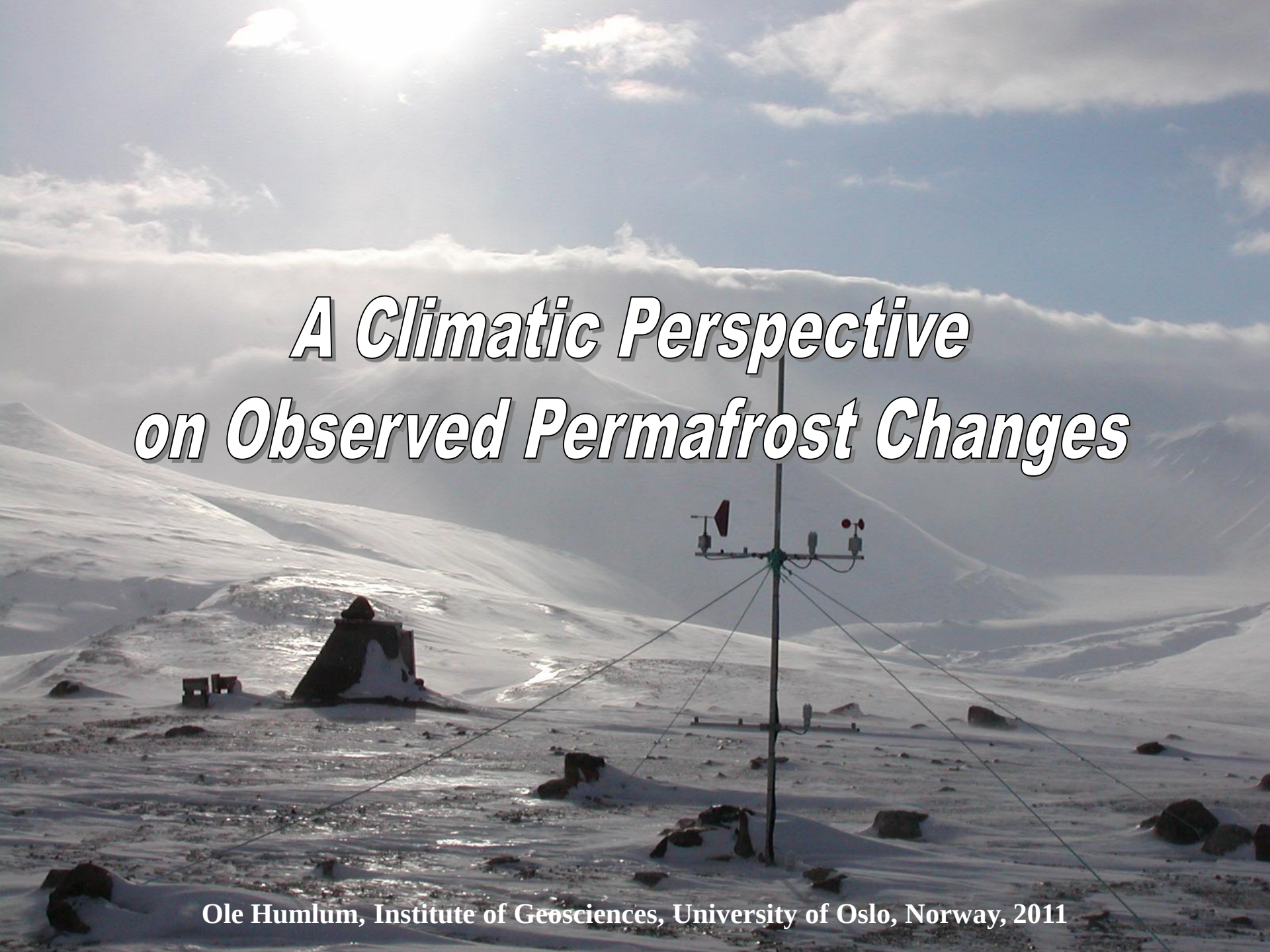


A Climatic Perspective on Observed Permafrost Changes

Ole Humlum, Institute of Geosciences, University of Oslo, Norway, 2011

A Climatic Perspective on Observed Permafrost Changes

1: Quaternary climate and permafrost

2: Holocene climate and permafrost

3: Modern climate and permafrost

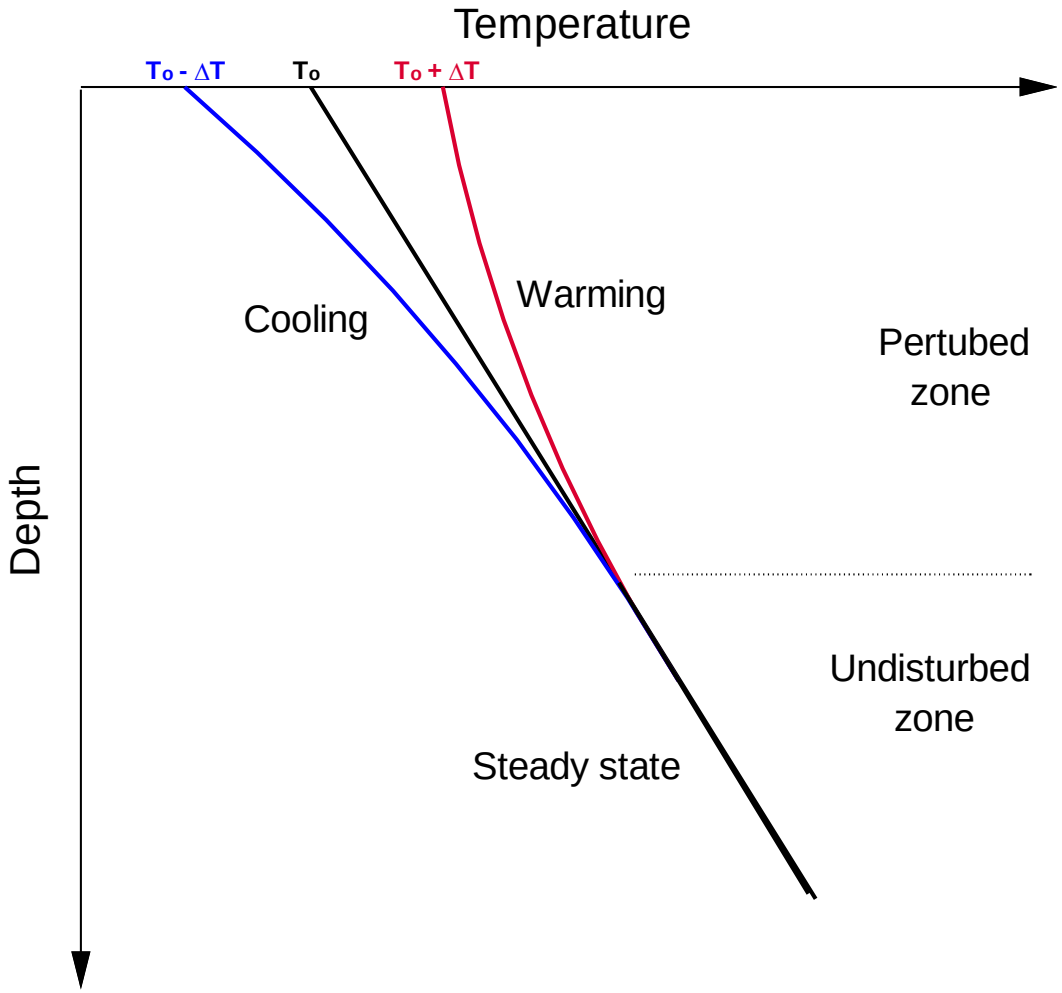
Modern permafrost distribution

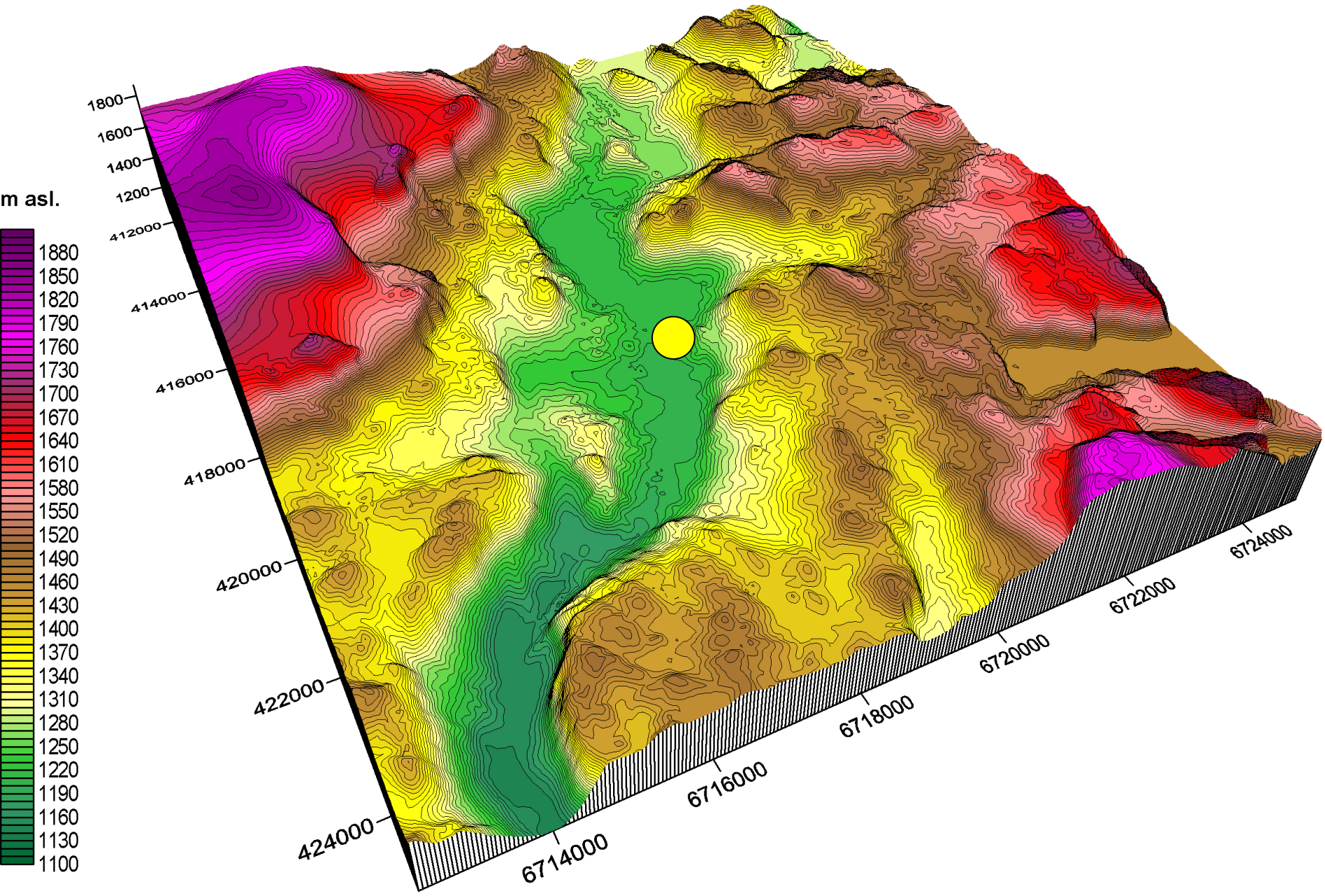
Northern Hemisphere permafrost:

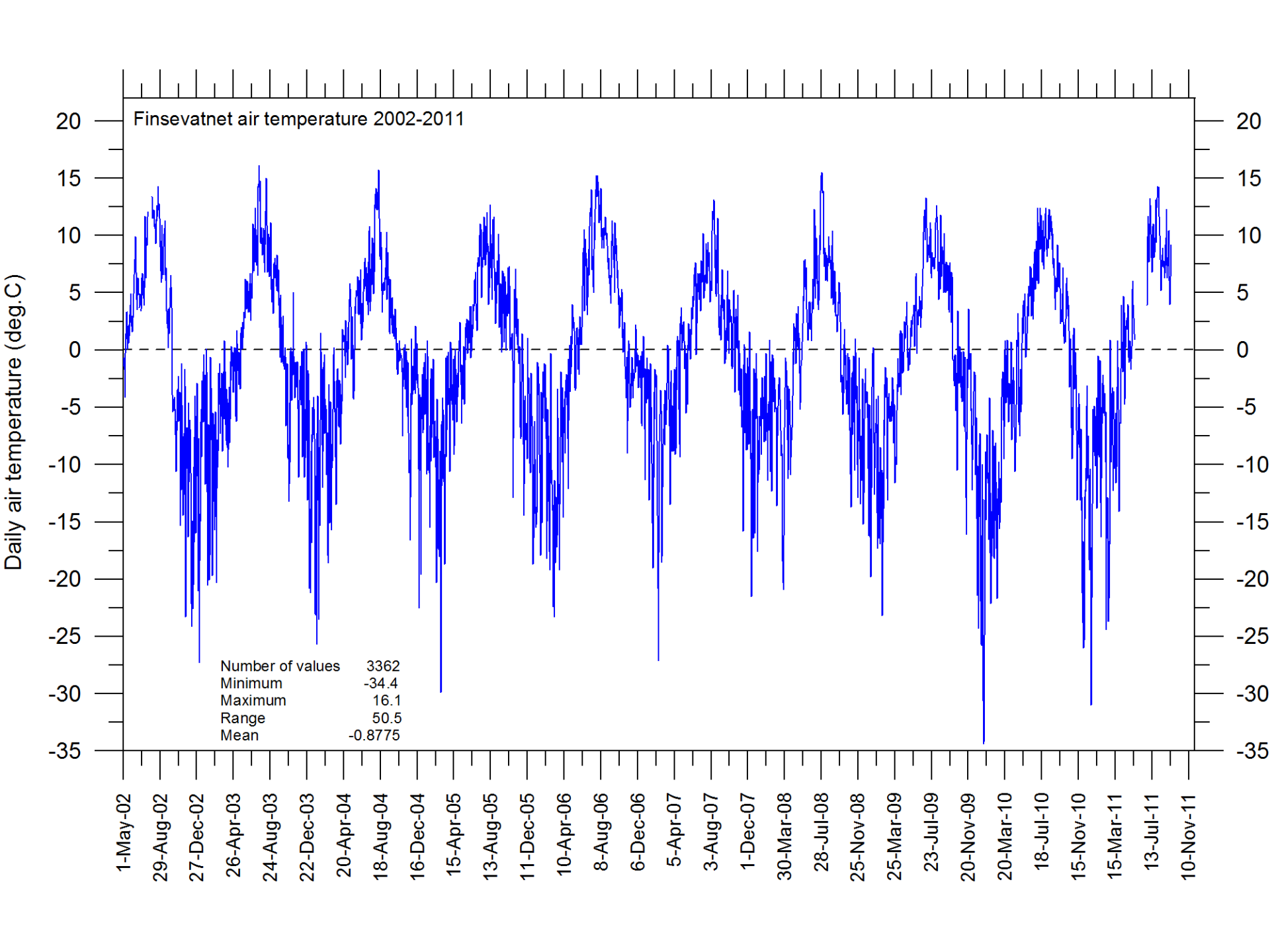
c. 24 % of the exposed land area

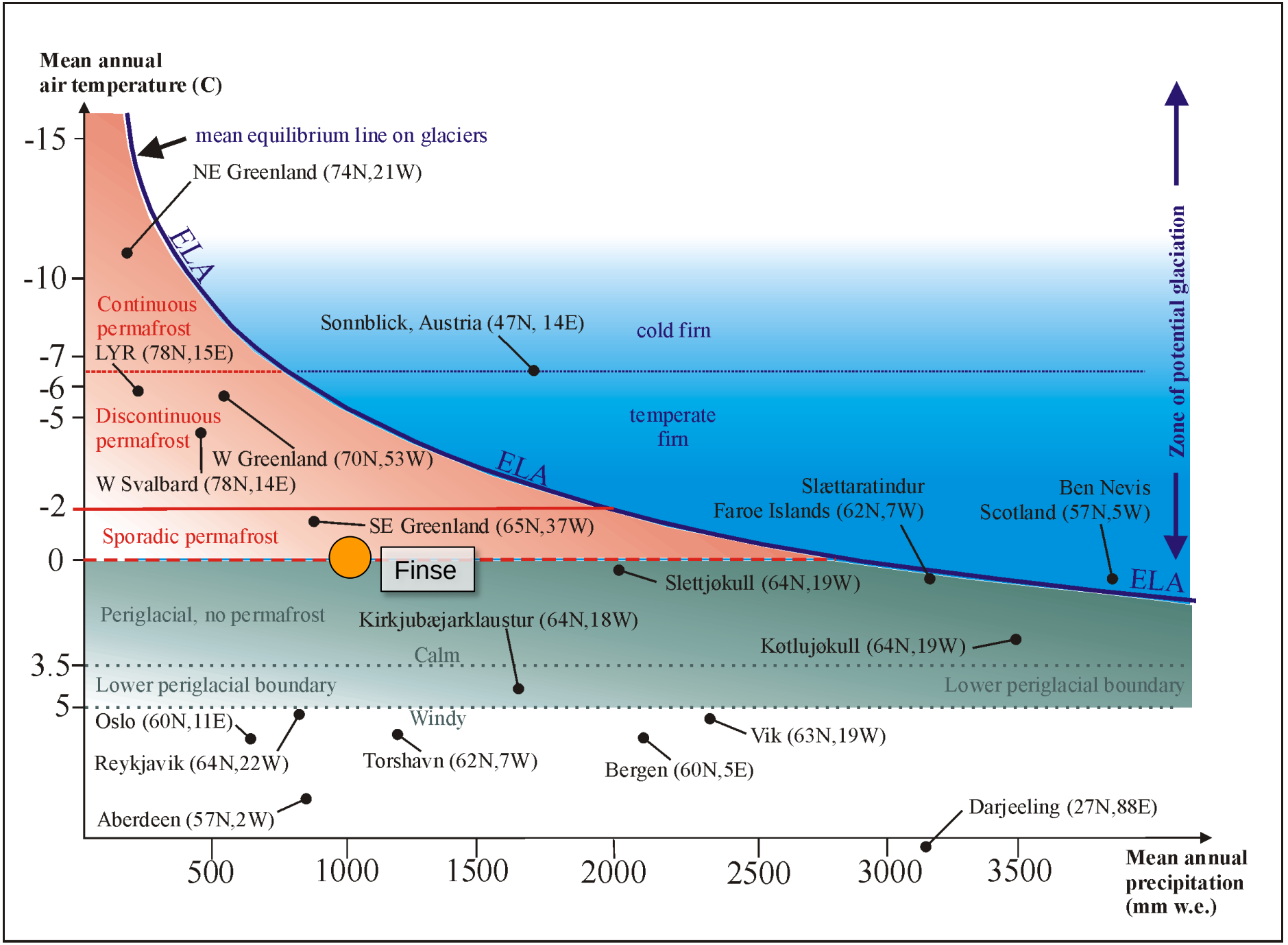
Permafrost and climate

- Geothermic response to changes in surface temperature

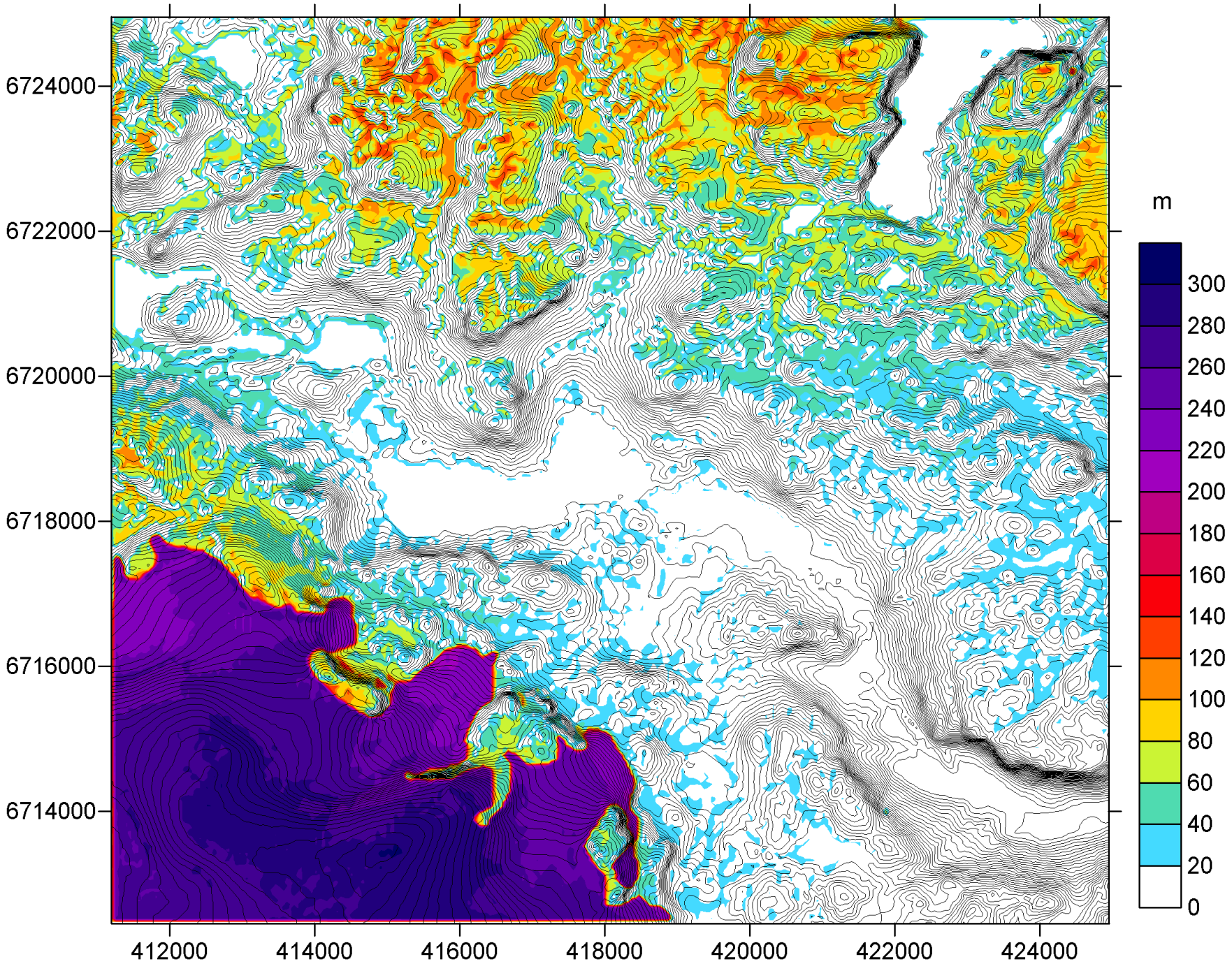


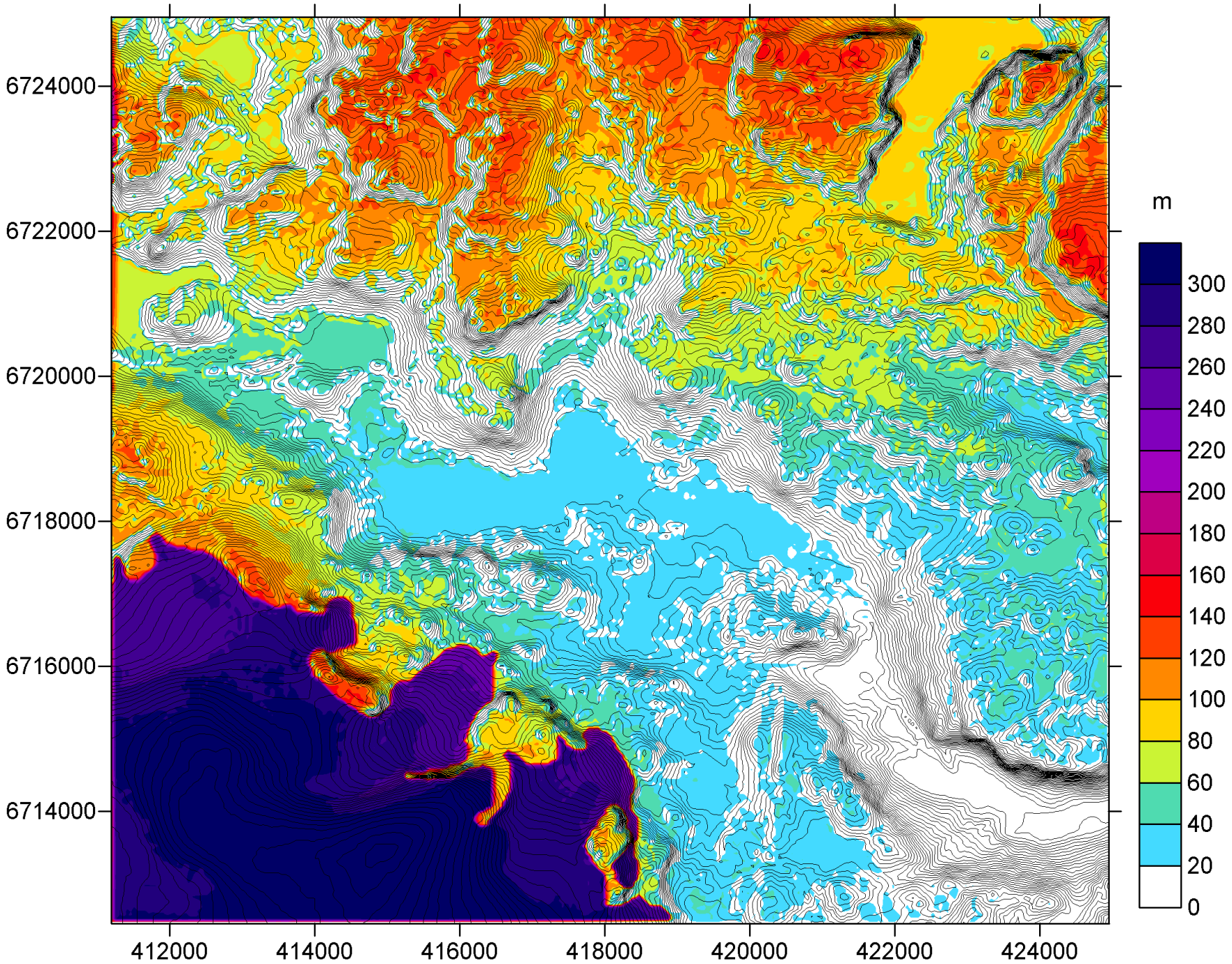

m asl.
1880
1850
1820
1790
1760
1730
1700
1670
1640
1610
1580
1550
1520
1490
1460
1430
1400
1370
1340
1310
1280
1250
1220
1190
1160
1130
1100
1800
1600
1400
1200
412000
414000
416000
418000
420000
422000
424000
6714000
6716000
6718000
6720000
6722000
6724000

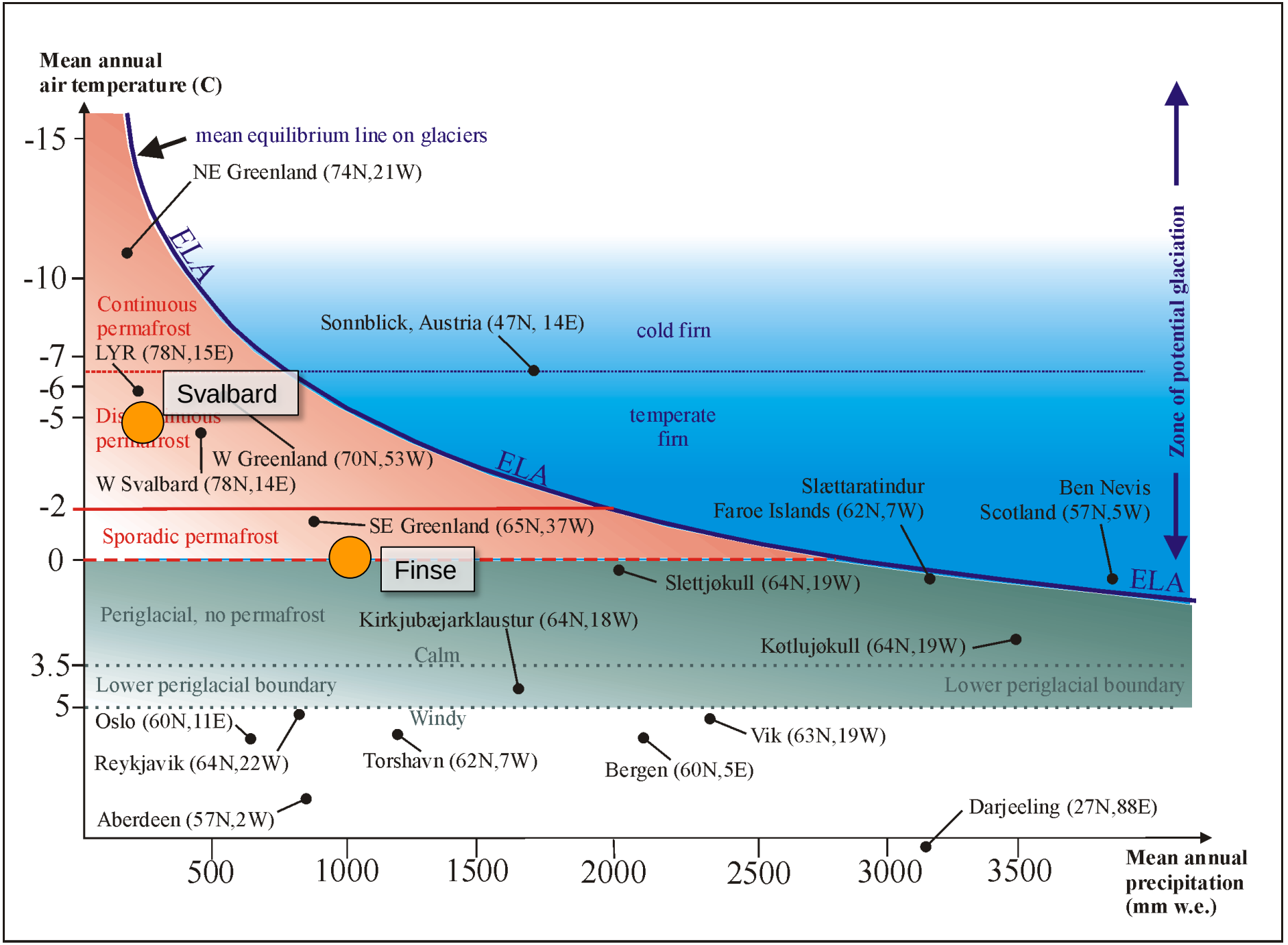

Finsevatnet air temperature 2002-2011
Daily air temperature (deg.C)
Number of values 3362
Minimum -34.4
Maximum 16.1
Range 50.5
Mean -0.8775
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
1-May-02
29-Aug-02
27-Dec-02
26-Apr-03
24-Aug-03
22-Dec-03
20-Apr-04
18-Aug-04
16-Dec-04
15-Apr-05
13-Aug-05
11-Dec-05
10-Apr-06
8-Aug-06
6-Dec-06
5-Apr-07
3-Aug-07
1-Dec-07
30-Mar-08
28-Jul-08
25-Nov-08
25-Mar-09
23-Jul-09
20-Nov-09
20-Mar-10
18-Jul-10
15-Nov-10
15-Mar-11
13-Jul-11
10-Nov-11


Mean annual
air temperature (C)
-15
-10
-7
-6
-5
-2
0
3.5
5
mean equilibrium line on glaciers
NE Greenland (74N,21W)
ELA
Continuous
permafrost
LYR (78N,15E)
Discontinuous
permafrost
W Svalbard (78N,14E)
W Greenland (70N,53W)
Sporadic permafrost
SE Greenland (65N,37W)
Finse
Periglacial, no permafrost
Lower periglacial boundary
Oslo (60N,11E)
Reykjavik (64N,22W)
Aberdeen (57N,2W)
Sonnblick, Austria (47N, 14E)
cold firn
temperate
firn
ELA
Slettjøkull (64N,19W)
Kirkjubæjarklaustur (64N,18W)
Calm
Windy
Torshavn (62N,7W)
Bergen (60N,5E)
Slættaratindur
Faroe Islands (62N,7W)
Køtlujøkull (64N,19W)
Vik (63N,19W)
Ben Nevis
Scotland (57N,5W)
ELA
Lower periglacial boundary
Darjeeling (27N,88E)
Zone of potential glaciation
500
1000
1500
2000
2500
3000
3500
Mean annual
precipitation
(mm w.e.)

