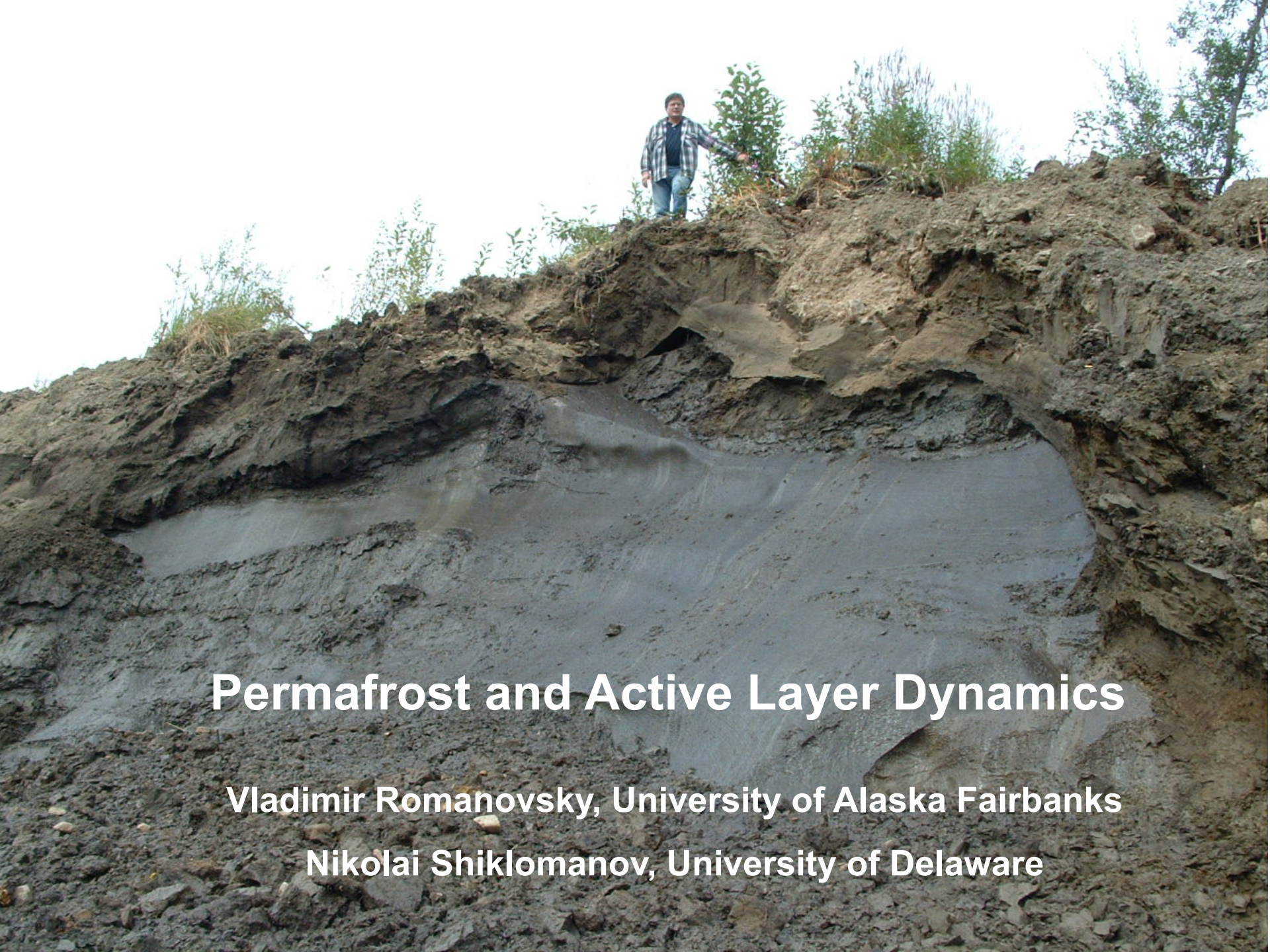


Permafrost and Active Layer Dynamics

Vladimir Romanovsky, University of Alaska Fairbanks

Nikolai Shiklomanov, University of Delaware

Database boreholes: Global Terrestrial Network-Permafrost (GTN-P)

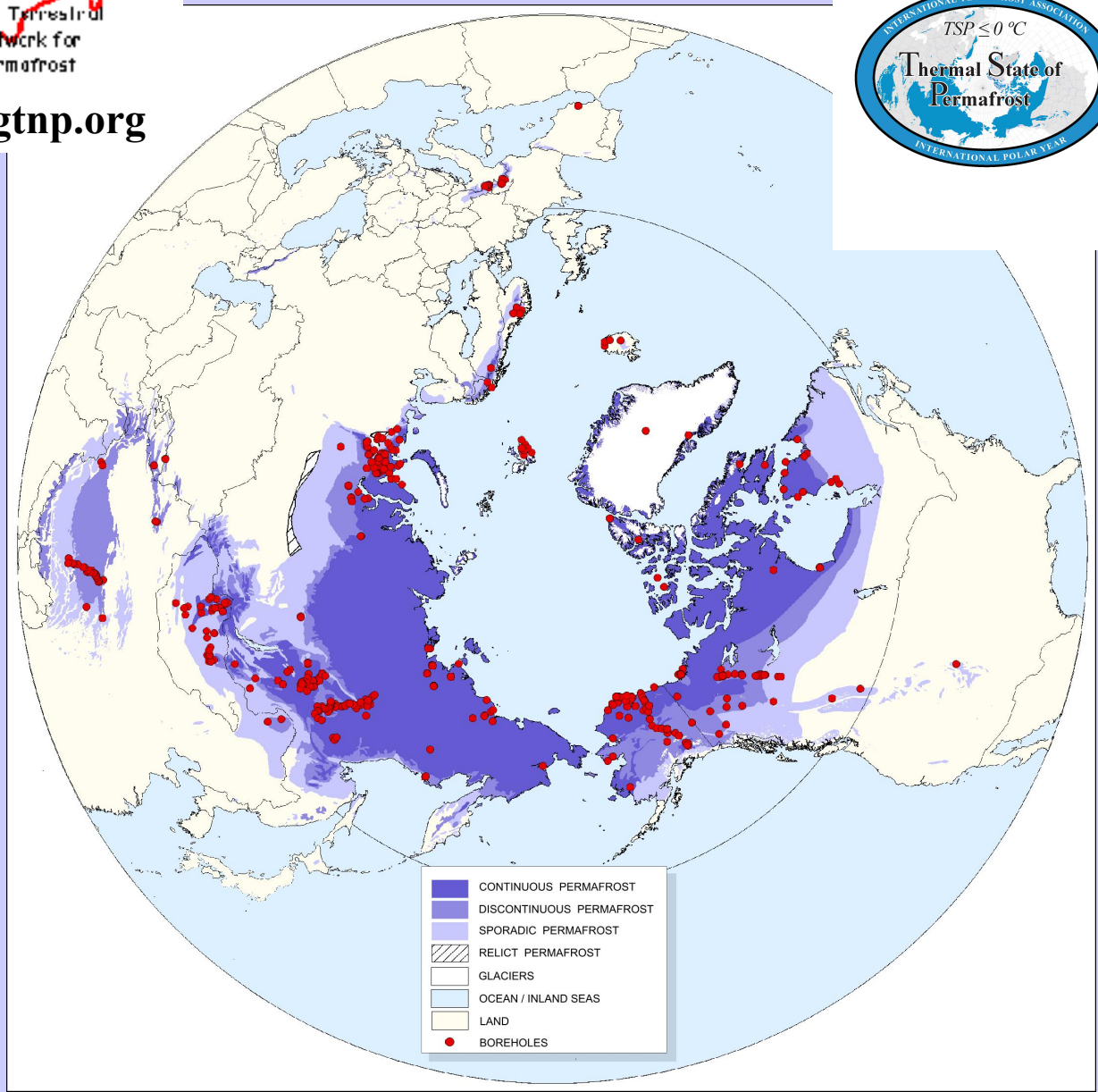
GTN-P
Global Terrestrial Network for Permafrost

www.gtnp.org

TSP ≤ 0 °C
Thermal State of Permafrost

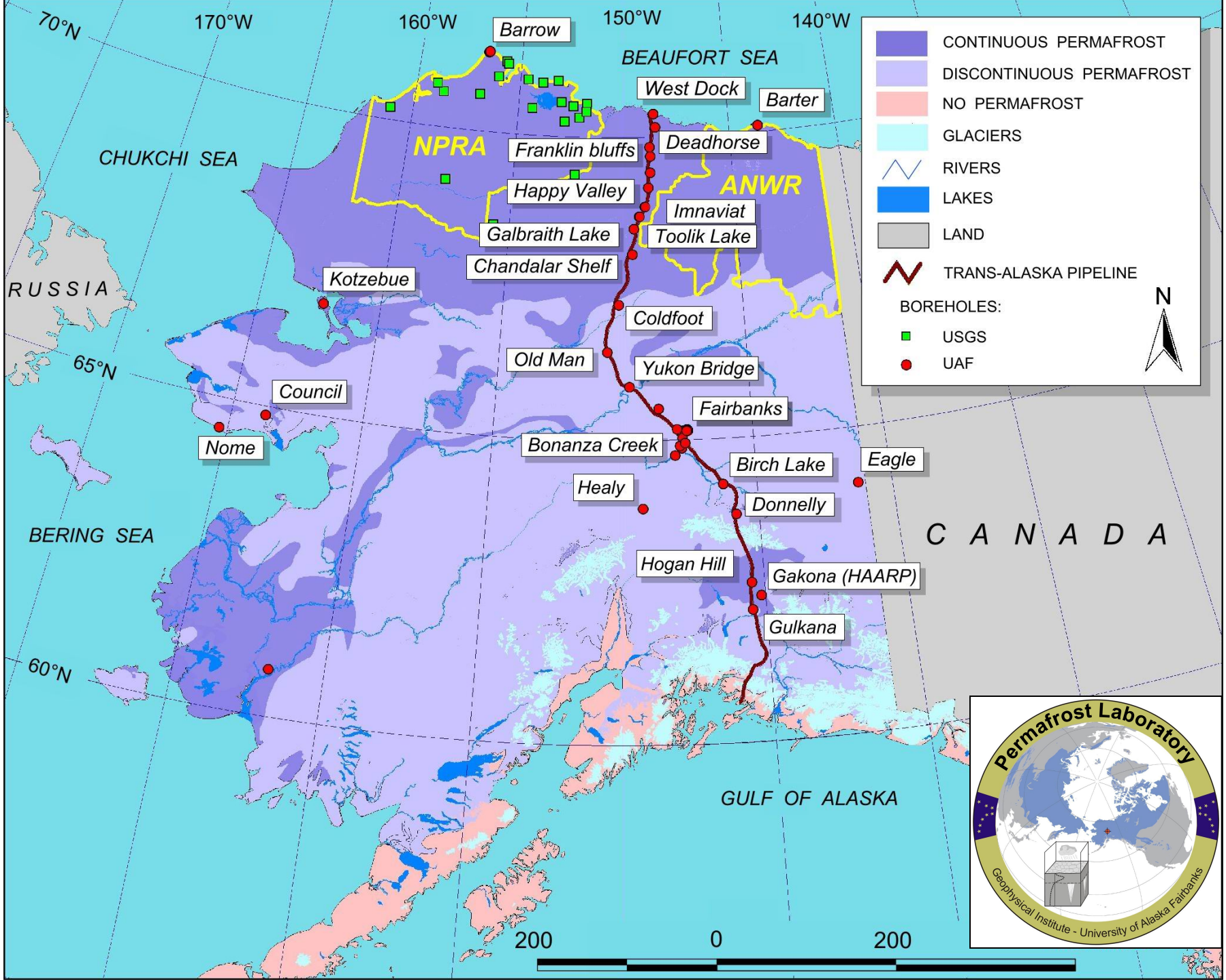
TSP Countries
Canada
China
Denmark (Greenland)
Germany (Russia)
Iceland
Italy
Kazakhstan
Mongolia
Norway (NORPERM)
Poland
Russia
Sweden
Switzerland (PERMOS)
USA

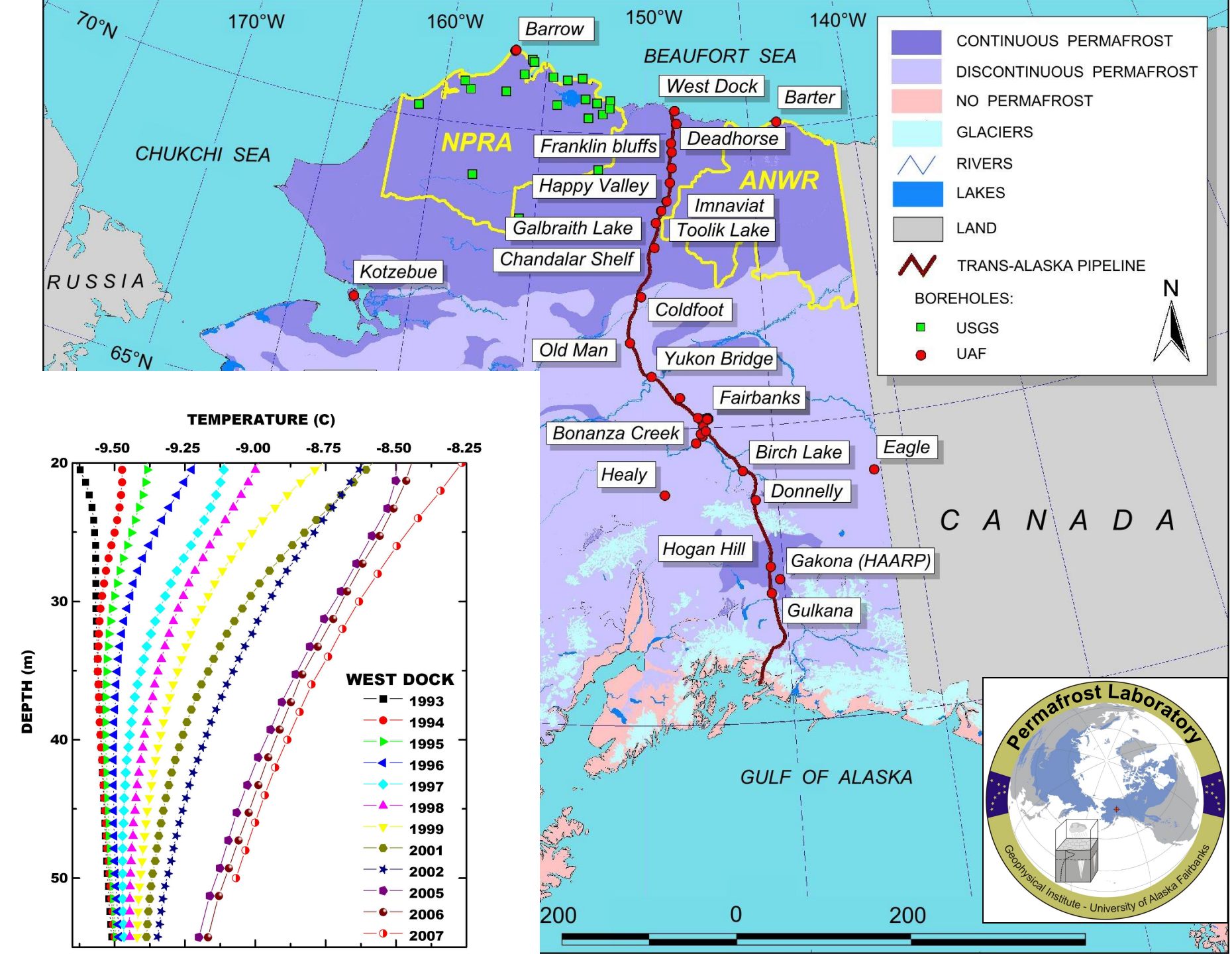
Southern Hemisphere
Italy
New Zealand
Portugal-Spain
Russia
USA