Ole Humlum


Finse stable permafrost 20040901-20050831
6724000
6722000
6720000
6718000
6716000
6714000
412000
414000
416000
418000
420000
422000
424000
m
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0


Finse stable permafrost 16940901-16950831
6724000
6722000
6720000
6718000
6716000
6714000
412000
414000
416000
418000
420000
422000
424000
m
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0


Mean annual
air temperature (C)
-15
-10
-7
-6
-5
-2
0
3.5
5
mean equilibrium line on glaciers
NE Greenland (74N,21W)
ELA
Continuous
permafrost
LYR (78N,15E)
Svalbard
Sonnblick, Austria (47N, 14E)
cold firn
temperate
firn
W Greenland (70N,53W)
W Svalbard (78N,14E)
ELA
Slættaratindur
Faroe Islands (62N,7W)
Ben Nevis
Scotland (57N,5W)
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Periglacial, no permafrost
Kirkjubæjarklaustur (64N,18W)
Calm
Køtlujøkull (64N,19W)
Lower periglacial boundary
Lower periglacial boundary
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Windy
Vik (63N,19W)
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Torshavn (62N,7W)
Bergen (60N,5E)
Aberdeen (57N,2W)
Darjeeling (27N,88E)
500
1000
1500
2000
2500
3000
3500
Mean annual
precipitation
(mm w.e.)