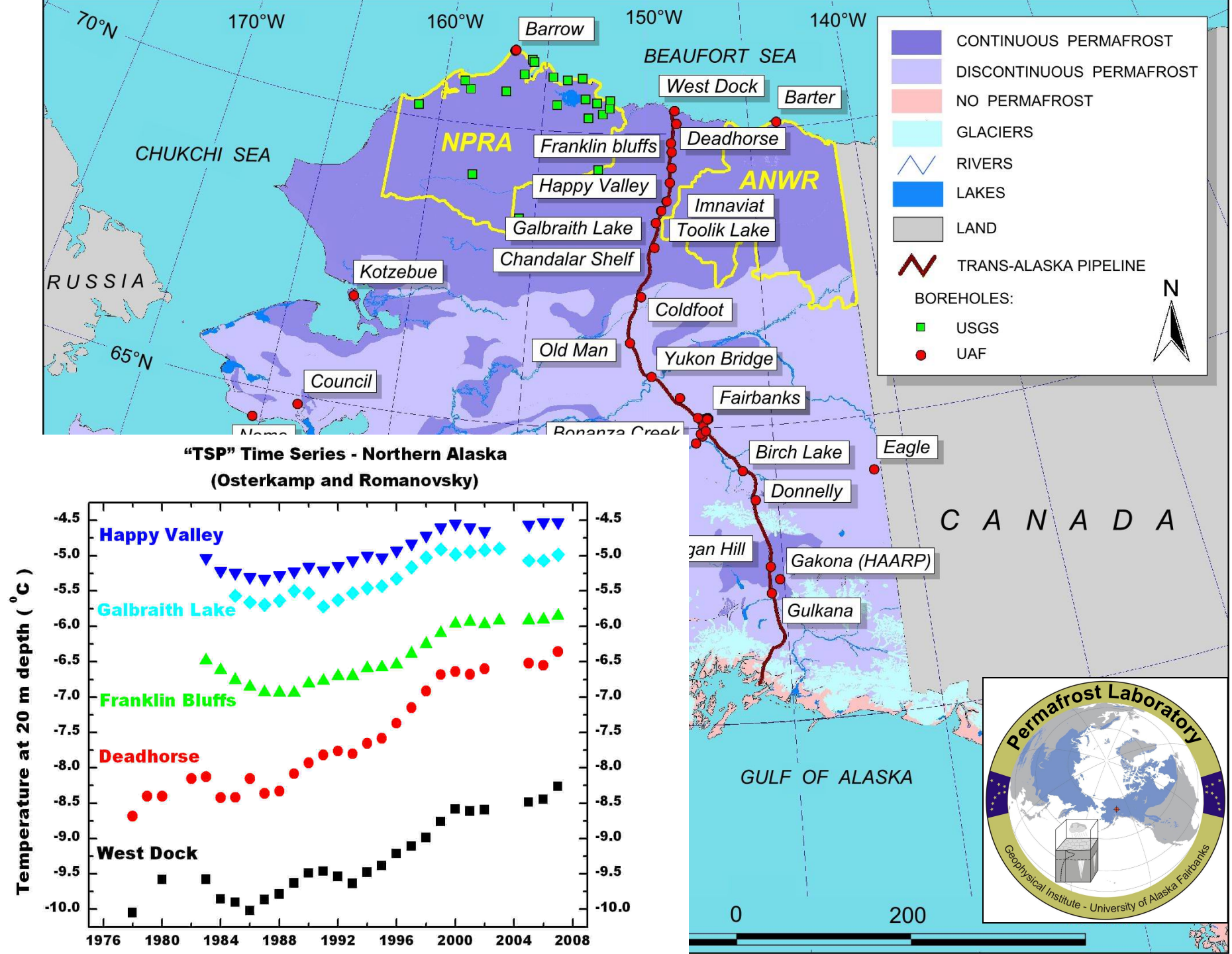


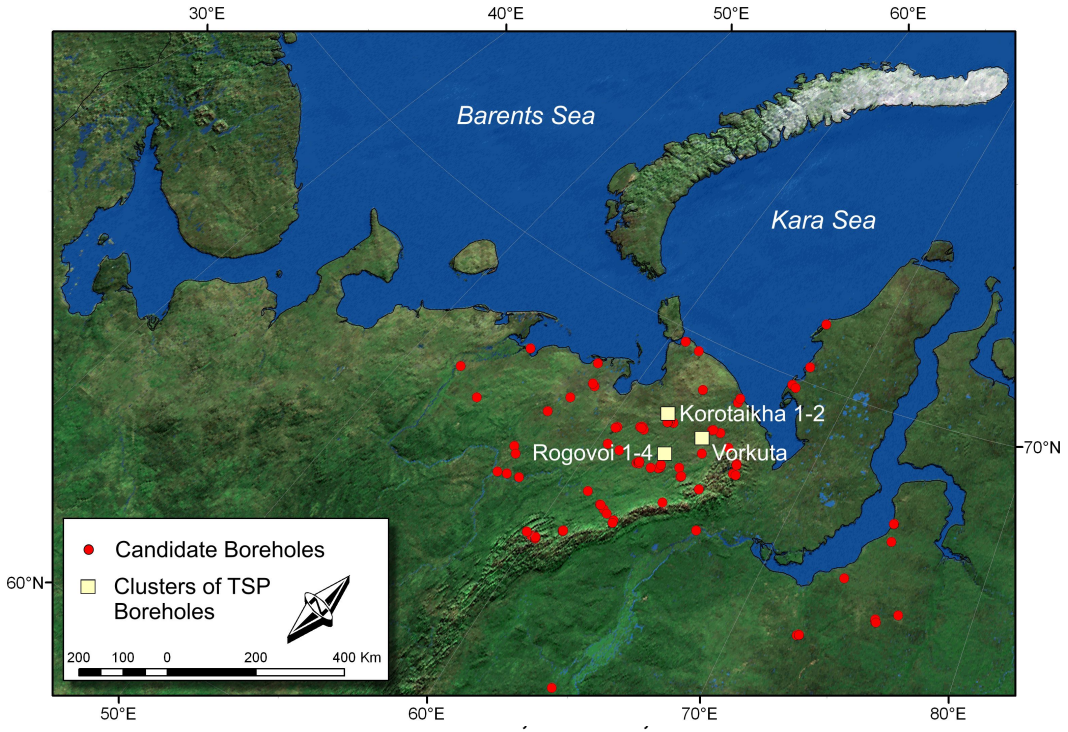
Recent (last 20 to 30 years) Trends in Permafrost

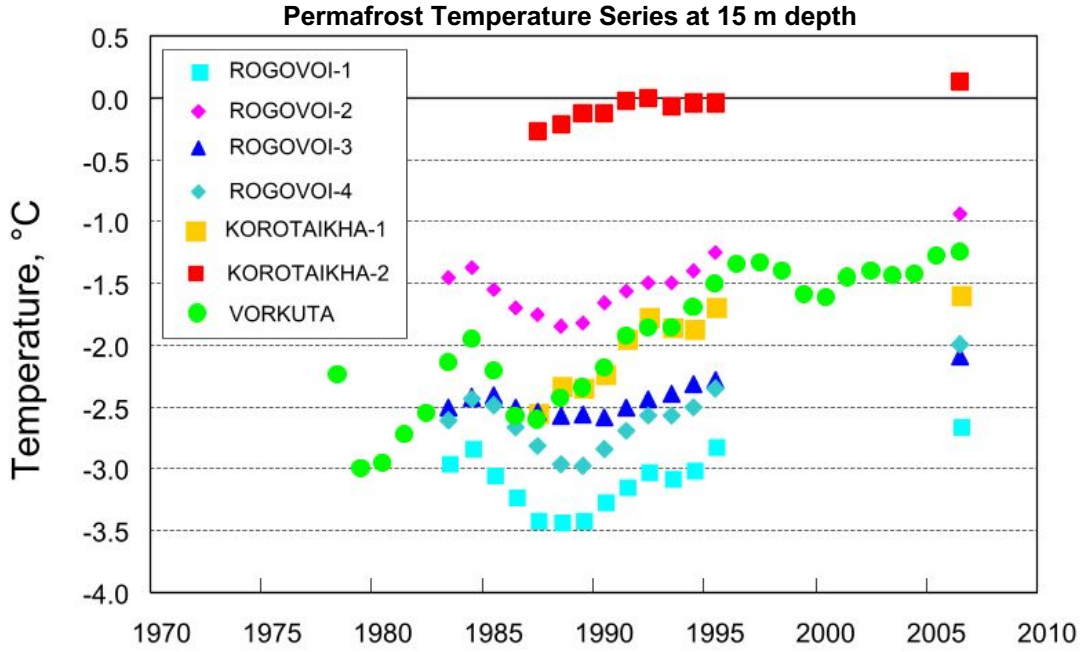
- Permafrost temperature is increasing in most locations in the Arctic and Sub-Arctic
- There are some places where we don’t see a noticeable increase, but there are no known sites where permafrost temperature is decreasing
- Typical increase in permafrost temperature is 1 to 2°C
- Active layer depth is increasing at some locations. There are some locations in the Interior Alaska where active layer doesn’t re-freeze completely every year anymore
- The long-term permafrost thawing already started at some locations in natural undisturbed conditions

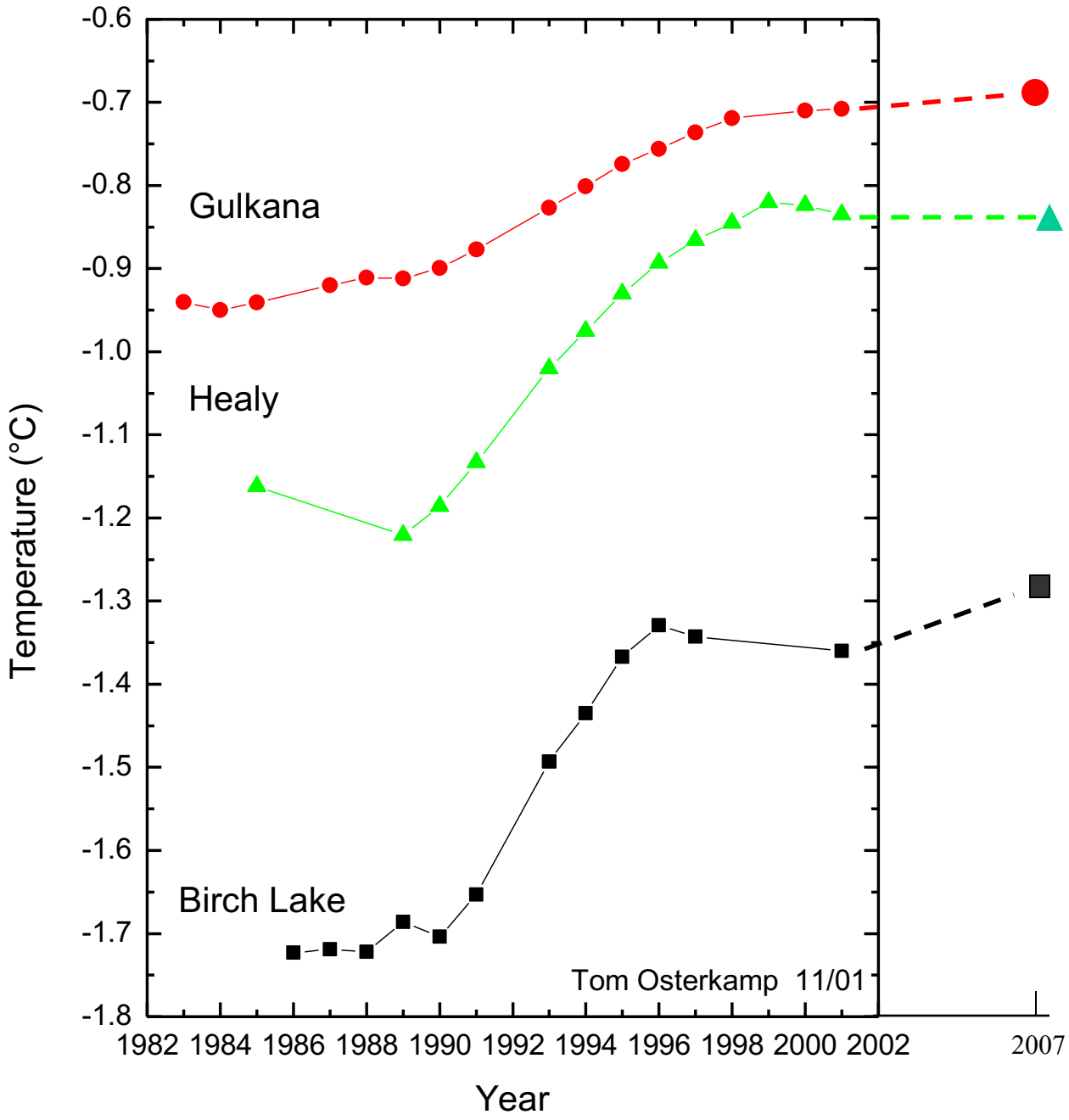

70°N
170°W
160°W
150°W
140°W
65°N
60°N
Barrow
BEAUFORT SEA
West Dock
Barter
NPRA
Franklin bluffs
Deadhorse
ANWR
CHUKCHI SEA
Happy Valley
Imnaviat
Galbraith Lake
Toolik Lake
Chandalar Shelf
Kotzebue
RUSSIA
Coldfoot
Old Man
Yukon Bridge
Council
Fairbanks
Nome
Bonanza Creek
Birch Lake
Eagle
Healy
Donnelly
BERING SEA
CANADA
Hogan Hill
Gakona (HAARP)
Gulkana
GULF OF ALASKA
CONTINUOUS PERMAFROST
DISCONTINUOUS PERMAFROST
NO PERMAFROST
GLACIERS
RIVERS
LAKES
LAND
TRANS-ALASKA PIPELINE
BOREHOLES:
USGS
UAF
N
200
0
200
Permafrost Laboratory
Geophysical Institute - University of Alaska Fairbanks


70°N
170°W
160°W
150°W
140°W
65°N
Barrow
BEAUFORT SEA
West Dock
Barter
Deadhorse
NPRA
Franklin bluffs
ANWR
Happy Valley
Imnaviat
Galbraith Lake
Toolik Lake
Chandalar Shelf
Kotzebue
CHUKCHI SEA
RUSSIA
Coldfoot
Old Man
Yukon Bridge
Fairbanks
Bonanza Creek
Birch Lake
Eagle
Healy
Donnelly
CANADA
Hogan Hill
Gakona (HAARP)
Gulkana
GULF OF ALASKA
200
0
200
CONTINUOUS PERMAFROST
DISCONTINUOUS PERMAFROST
NO PERMAFROST
GLACIERS
RIVERS
LAKES
LAND
TRANS-ALASKA PIPELINE
BOREHOLES:
USGS
UAF
N
TEMPERATURE (C)
-9.50
-9.25
-9.00
-8.75
-8.50
-8.25
DEPTH (m)
20
30
40
50
WEST DOCK
1993
1994
1995
1996
1997
1998
1999
2001
2002
2005
2006
2007
Permafrost Laboratory
Geophysical Institute - University of Alaska Fairbanks

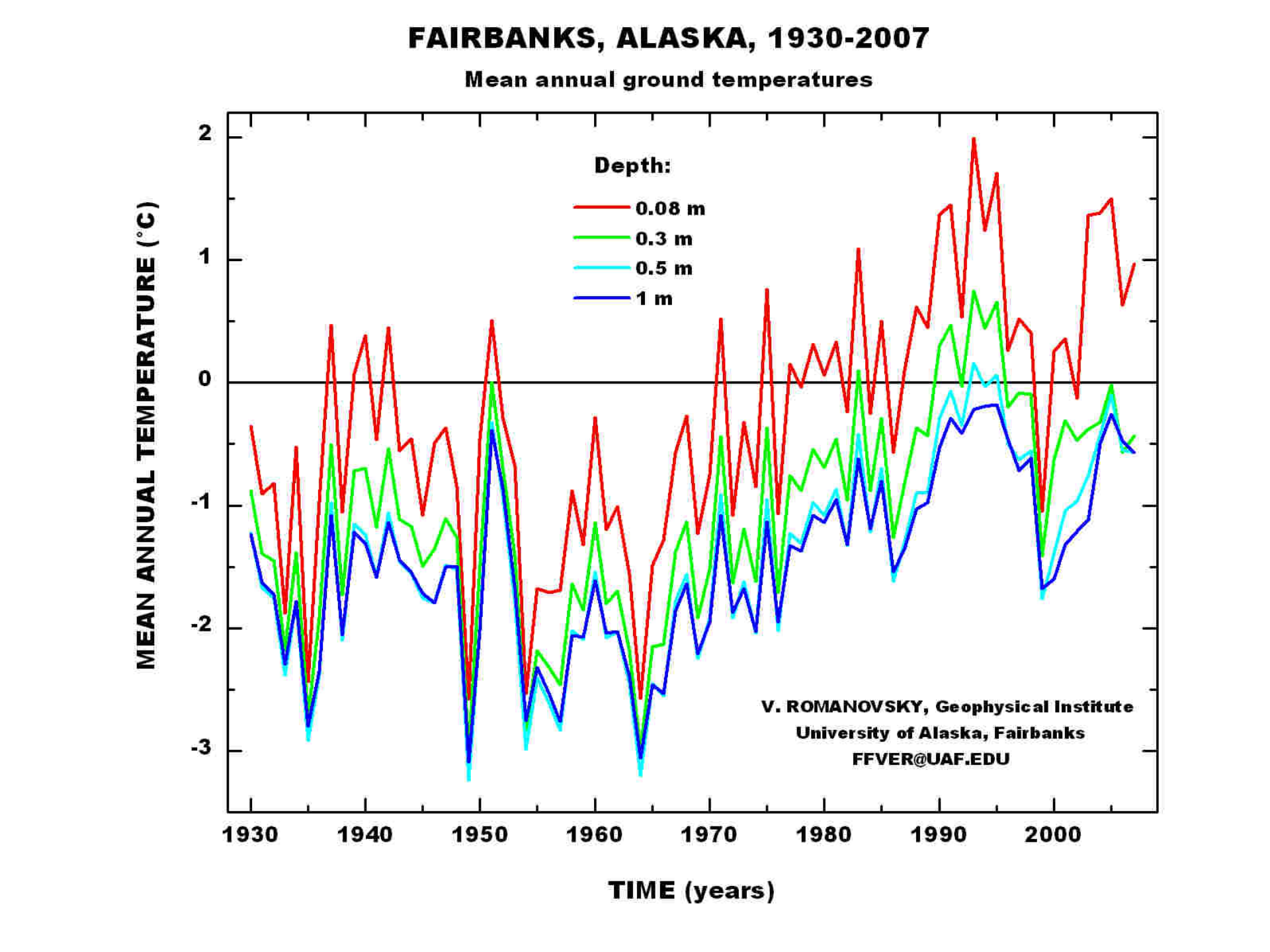

70°N
170°W
160°W
150°W
140°W
65°N
Barrow
BEAUFORT SEA
West Dock
Barter
Deadhorse
NPRA
Franklin bluffs
Happy Valley
ANWR
Imnaviat
Toolik Lake
Galbraith Lake
Chandalar Shelf
CHUKCHI SEA
RUSSIA
Kotzebue
Coldfoot
Old Man
Yukon Bridge
Council
Fairbanks
Birch Lake
Eagle
Donnelly
CANADA
Gakona (HAARP)
Gulkana
GULF OF ALASKA
0
200
CONTINUOUS PERMAFROST
DISCONTINUOUS PERMAFROST
NO PERMAFROST
GLACIERS
RIVERS
LAKES
LAND
TRANS-ALASKA PIPELINE
BOREHOLES:
USGS
UAF
N
"TSP" Time Series - Northern Alaska
(Osterkamp and Romanovsky)
Temperature at 20 m depth (°C)
Happy Valley
Galbraith Lake
Franklin Bluffs
Deadhorse
West Dock
-4.5
-5.0
-5.5
-6.0
-6.5
-7.0
-7.5
-8.0
-8.5
-9.0
-9.5
-10.0
1976
1980
1984
1988
1992
1996
2000
2004
2008
Permafrost Laboratory
Geophysical Institute - University of Alaska Fairbanks