Ole Humlum

Permafrost: surface phenomena and dynamics

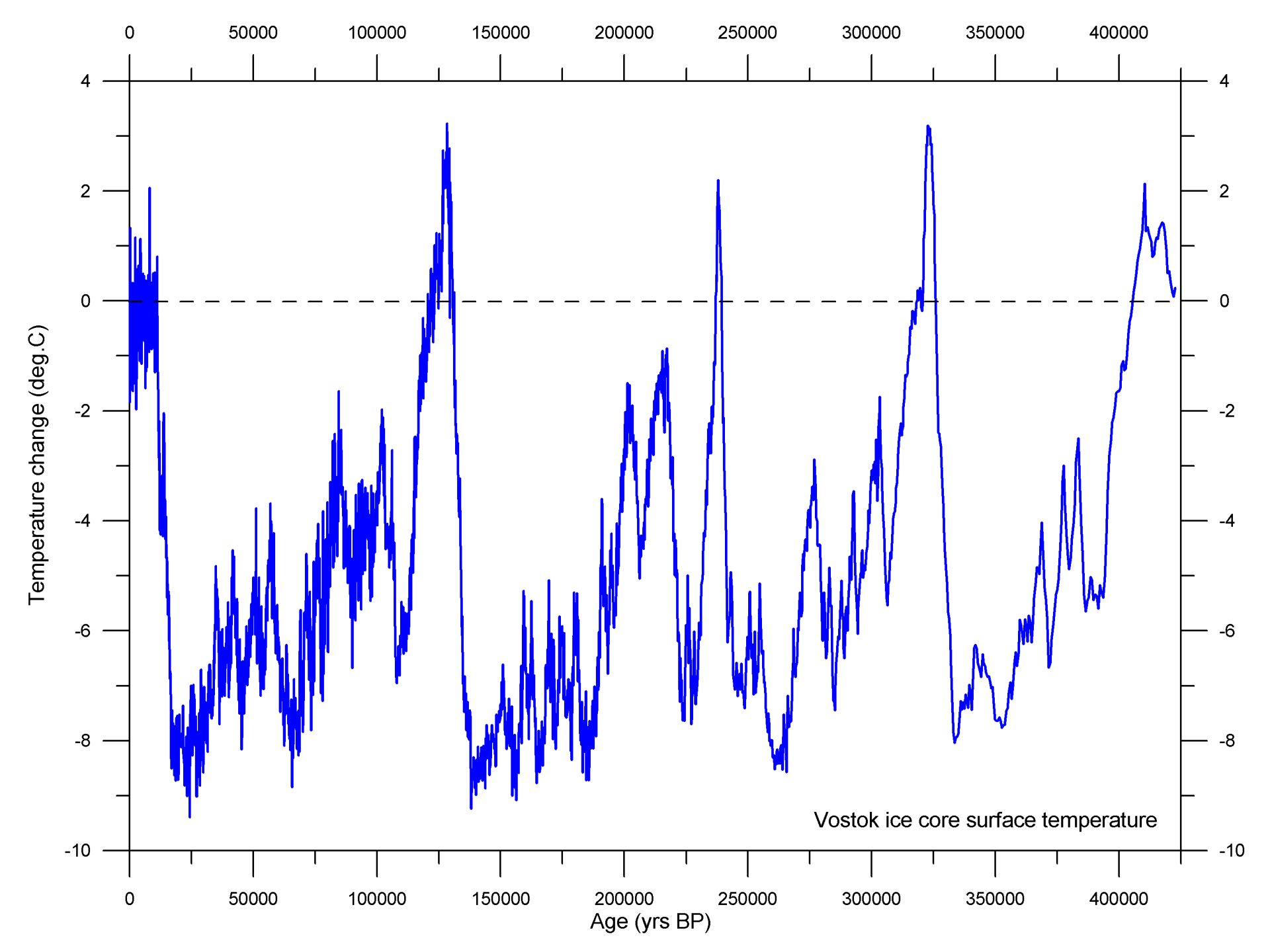

Ice wedges; about 3100 years old

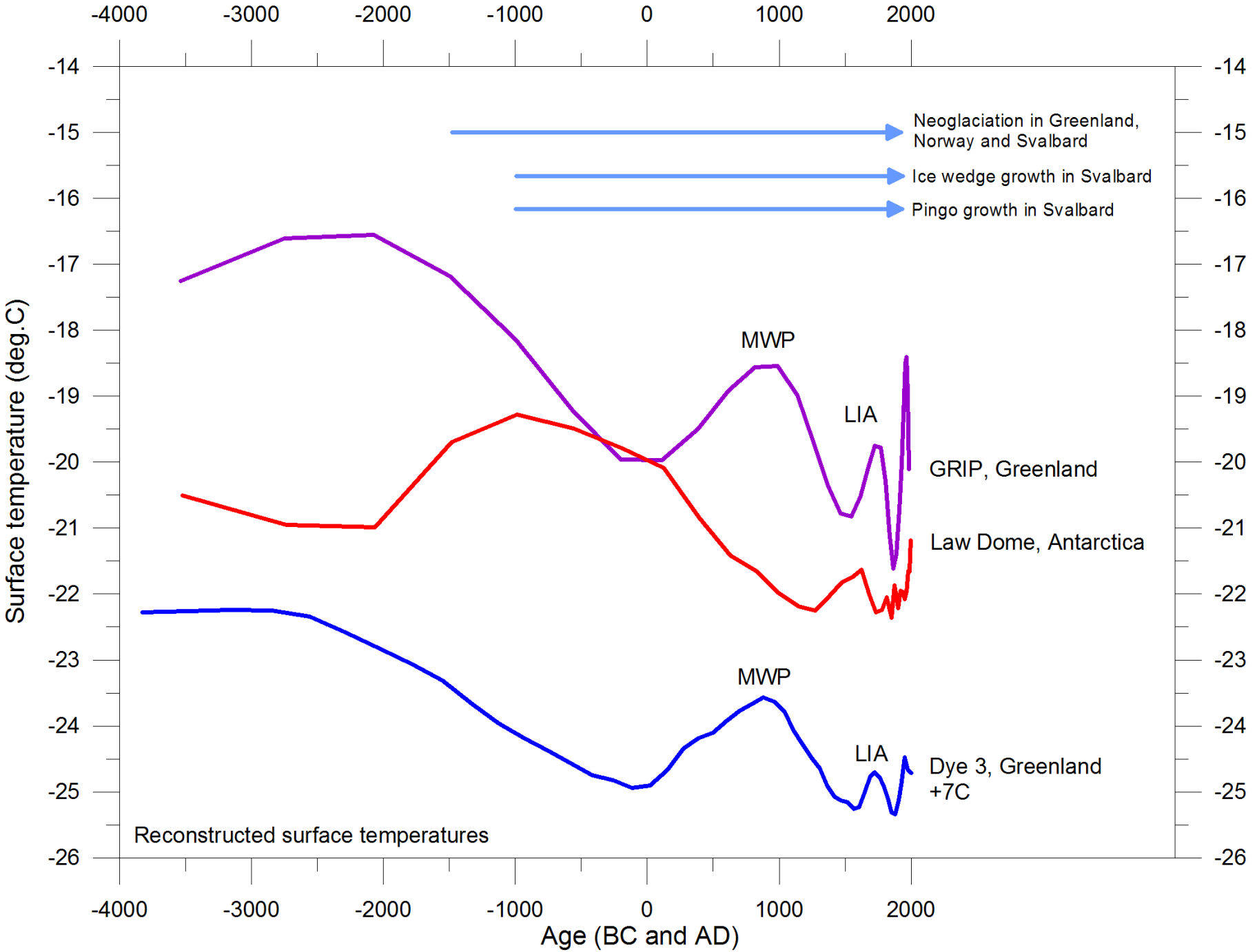
Rock glaciers in Northern Iceland


Ground ice

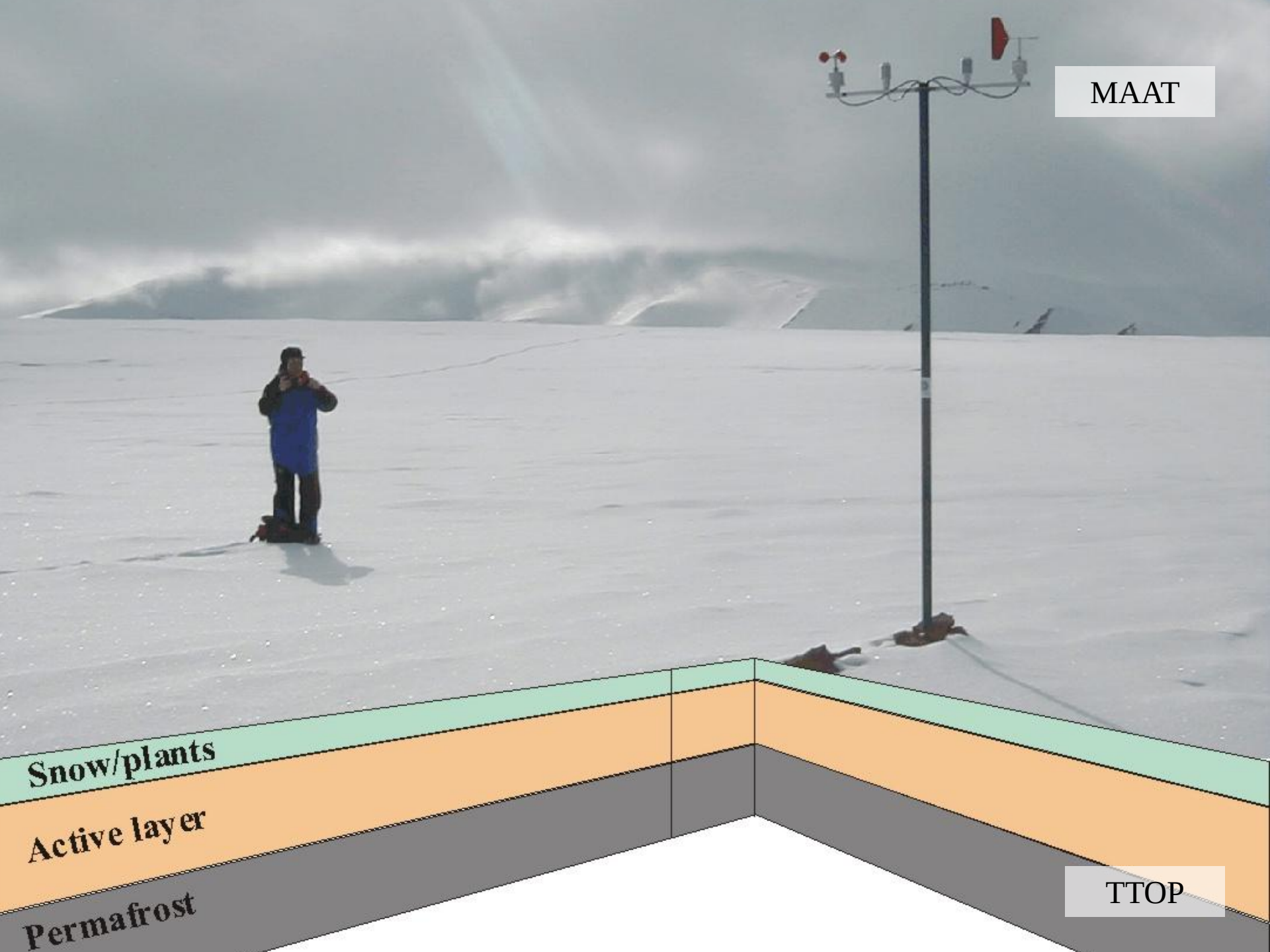

Active layer dynamics
Cryoturbation

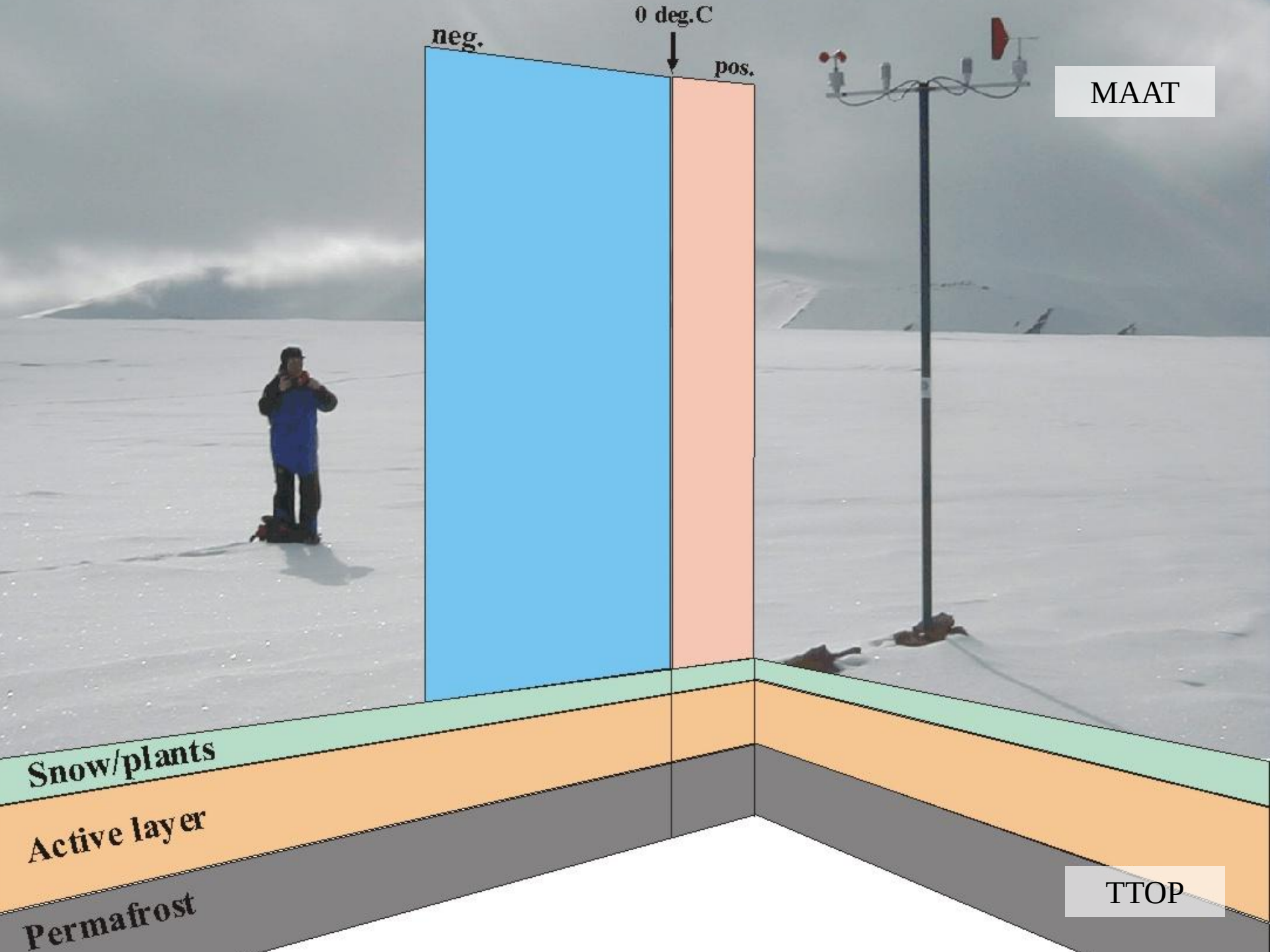
Polygonal networks in former cold-climatic areas in S Sweden

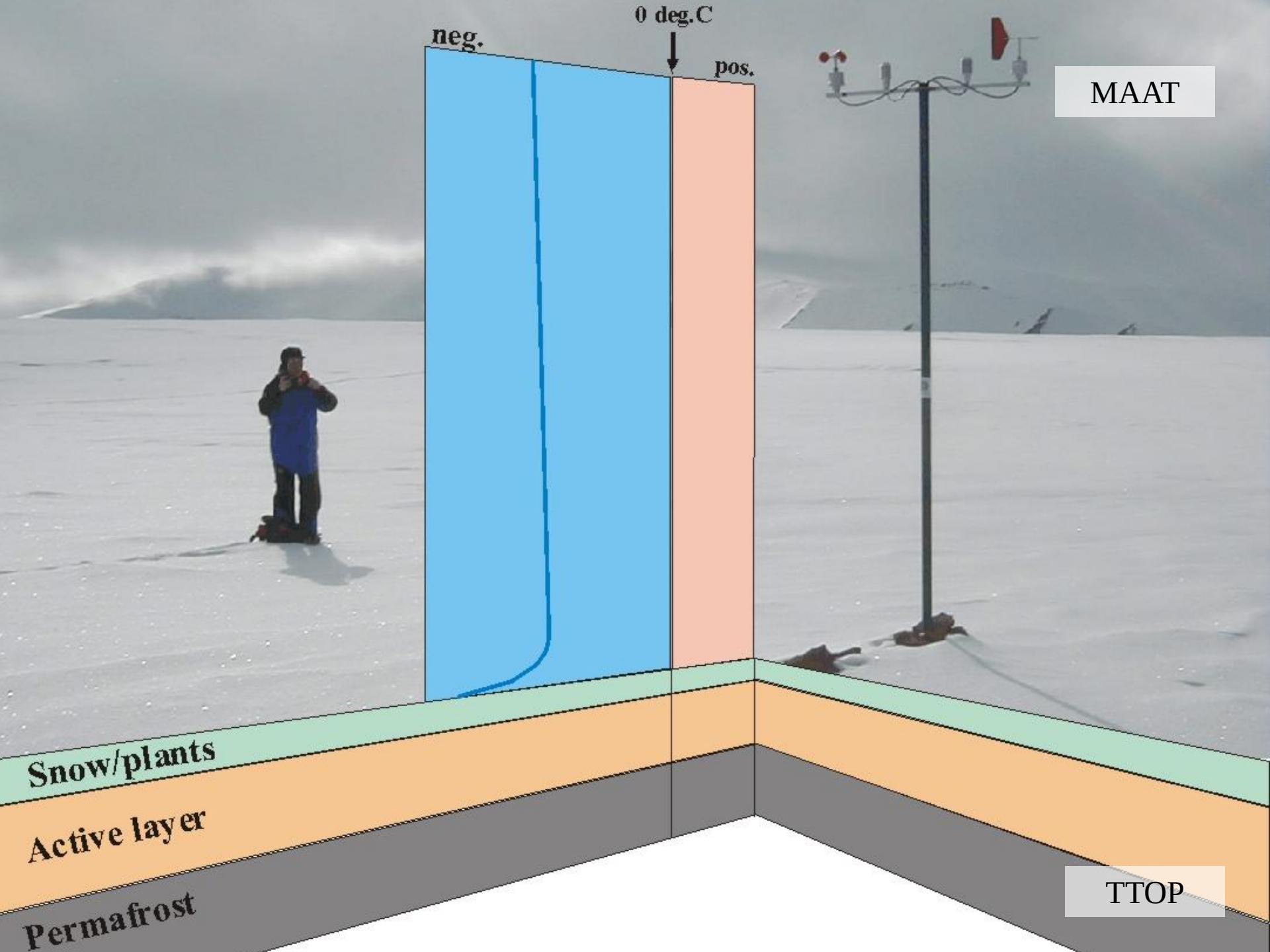

0
50000
100000
150000
200000
250000
300000
350000
400000
4
2
0
-2
-4
-6
-8
-10
Temperature change (deg.C)
Vostok ice core surface temperature
Age (yrs BP)

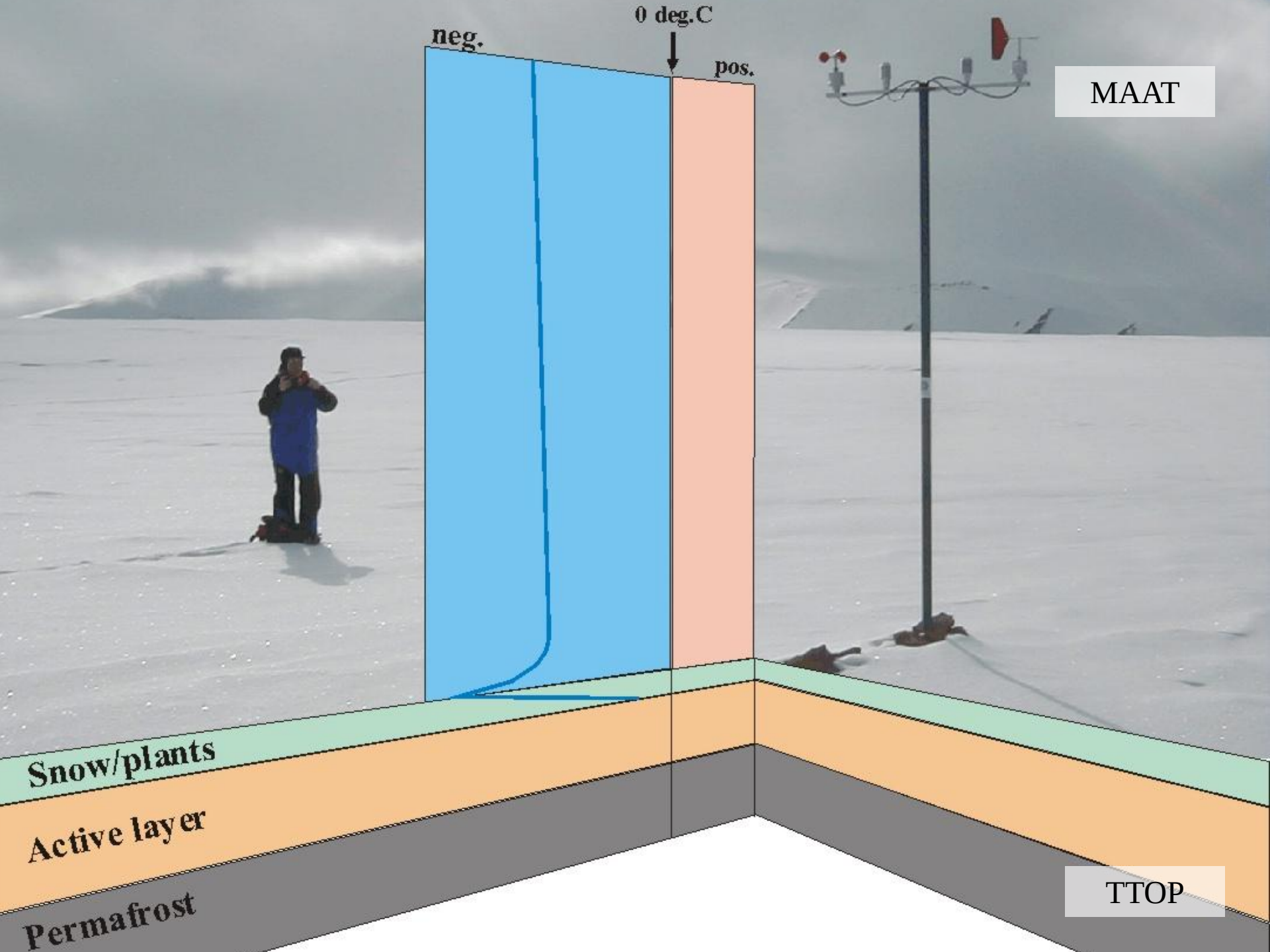

-4000
-3000
-2000
-1000
0
1000
2000
-14
-15
-16
-17
-18
-19
-20
-21
-22
-23
-24
-25
-26
Surface temperature (deg.C)
Age (BC and AD)
Neoglaciation in Greenland, Norway and Svalbard
Ice wedge growth in Svalbard
Pingo growth in Svalbard
MWP
LIA
GRIP, Greenland
Law Dome, Antarctica
MWP
LIA
Dye 3, Greenland +7C
Reconstructed surface temperatures

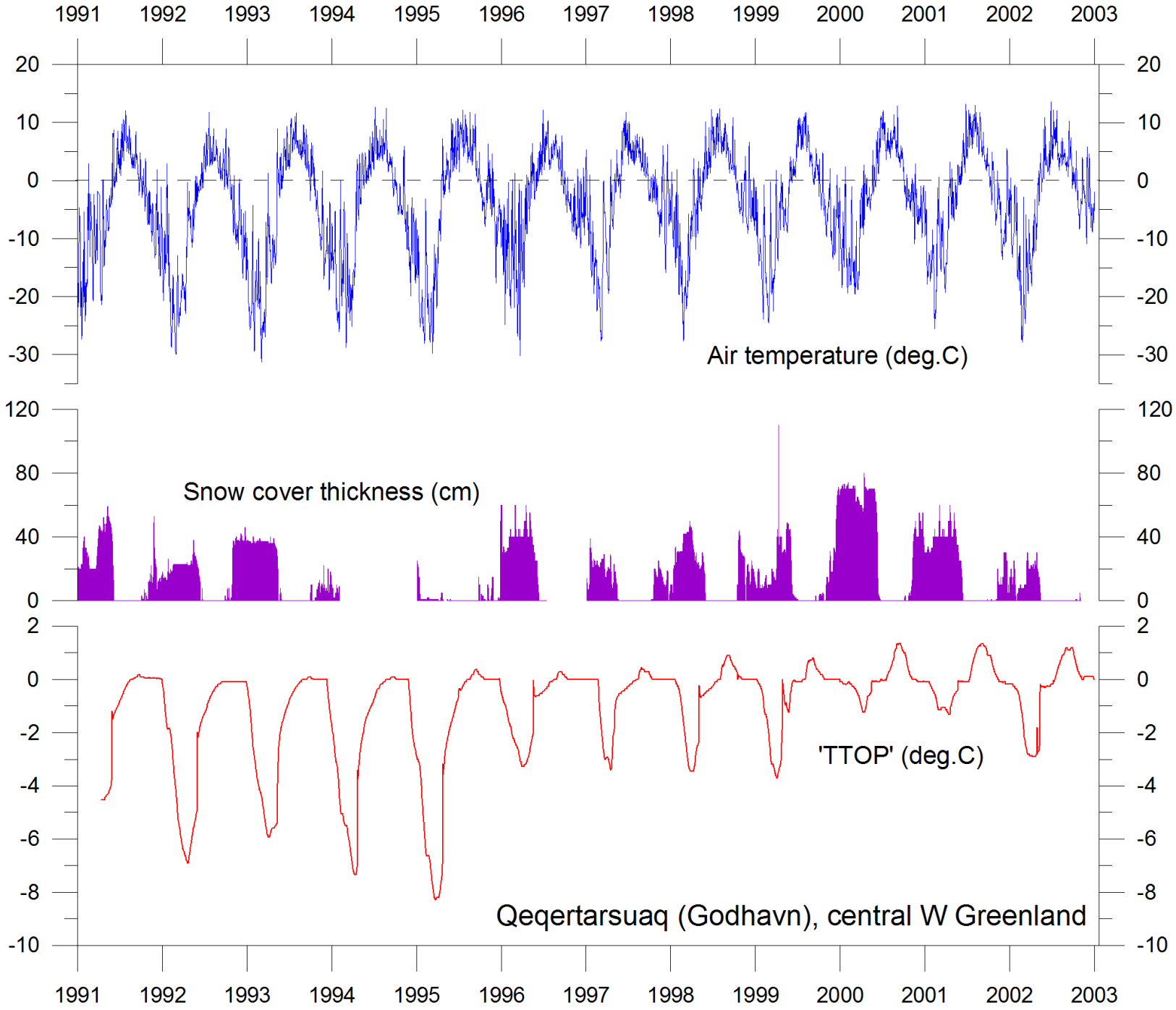
Gruvefjellet meteorological station, central Spitsbergen, Svalbard, 18th May 2002