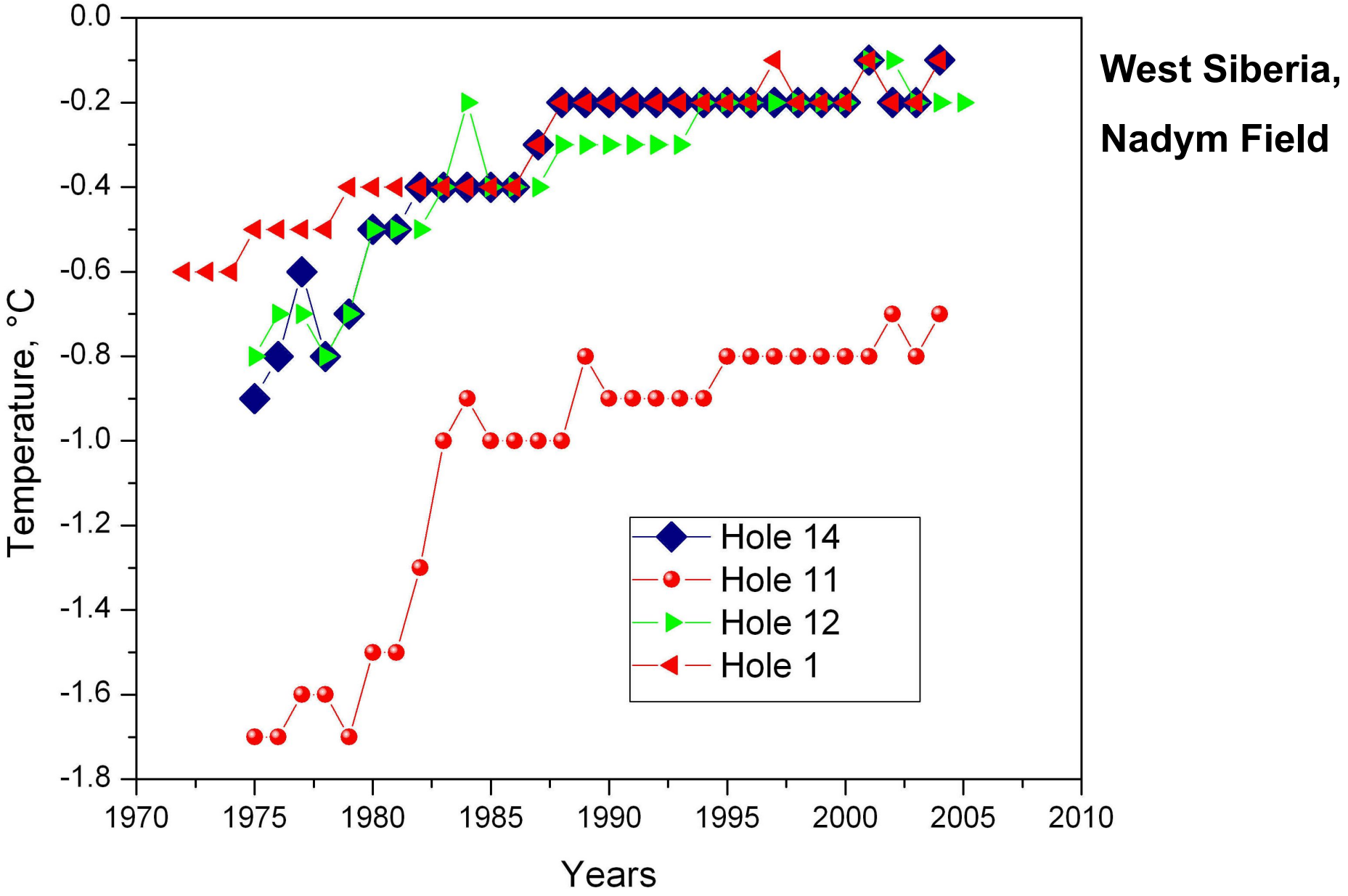

30°E
40°E
50°E
60°E
Barents Sea
Kara Sea
Korotaikha 1-2
Rogovoi 1-4
Vorkuta
70°N
60°N
Candidate Boreholes
Clusters of TSP Boreholes
200 100 0 200 400 Km
50°E
60°E
70°E
80°E


Permafrost Temperature Series at 15 m depth
Temperature, °C
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
ROGOVOI-1
ROGOVOI-2
ROGOVOI-3
ROGOVOI-4
KOROTAIKHA-1
KOROTAIKHA-2
VORKUTA
1970
1975
1980
1985
1990
1995
2000
2005
2010



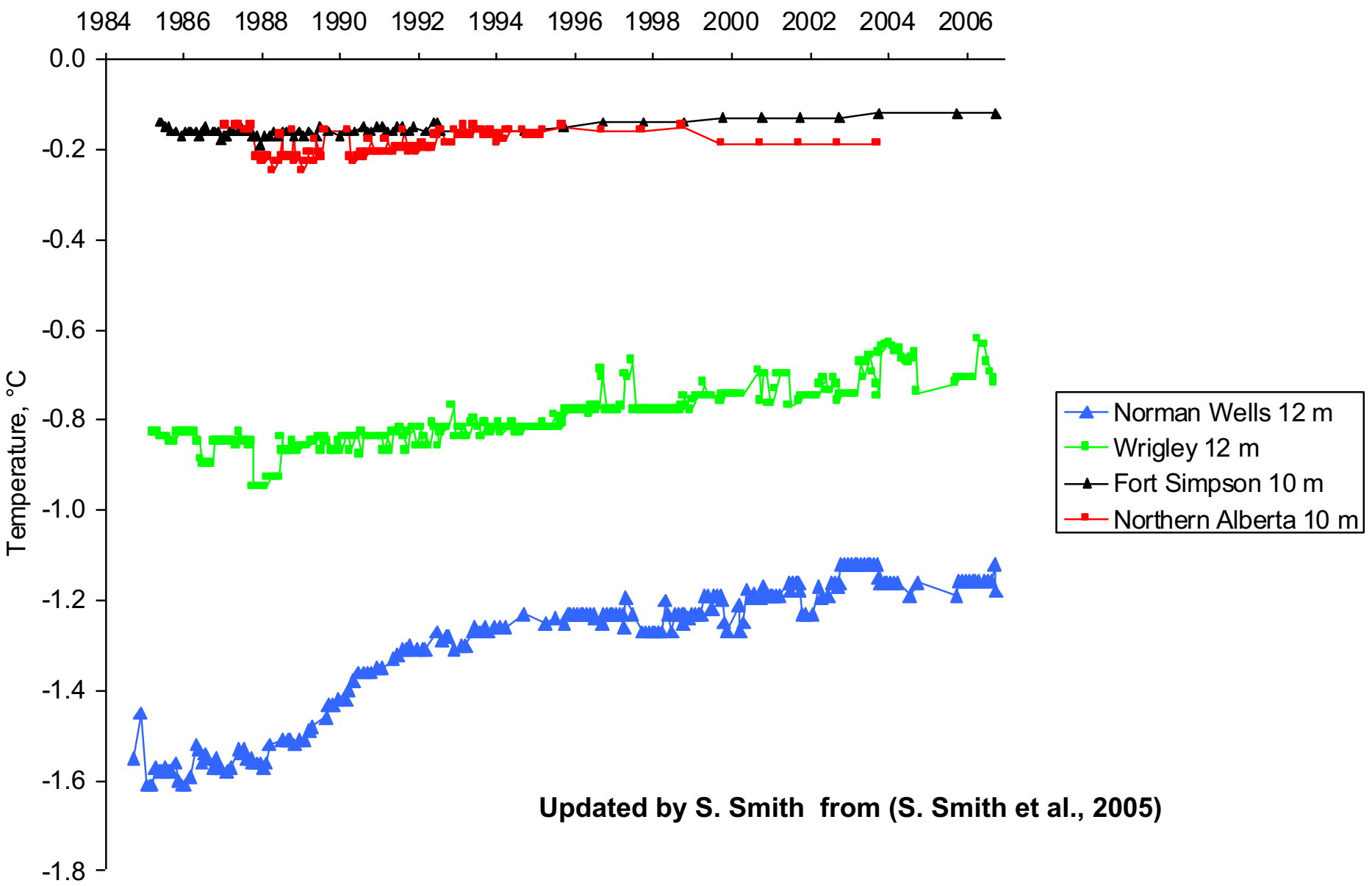
Temperatures at the 20 m depth in discontinuous permafrost in Interior Alaska.

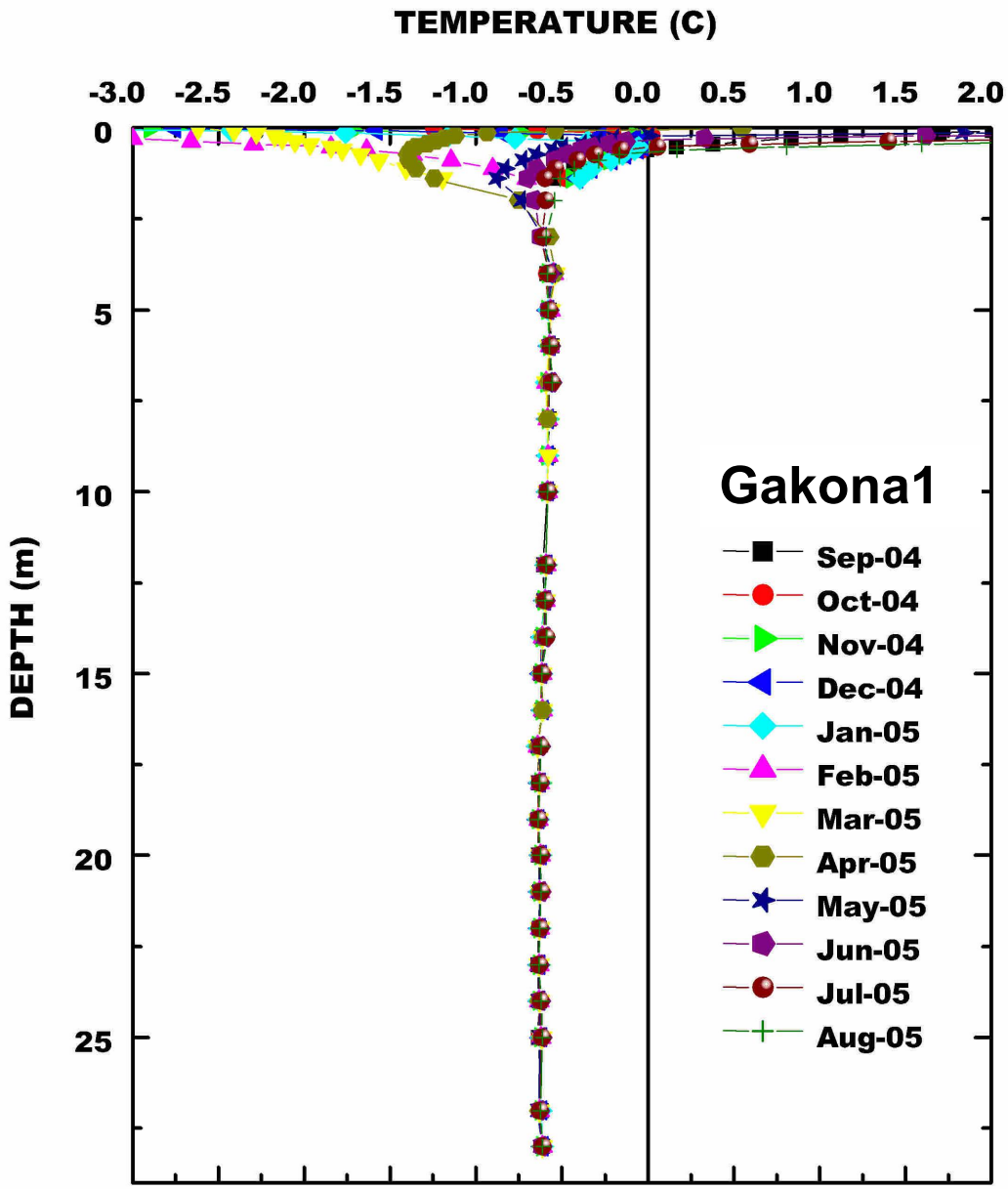

FAIRBANKS, ALASKA, 1930-2007
Mean annual ground temperatures
MEAN ANNUAL TEMPERATURE (°C)
TIME (years)
Depth:
0.08 m
0.3 m
0.5 m
1 m
2
1
0
-1
-2
-3
1930
1940
1950
1960
1970
1980
1990
2000
V. ROMANOVSKY, Geophysical Institute
University of Alaska, Fairbanks
FFVER@UAF.EDU

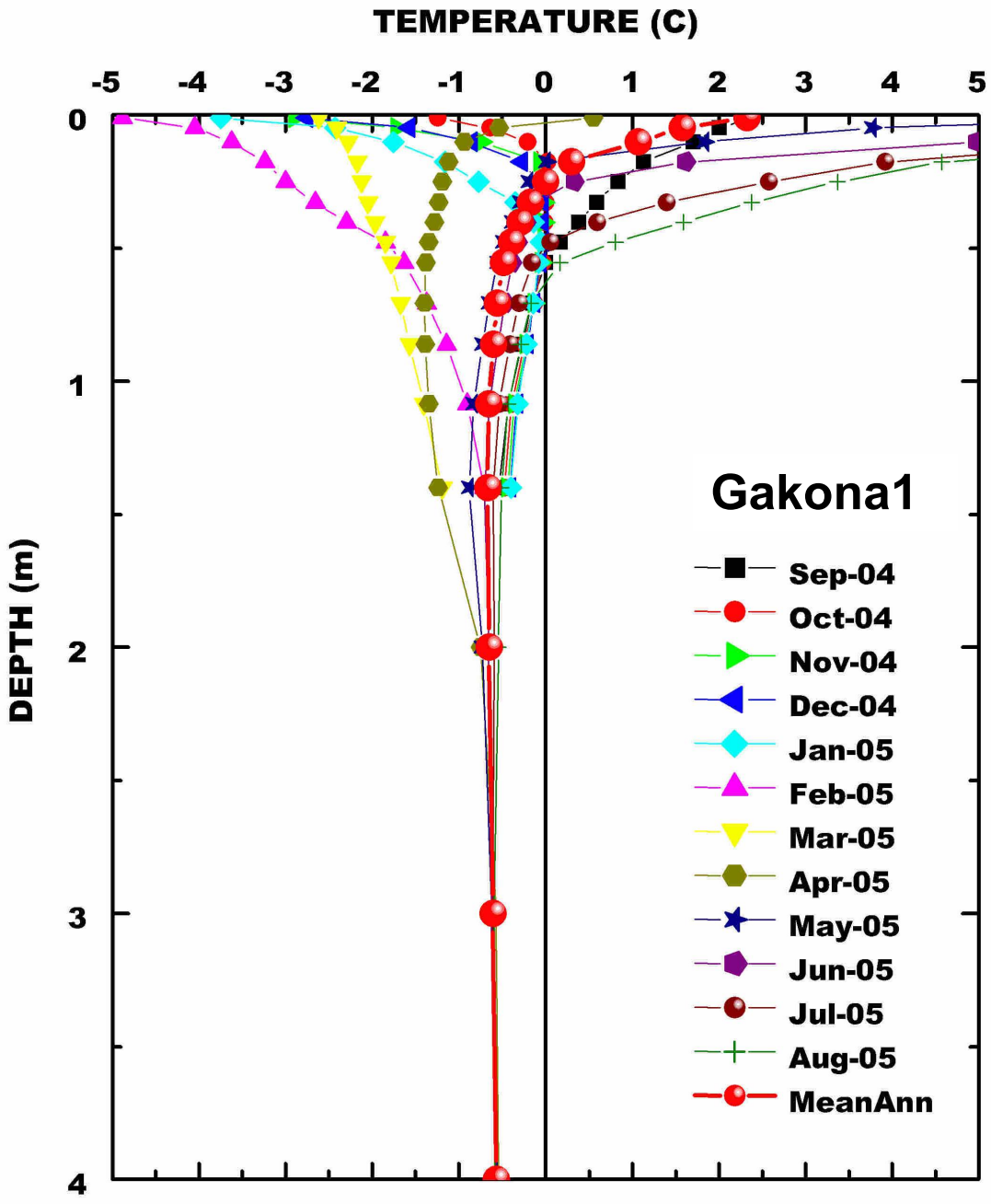


West Siberia,

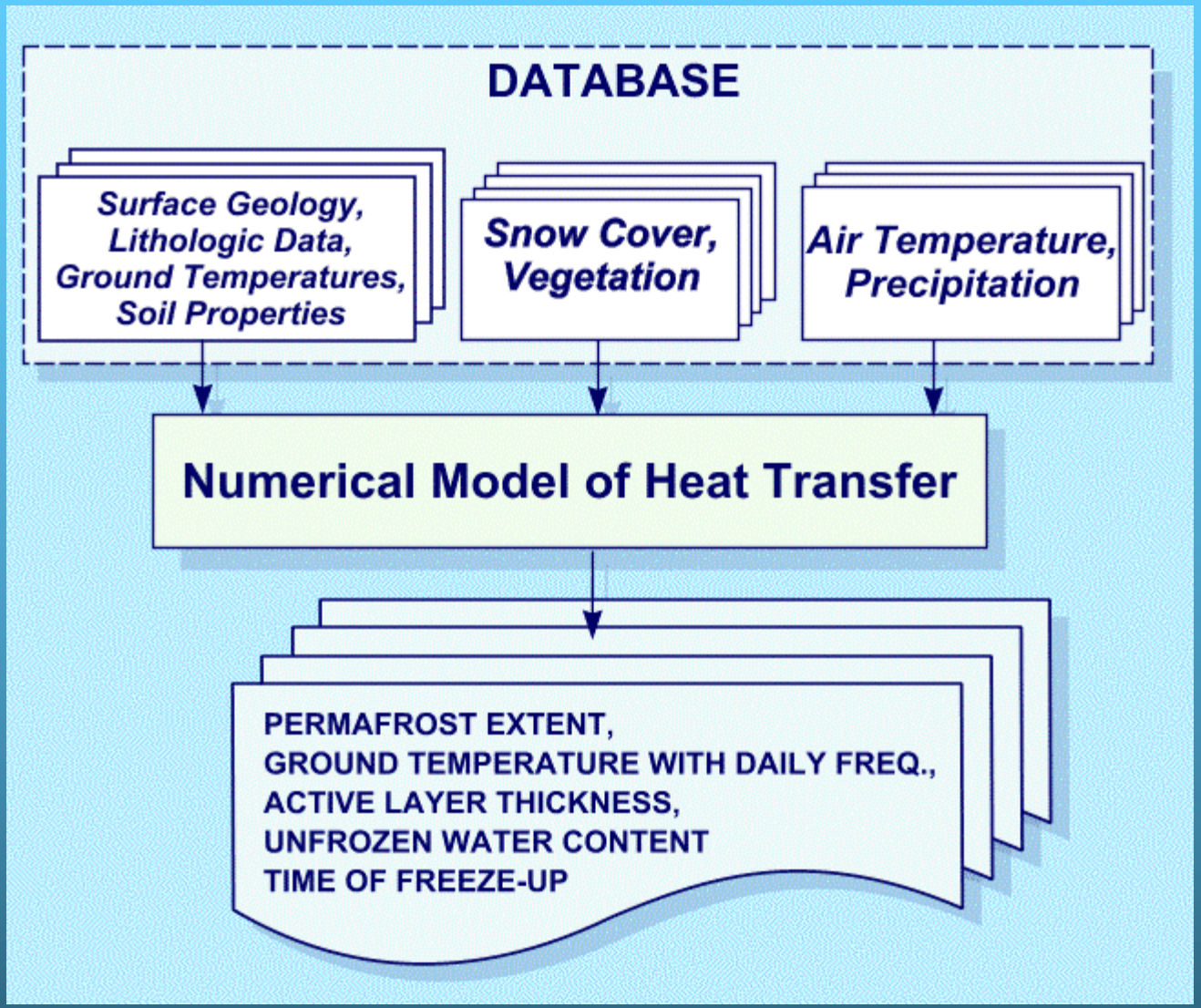
Nadym Field


1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
Temperature, °C
Norman Wells 12 m
Wrigley 12 m
Fort Simpson 10 m
Northern Alberta 10 m
Updated by S. Smith from (S. Smith et al., 2005)