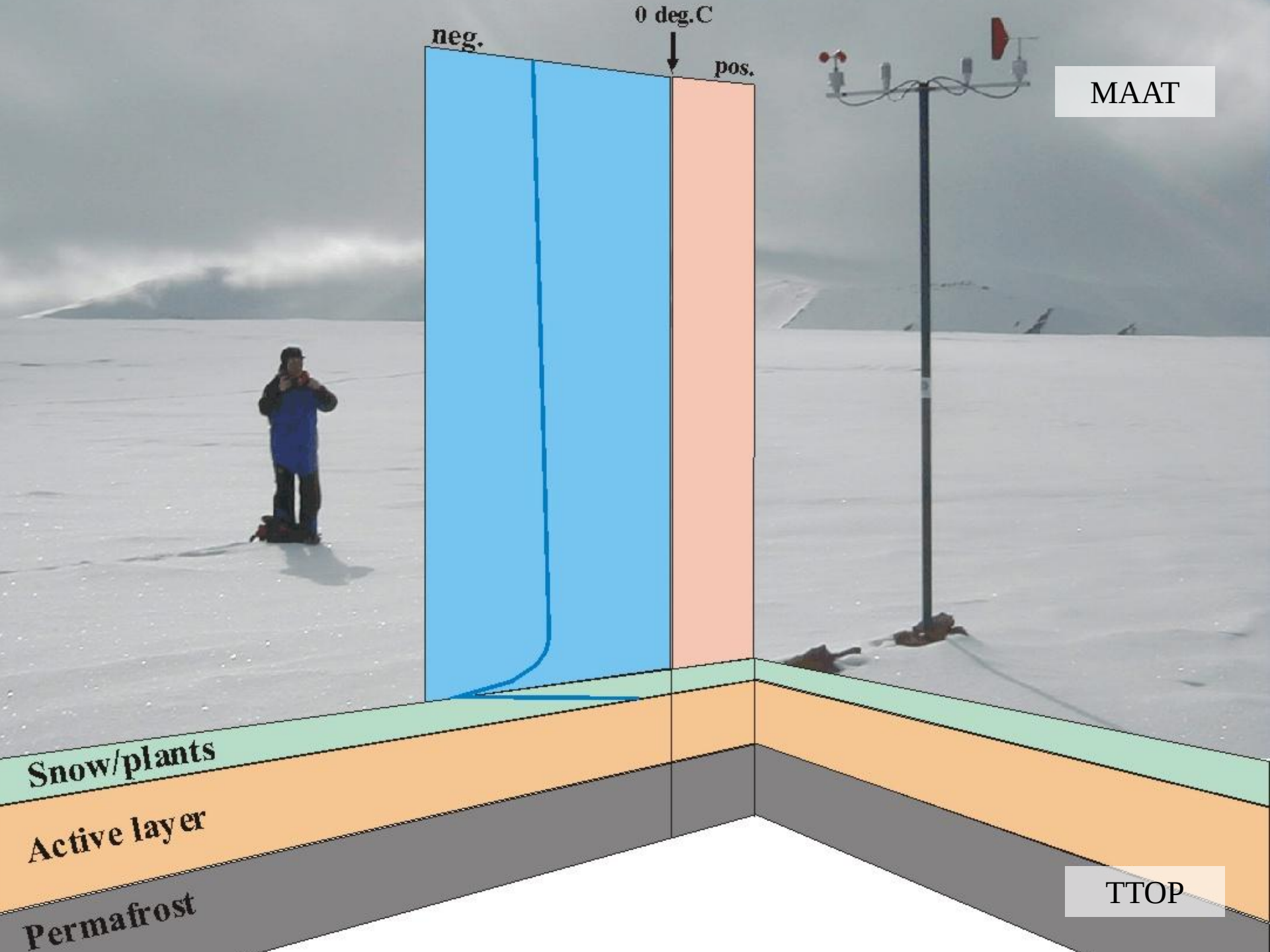

MAAT
Snow/plants
Active layer
Permafrost
TTOP

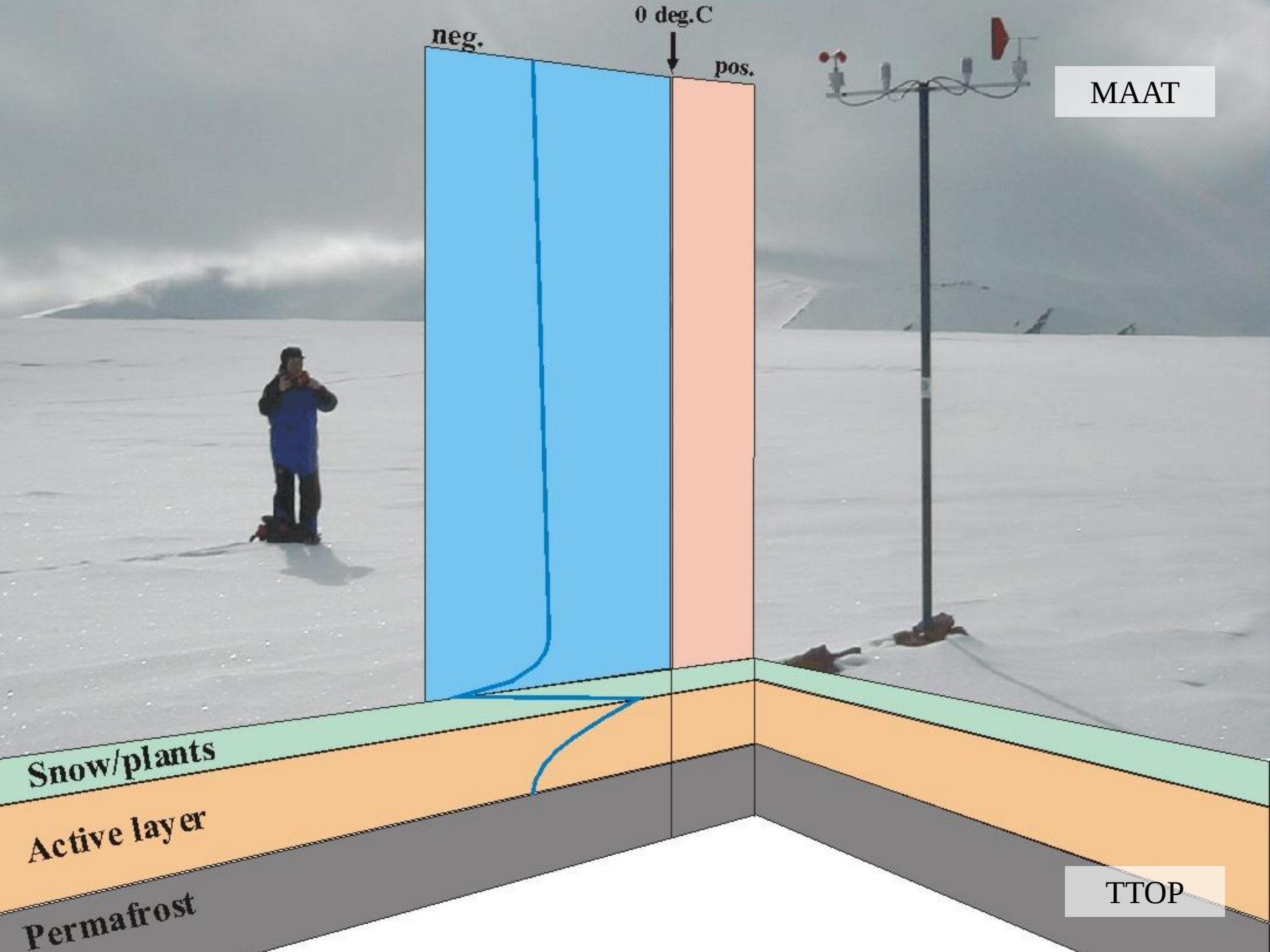

0 deg.C
neg.
pos.
MAAT
Snow/plants
Active layer
Permafrost
TTOP

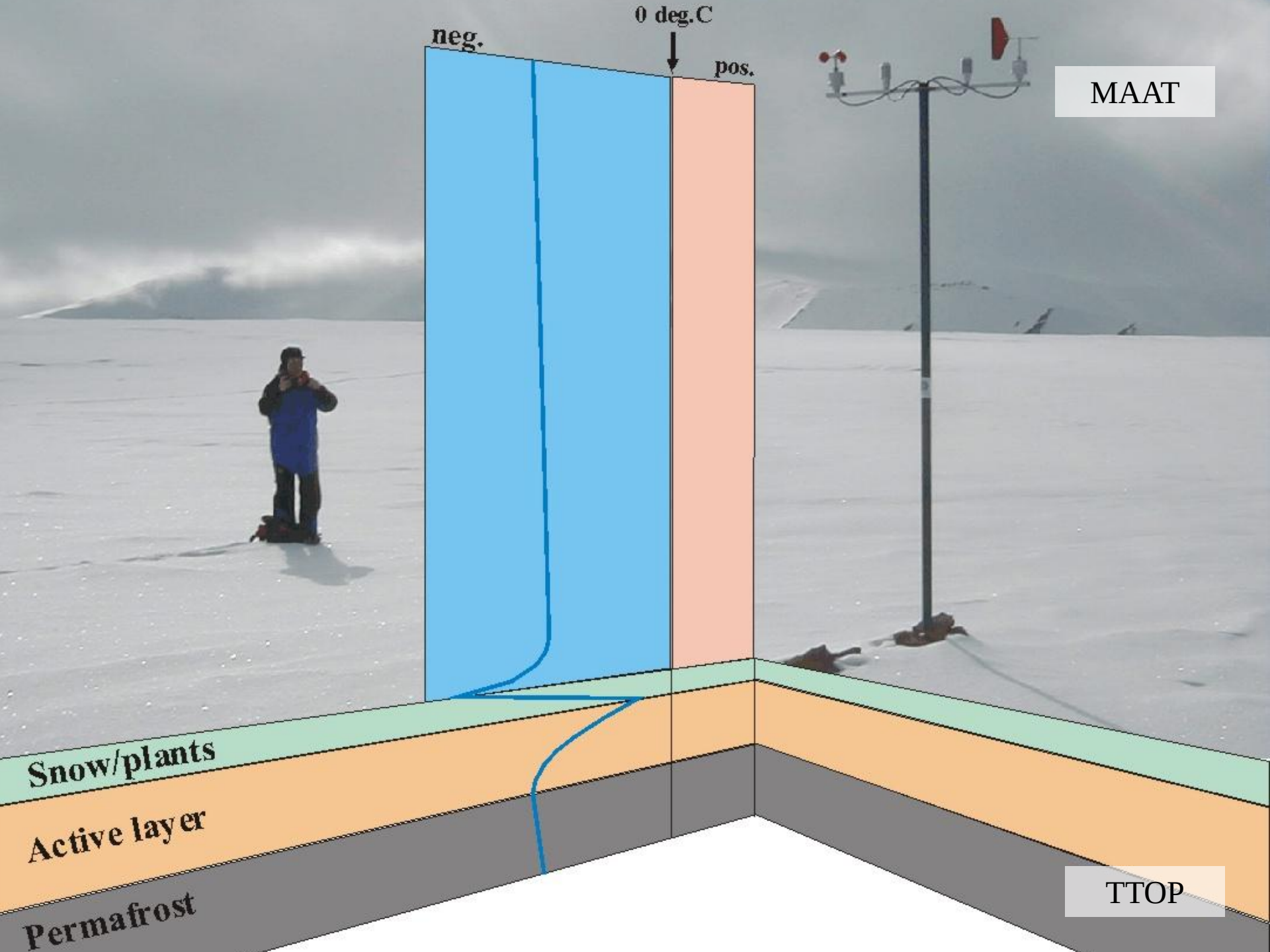

0 deg.C
neg.
pos.
MAAT
Snow/plants
Active layer
Permafrost
TTOP

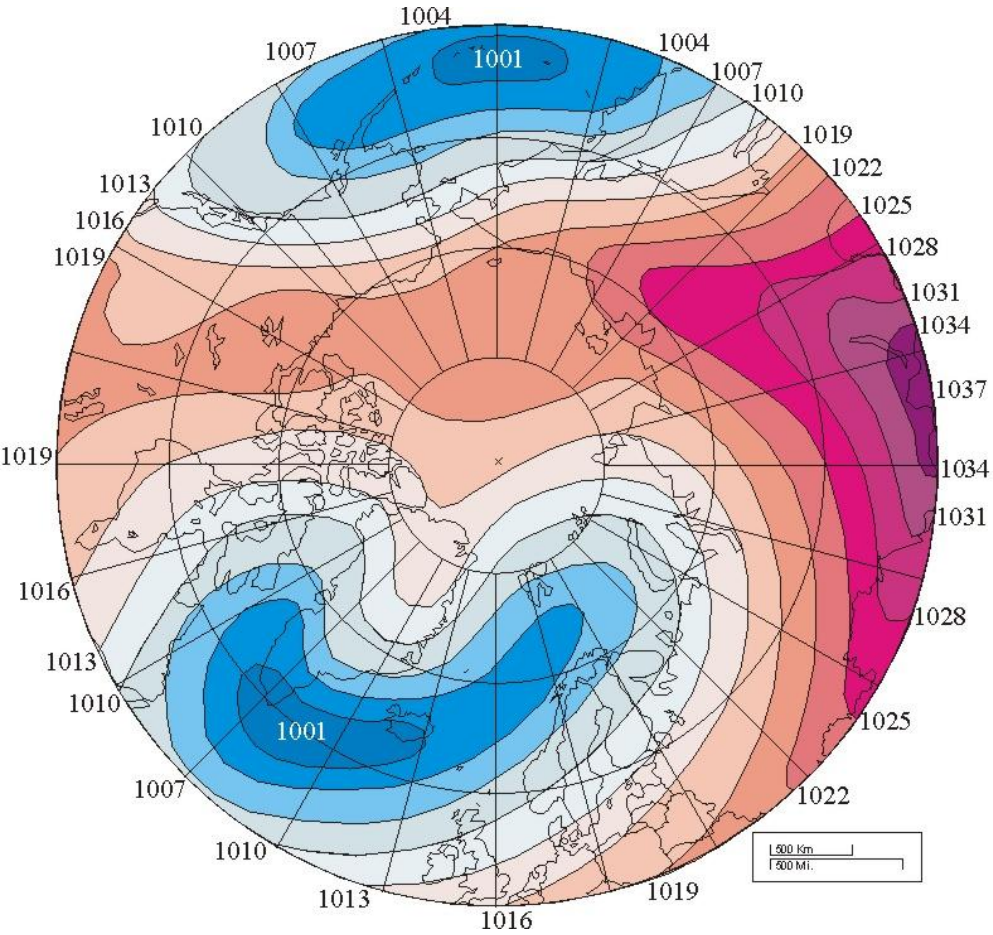

0 deg.C
neg.
pos.
MAAT
Snow/plants
Active layer
Permafrost
TTOP

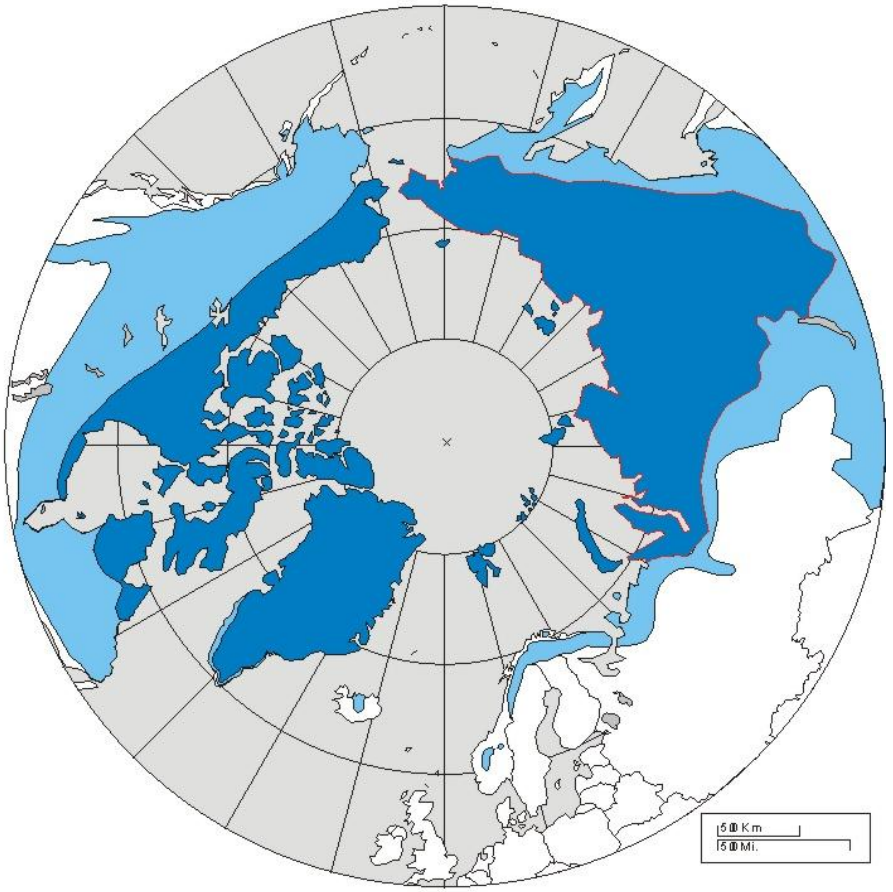

1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
20
10
0
-10
-20
-30
Air temperature (deg.C)
120
80
40
0
Snow cover thickness (cm)
2
0
-2
-4
-6
-8
-10
'TTOP' (deg.C)
Qeqertarsuaq (Godhavn), central W Greenland

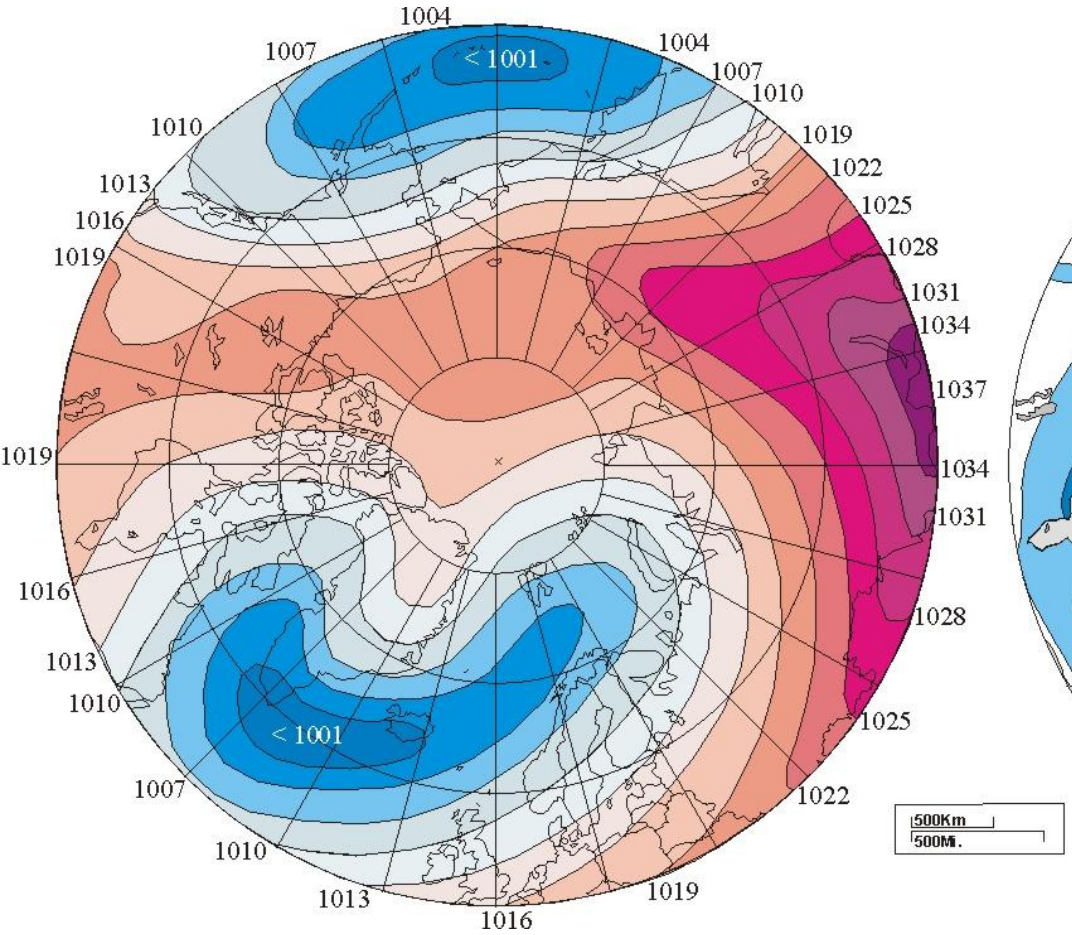

0 deg.C
neg.
pos.
MAAT
Snow/plants
Active layer
Permafrost
TTOP

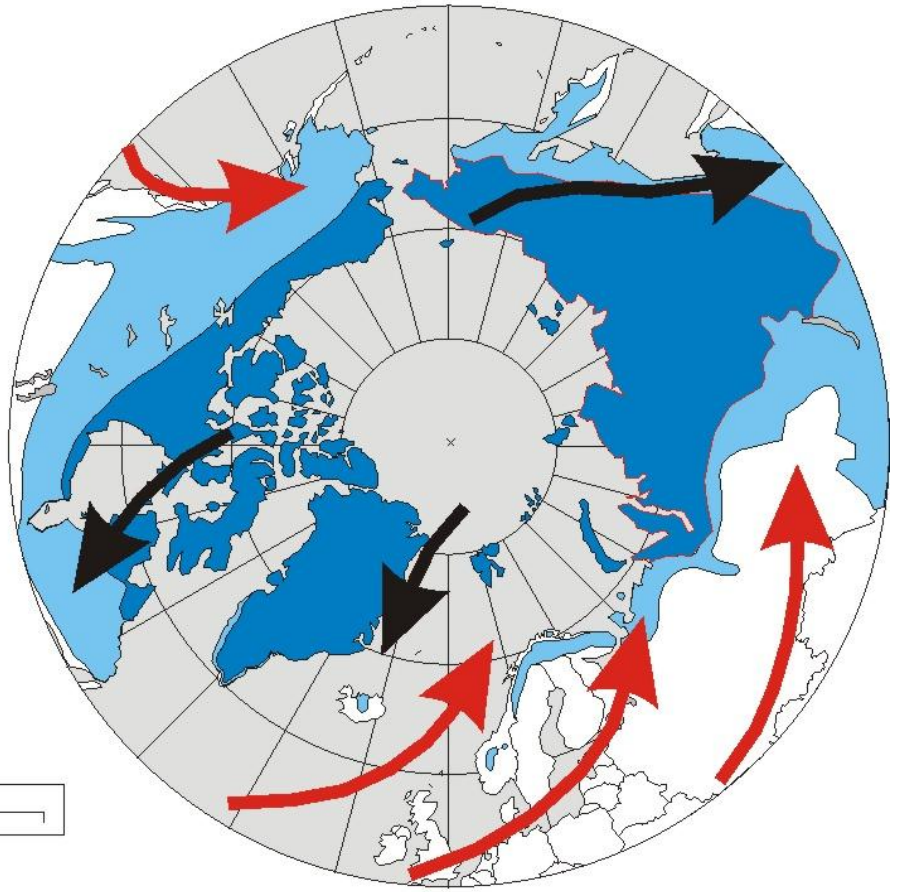

0 deg.C
neg.
pos.
MAAT
Snow/plants
Active layer
Permafrost
TTOP

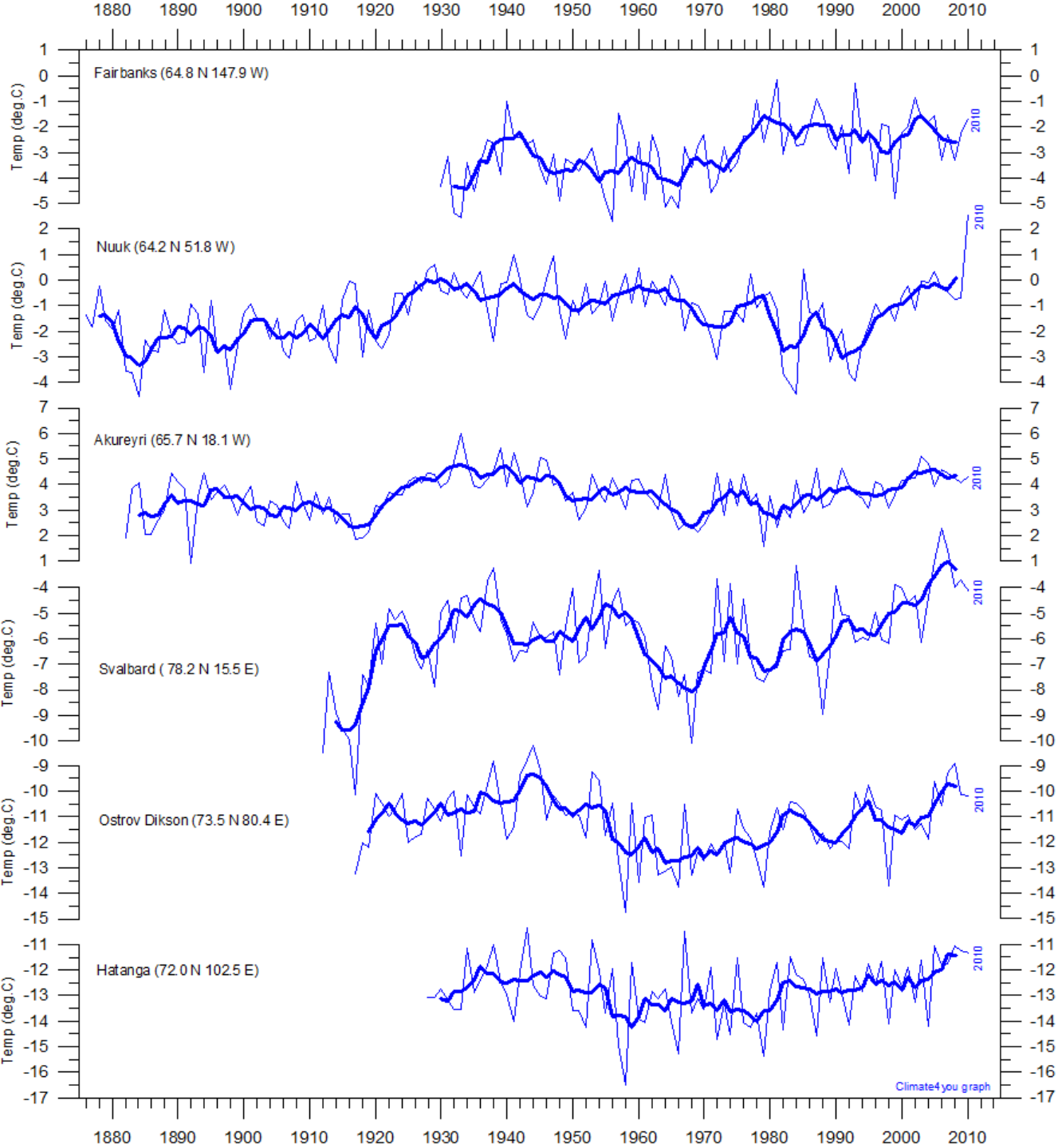

0 deg.C
neg.
pos.
MAAT
Snow/plants
Active layer
Permafrost
TTOP


1004
1007
1001
1004
1007
1010
1010
1019
1022
1013
1025
1016
1028
1019
1031
1034
1037
1019
1034
1031
1016
1028
1013
1010
1025
1001
1022
1007
1010
1013
1019
1016
500 Km
500 Mi.


500 Km
500 Mi.

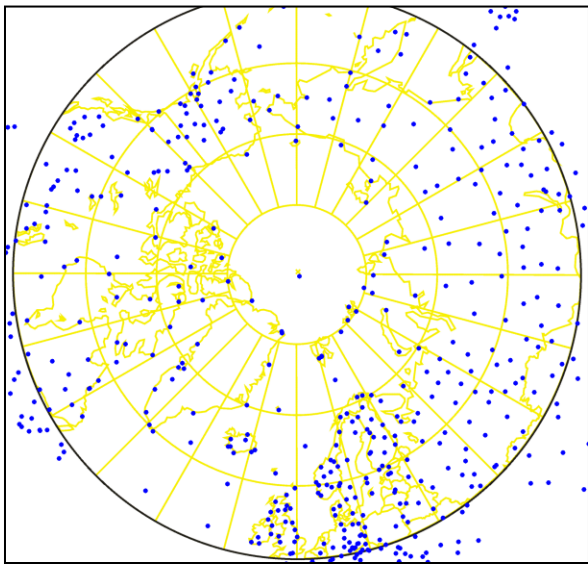

1004
1007
< 1001
1004
1007
1010
1010
1019
1022
1013
1025
1016
1028
1019
1031
1034
1037
1019
1034
1031
1016
1028
1013
1025
1010
< 1001
1022
1007
1010
1013
1019
1016
500Km
500Mi.