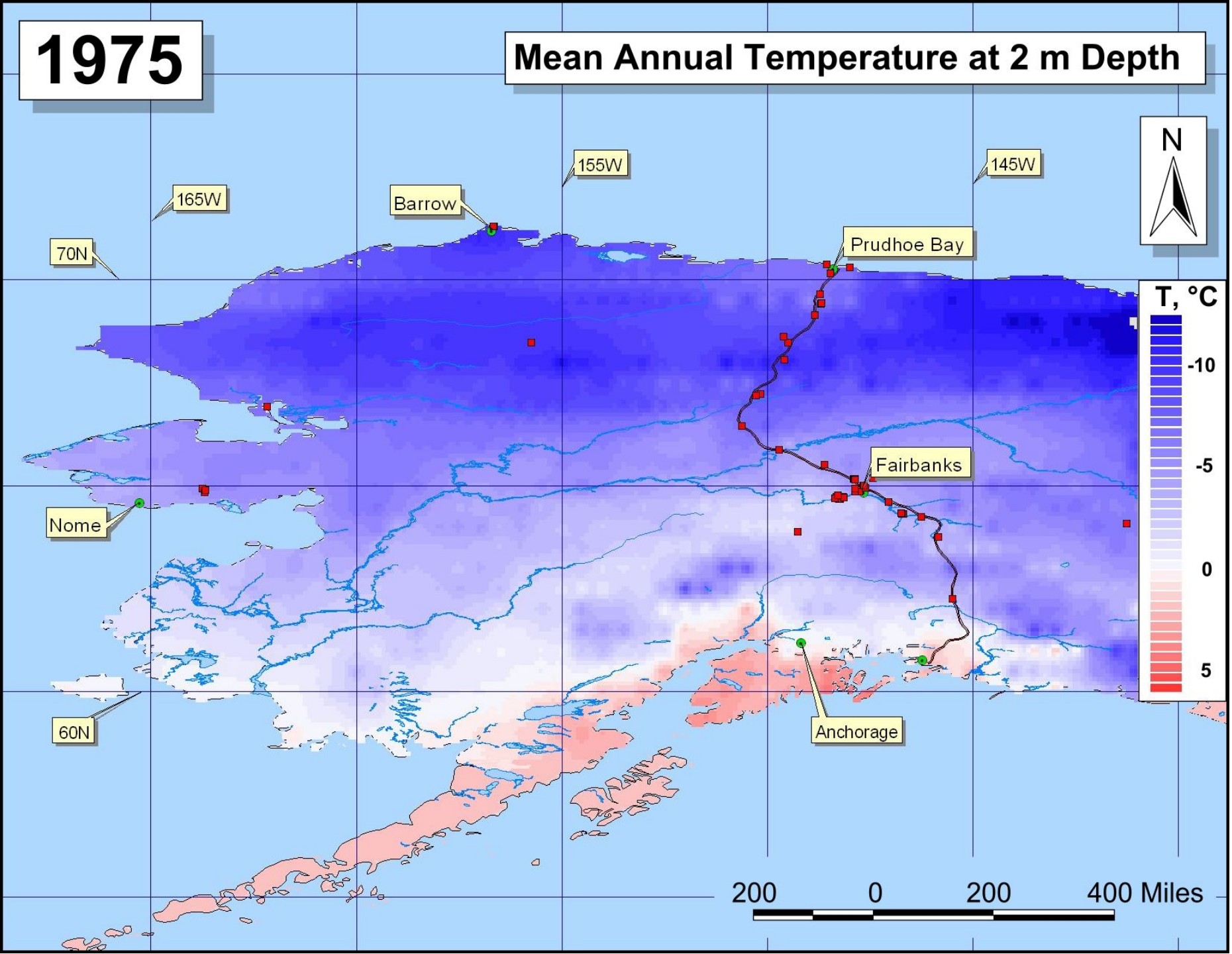

TEMPERATURE (C)
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
DEPTH (m)
0
5
10
15
20
25
Gakona1
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05

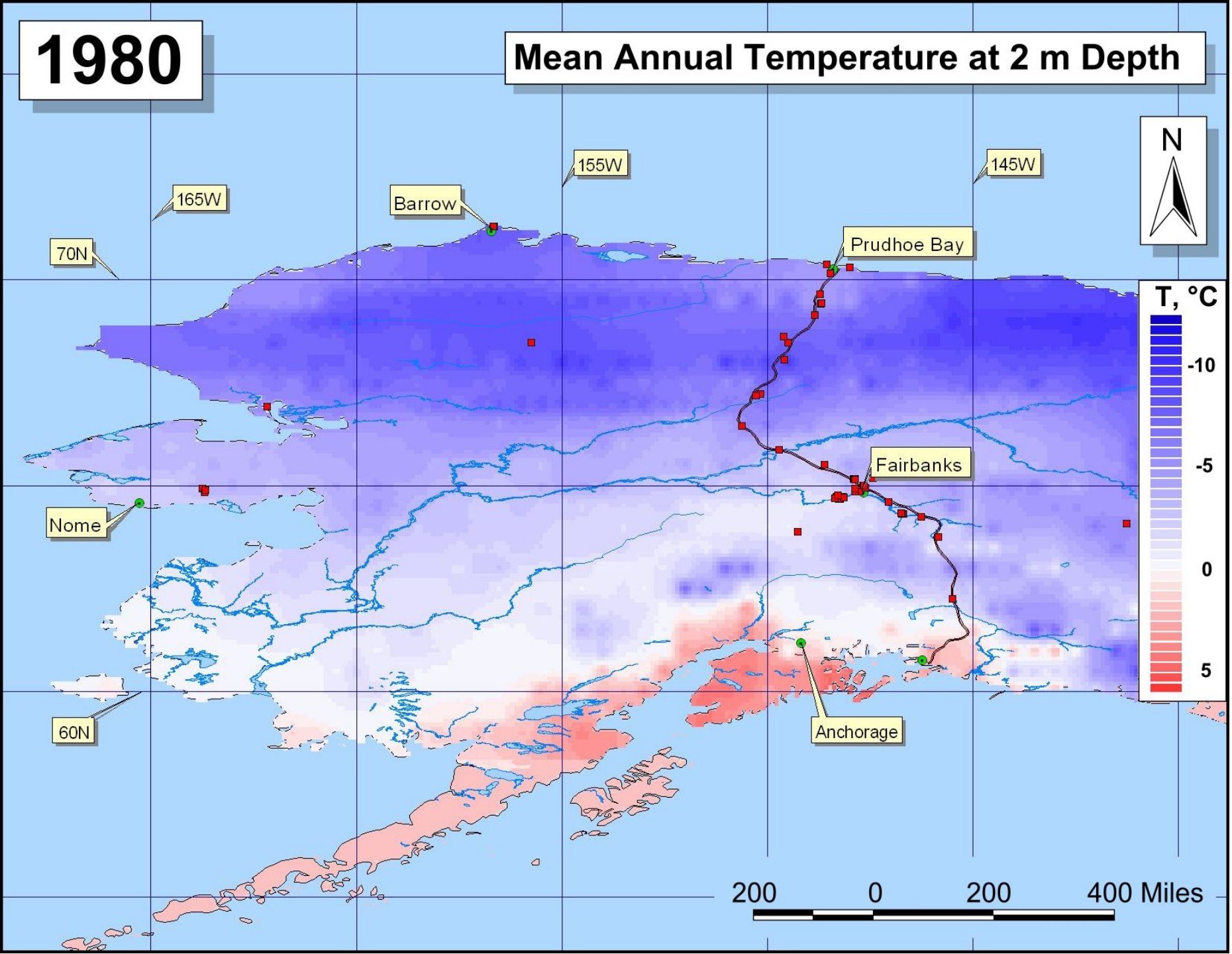

TEMPERATURE (C)
-5
-4
-3
-2
-1
0
1
2
3
4
5
DEPTH (m)
0
1
2
3
4
Gakona1
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
MeanAnn