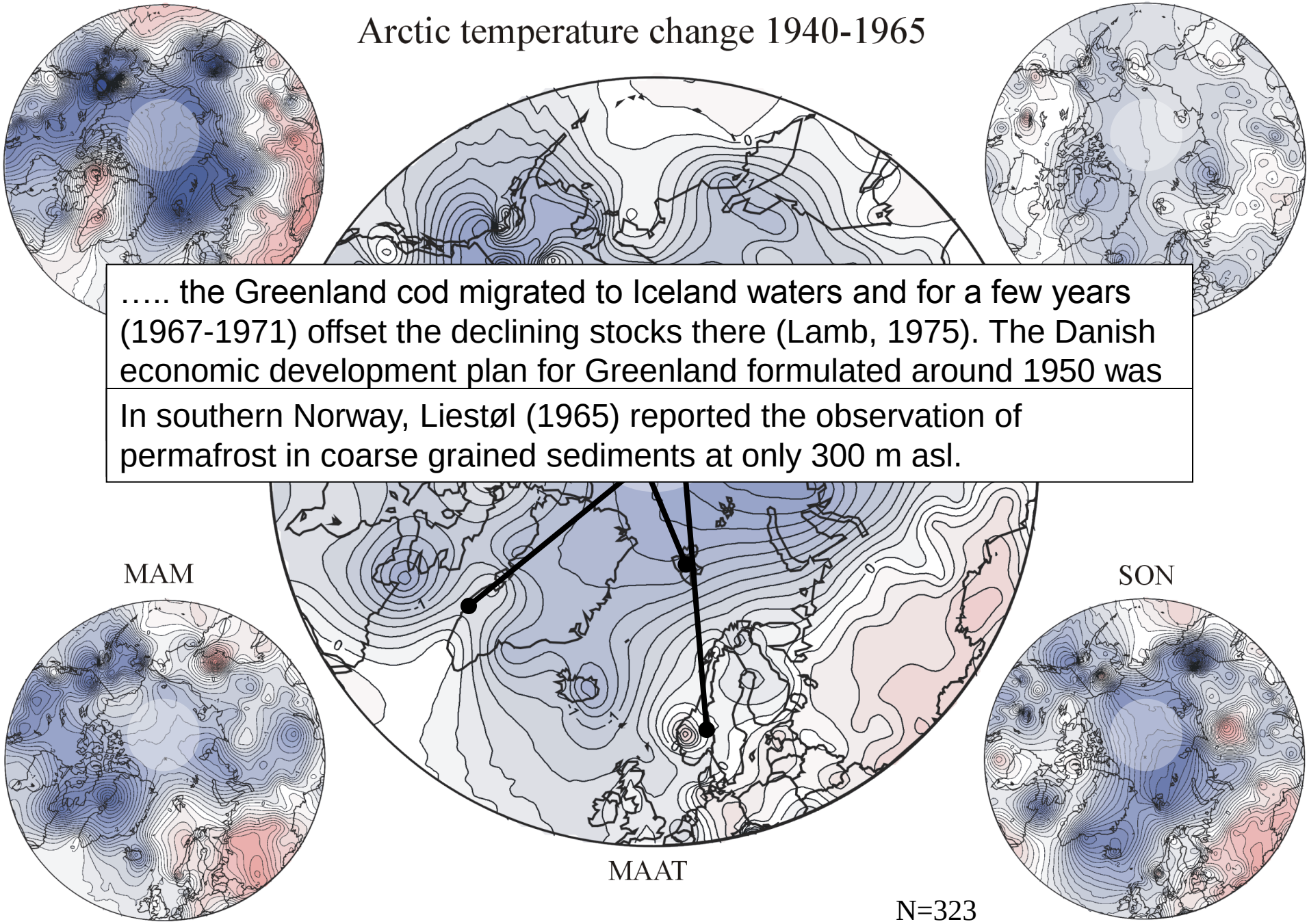


Meteorological stations

N=546



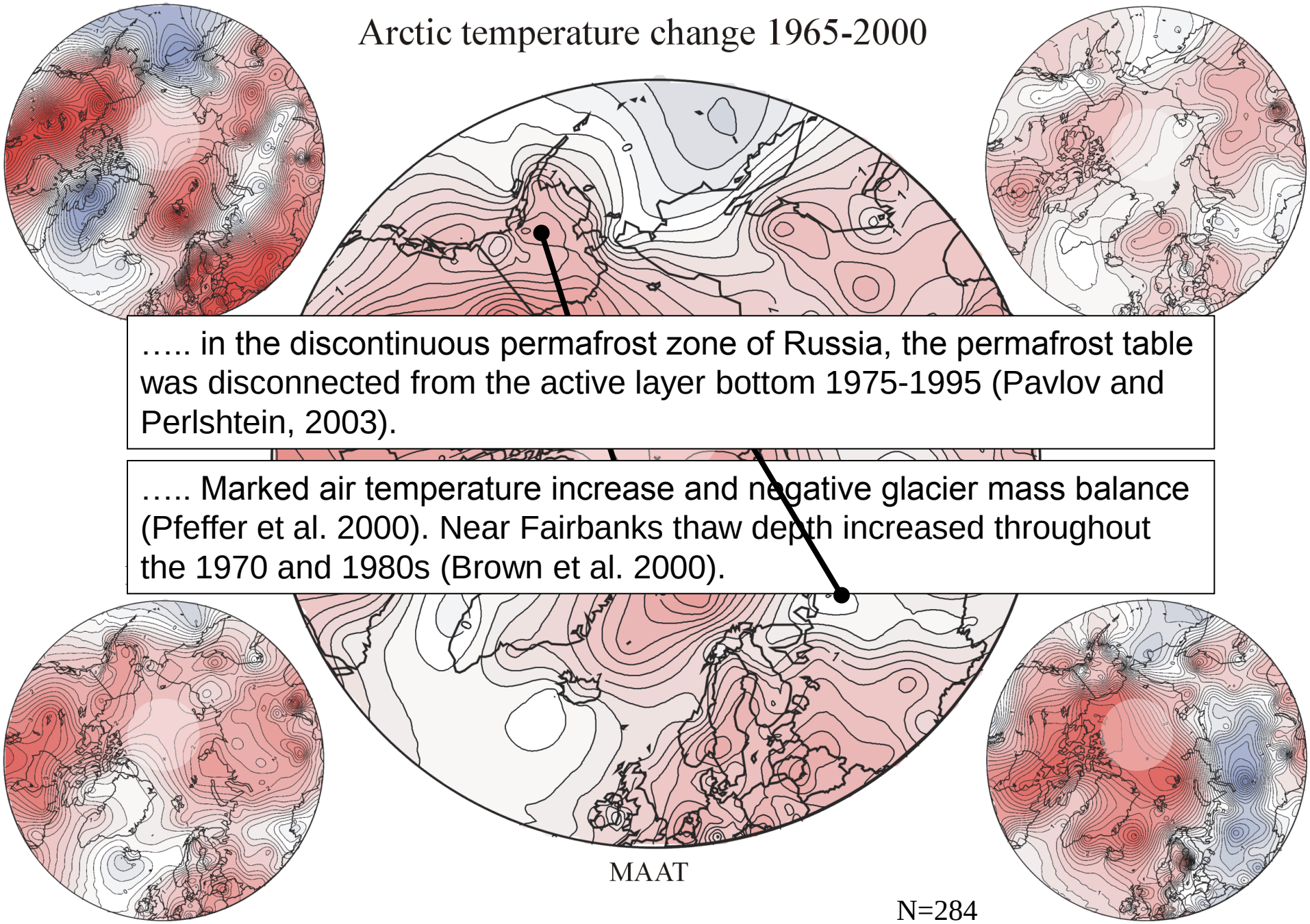
Arctic temperature change 1940-1965



….. the Greenland cod migrated to Iceland waters and for a few years (1967-1971) offset the declining stocks there (Lamb, 1975). The Danish economic development plan for Greenland formulated around 1950 was

In southern Norway, Liestøl (1965) reported the observation of permafrost in coarse grained sediments at only 300 m asl.

Arctic temperature change 1965-2000



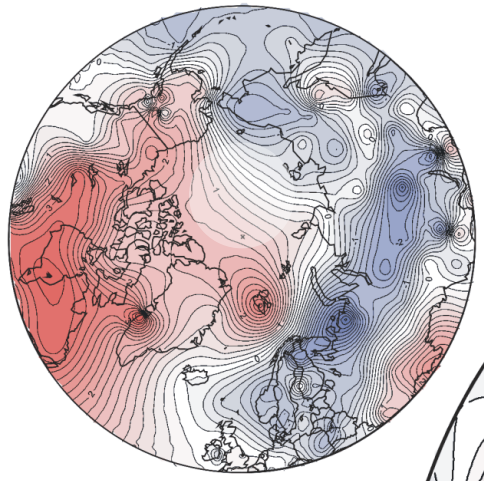
….. in the discontinuous permafrost zone of Russia, the permafrost table was disconnected from the active layer bottom 1975-1995 (Pavlov and Perlshtein, 2003).

….. Marked air temperature increase and negative glacier mass balance (Pfeffer et al. 2000). Near Fairbanks thaw depth increased throughout the 1970 and 1980s (Brown et al. 2000).

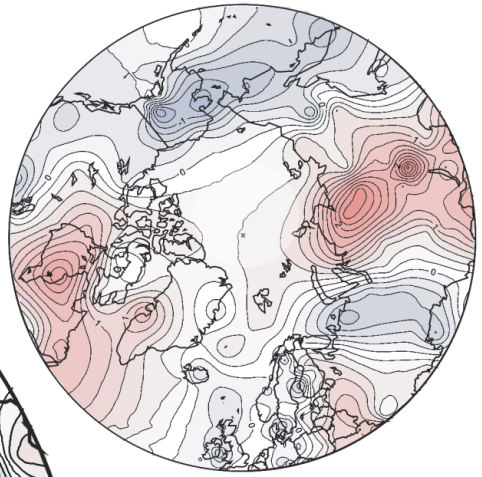
MAAT

N=284

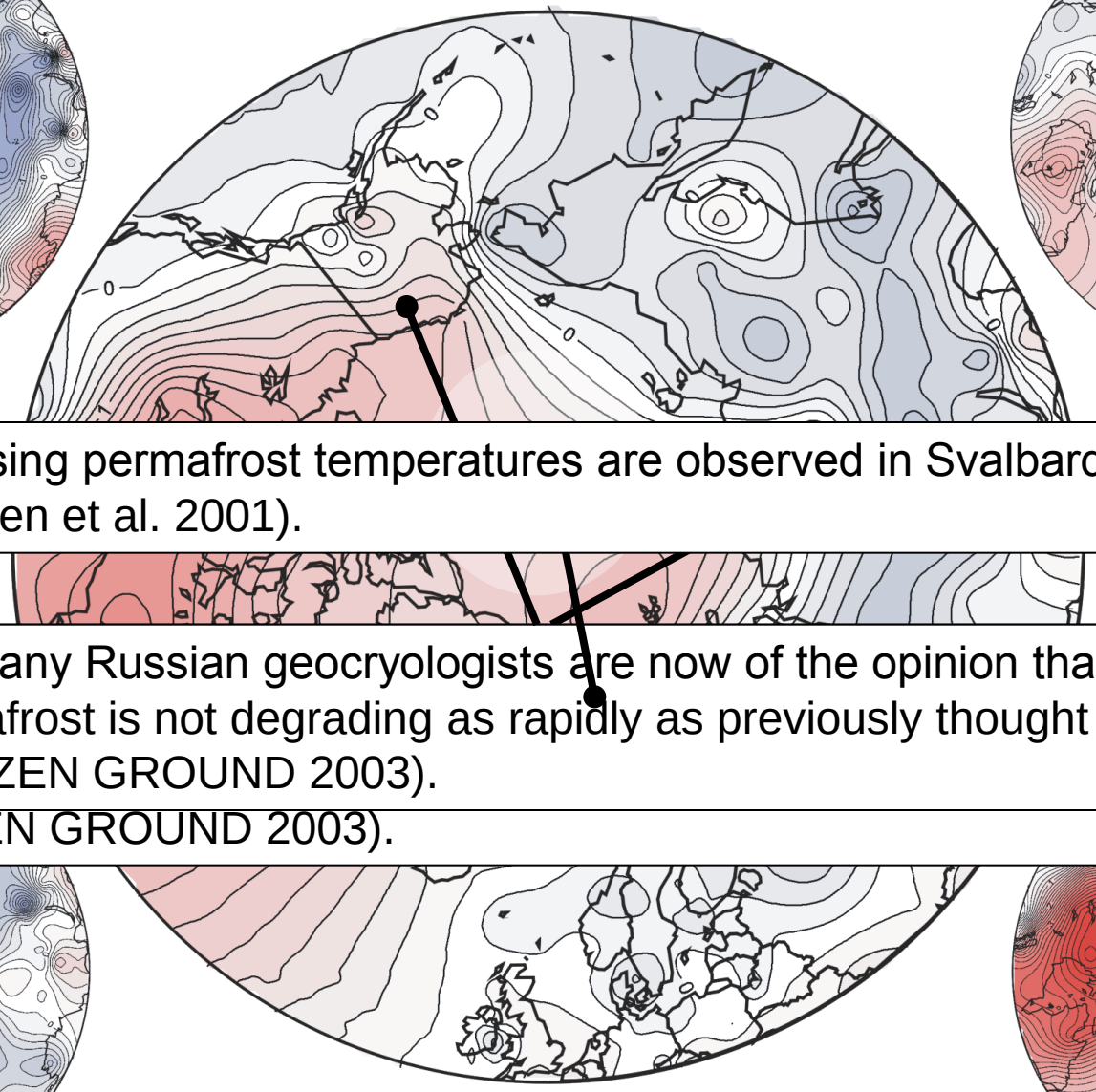
Arctic temperature change 1990-2000



DJF



JJA

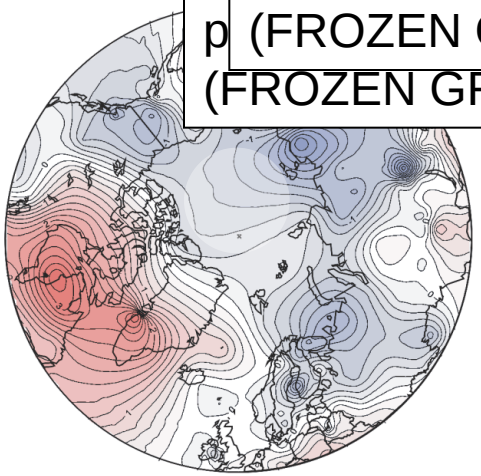


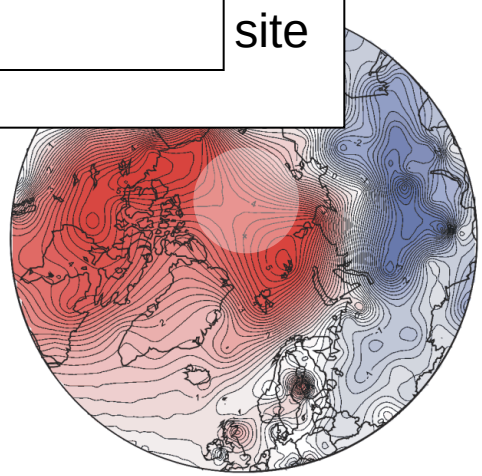
N=287

….. rising permafrost temperatures are observed in Svalbard (Isaksen et al. 2001).

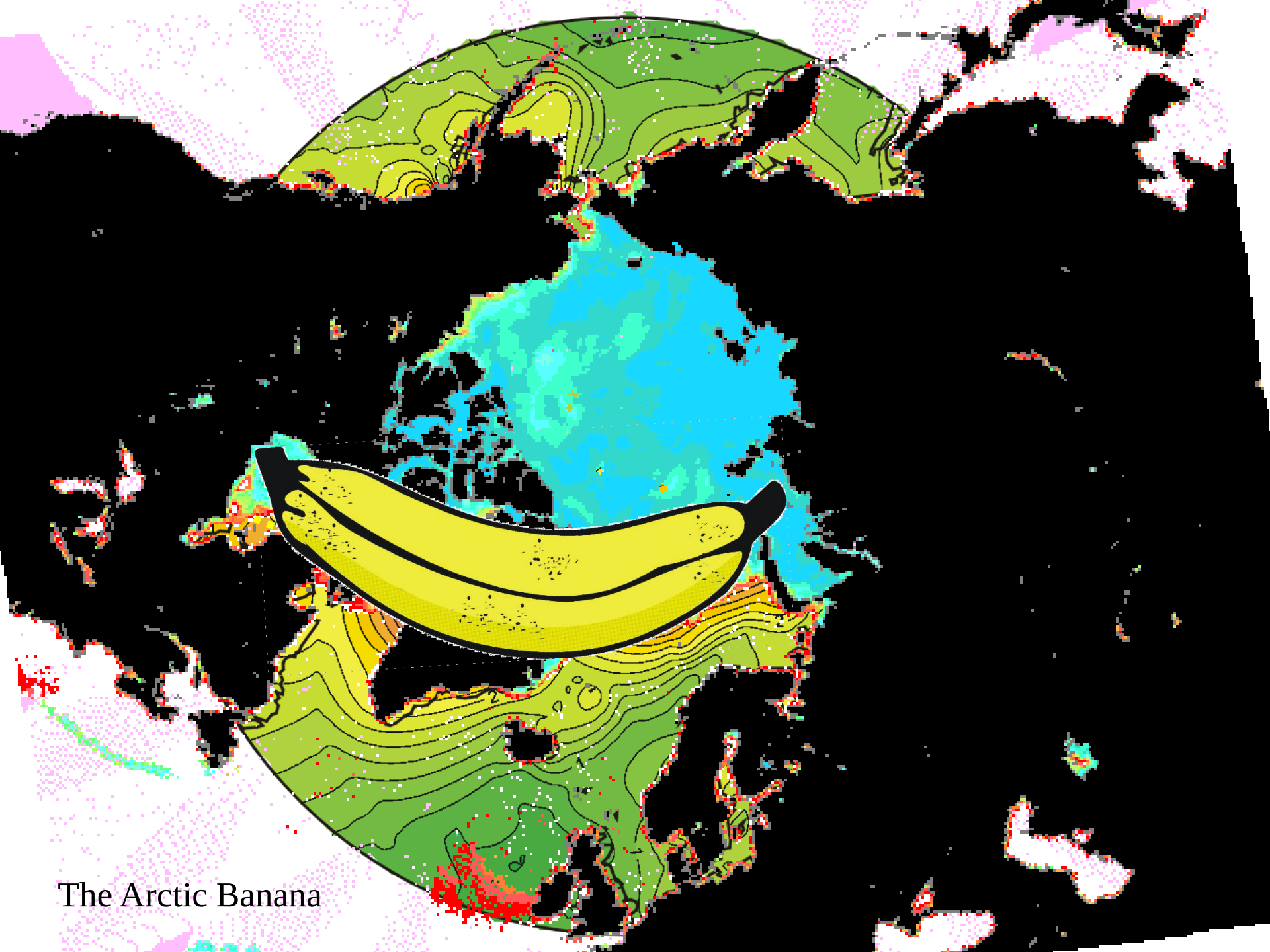
….. Many Russian geocryologists are now of the opinion that permafrost is not degrading as rapidly as previously thought (FROZEN GROUND 2003).

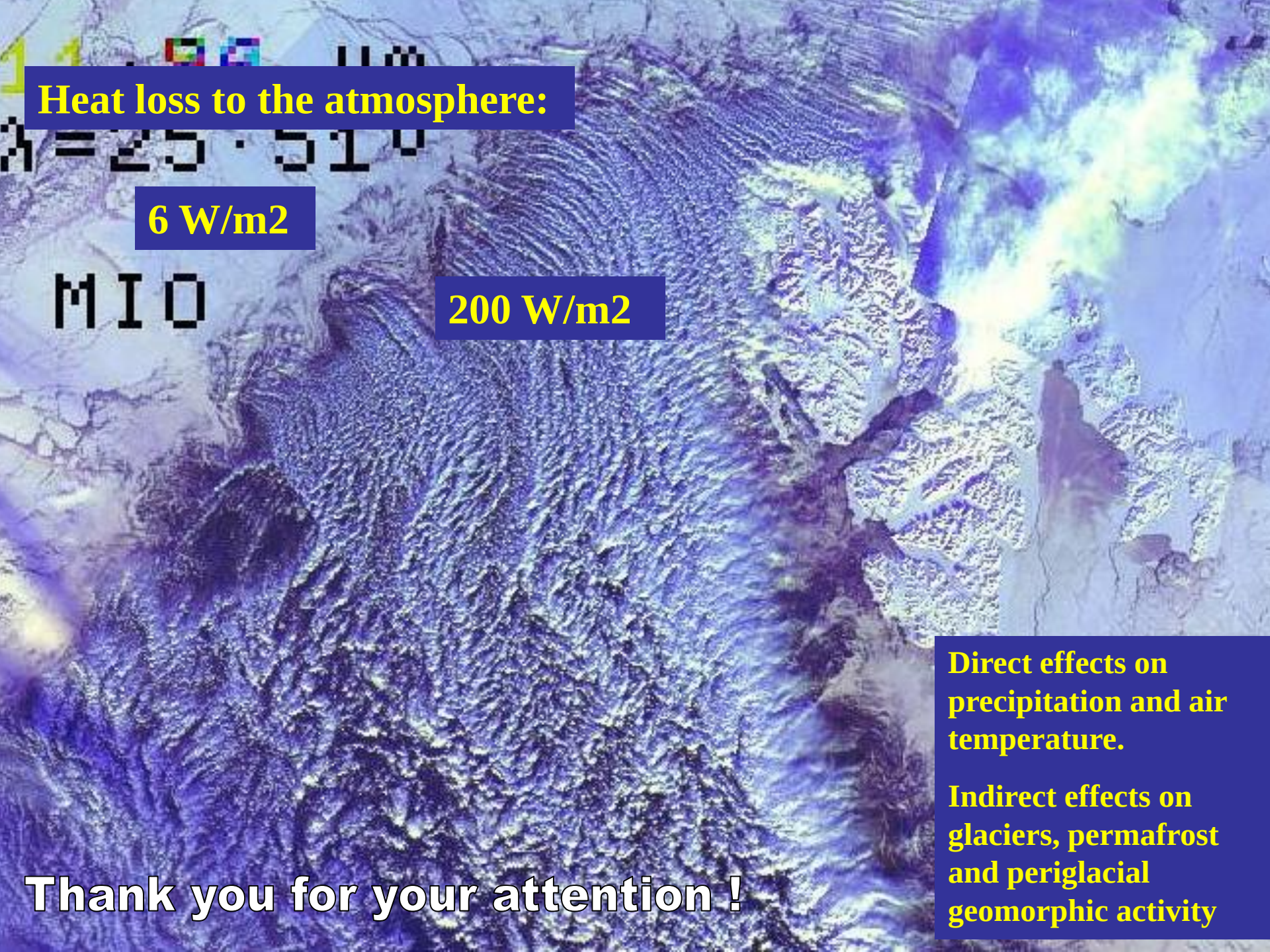
… e in
m
p site
(FROZEN GROUND 2003).





REGIONAL CHANGES IMPORTANT

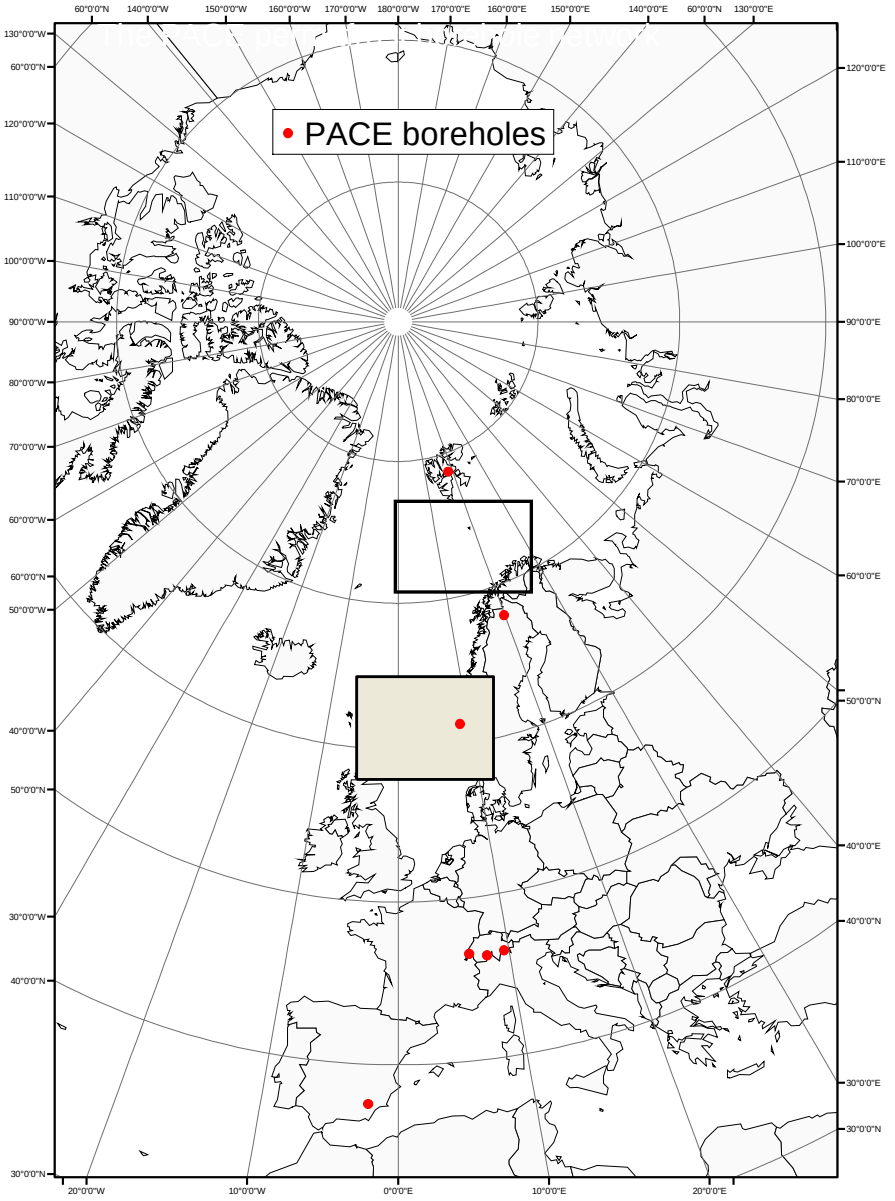

The Arctic Banana

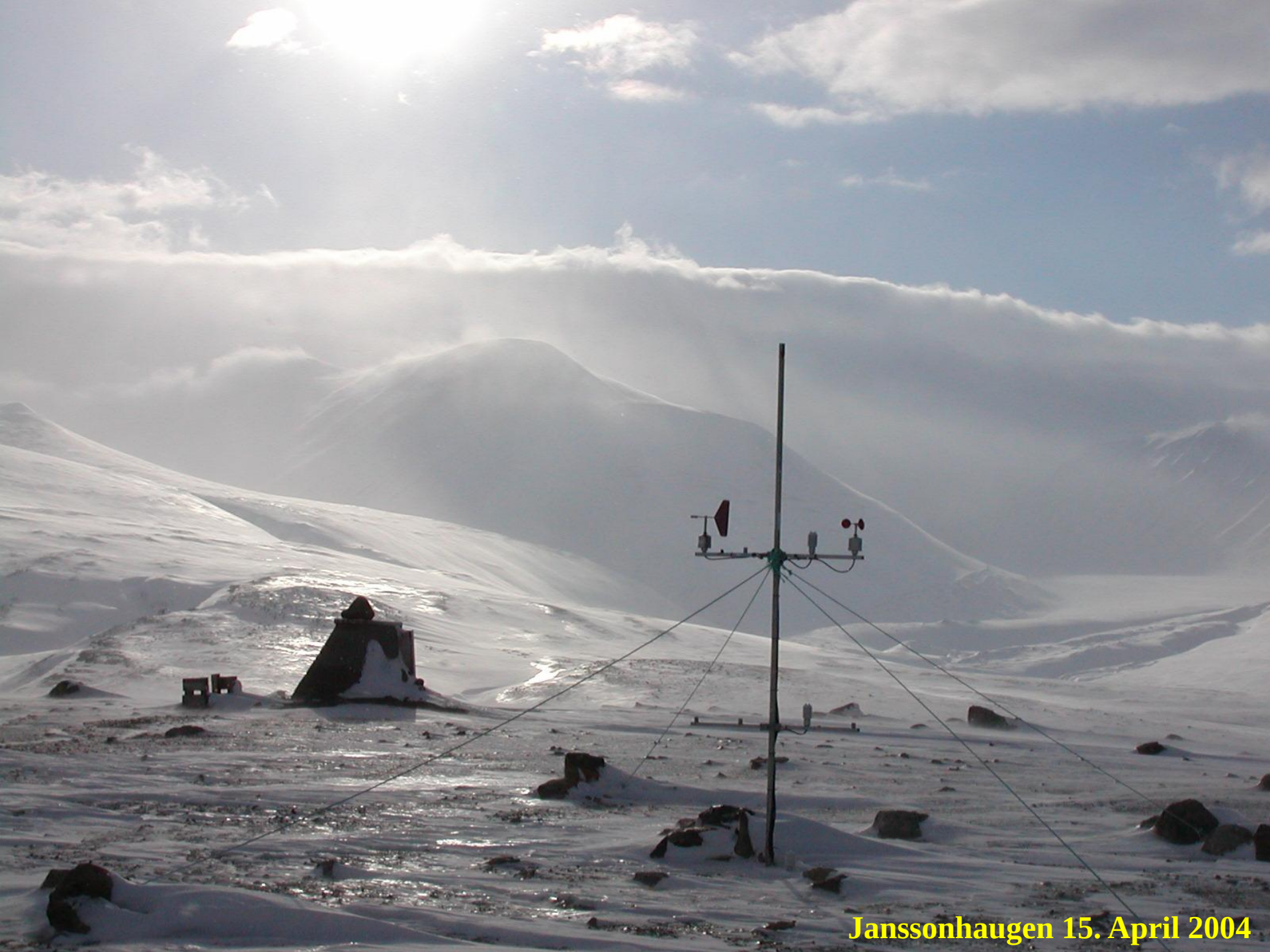

Heat loss to the atmosphere:
6 W/m2
200 W/m2
Direct effects on precipitation and air temperature.
Indirect effects on glaciers, permafrost and periglacial geomorphic activity
Thank you for your attention !

PACE21

EUROPEAN
SCIENCE FOUNDATION

- Contributes to GTN-P (Global Terrestrial Network for Permafrost) under GCOS (Global Climate Observing System)




Janssonhaugen 15. April 2004