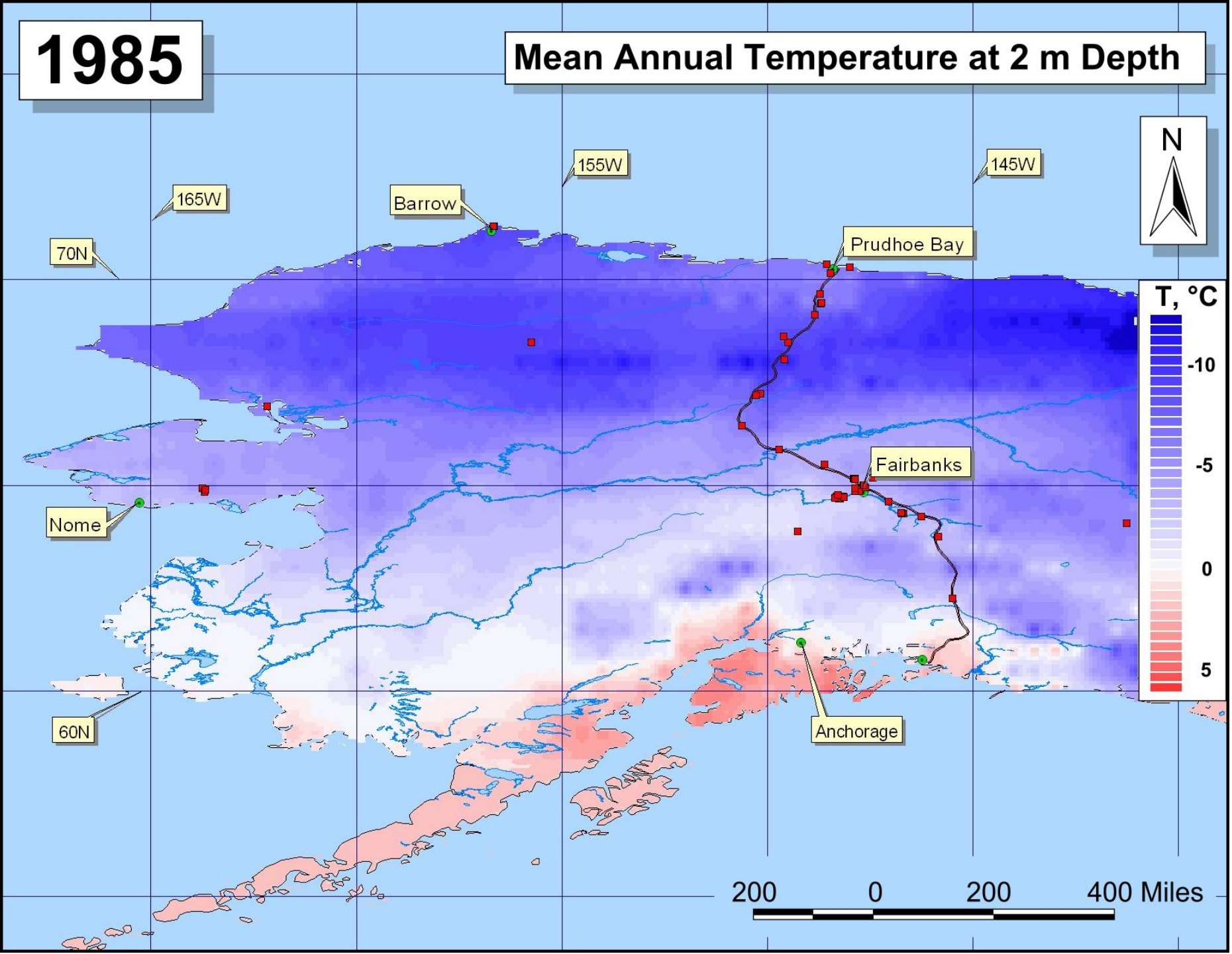
GIPL-2.0

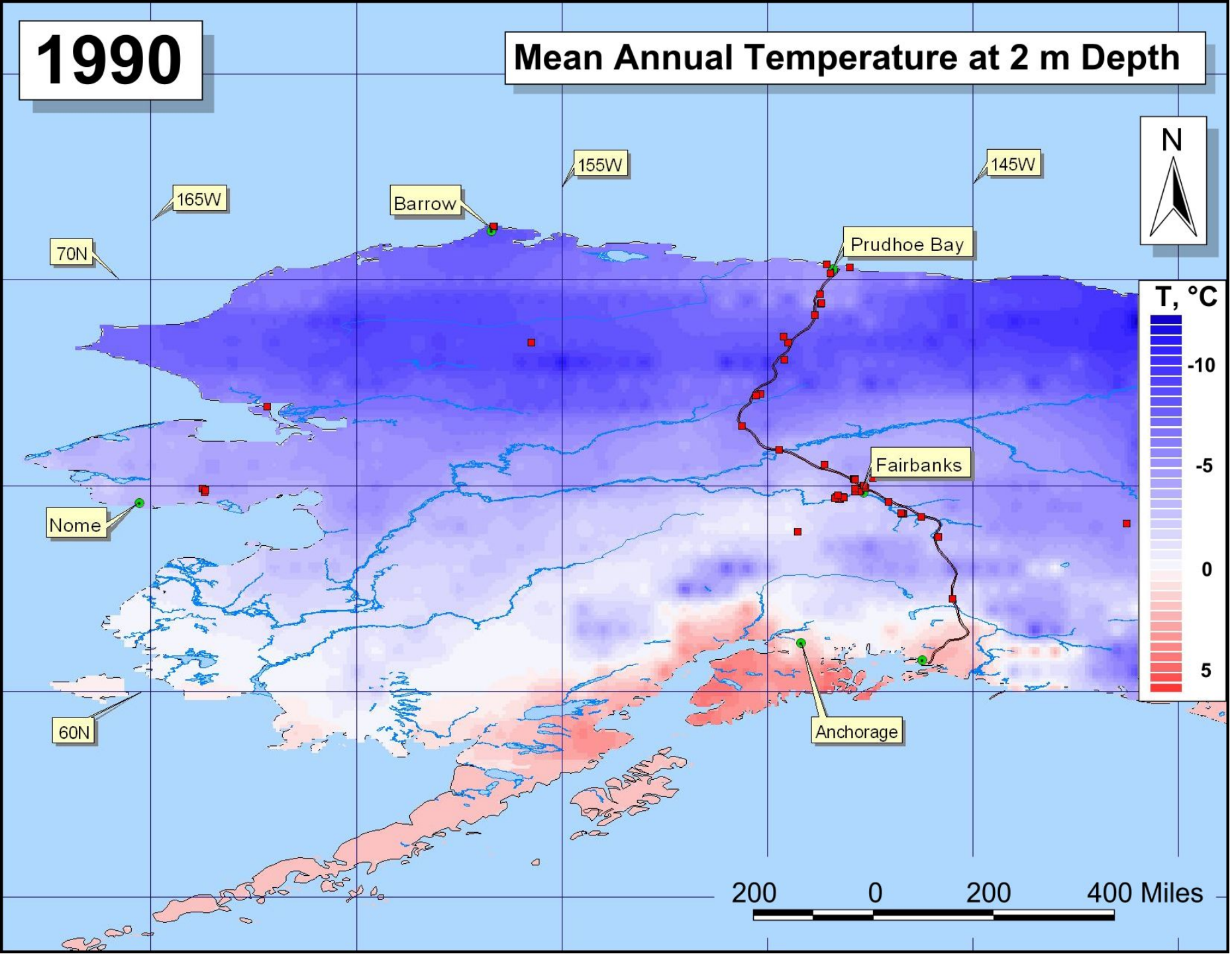

DATABASE
Surface Geology, Lithologic Data, Ground Temperatures, Soil Properties
Snow Cover, Vegetation
Air Temperature, Precipitation
Numerical Model of Heat Transfer
PERMAFROST EXTENT,
GROUND TEMPERATURE WITH DAILY FREQ.,
ACTIVE LAYER THICKNESS,
UNFROZEN WATER CONTENT
TIME OF FREEZE-UP

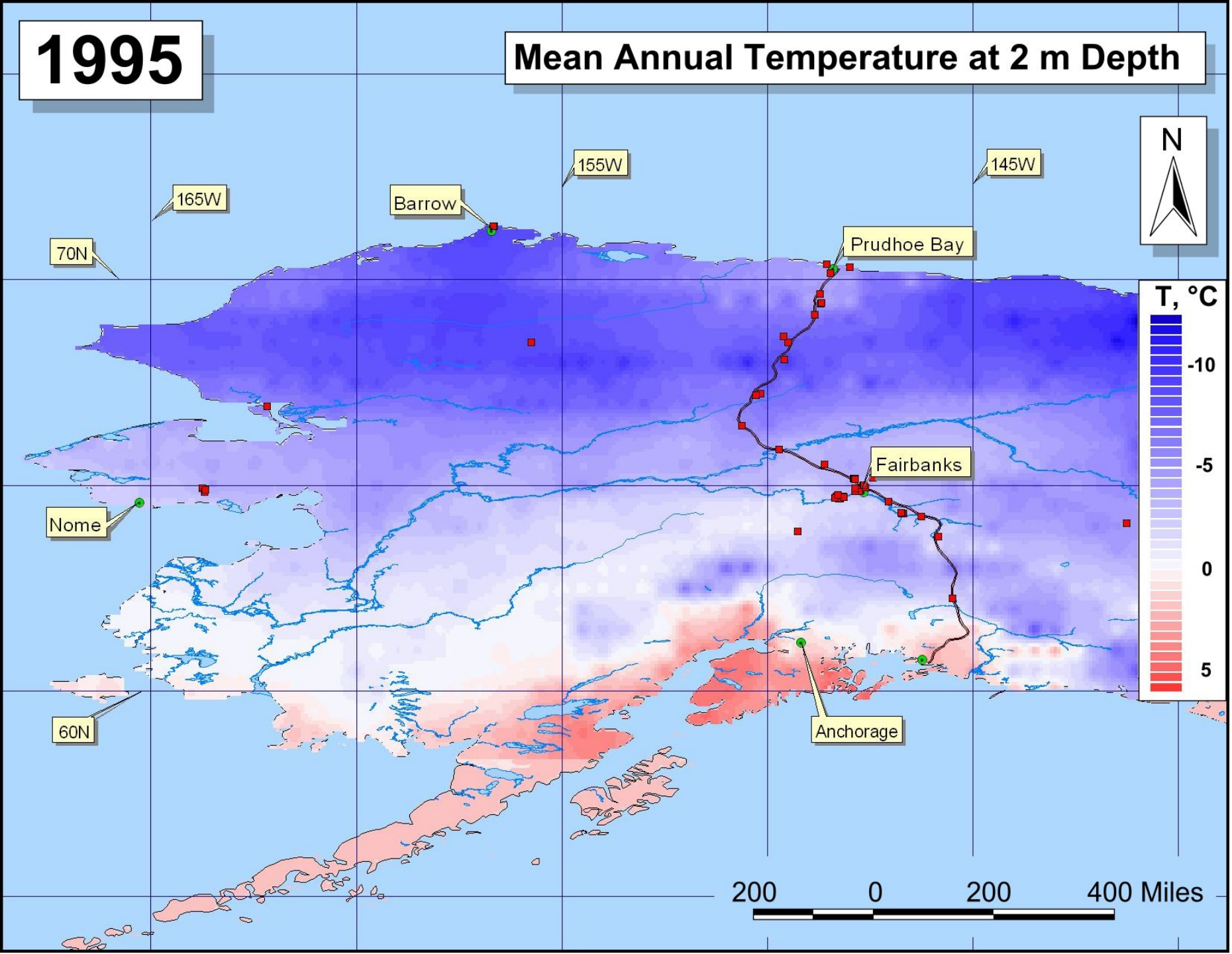
Reconstruction and Projection of Permafrost Dynamics for 1950-2100 Using the HADCM2 Model's Climate Forcing

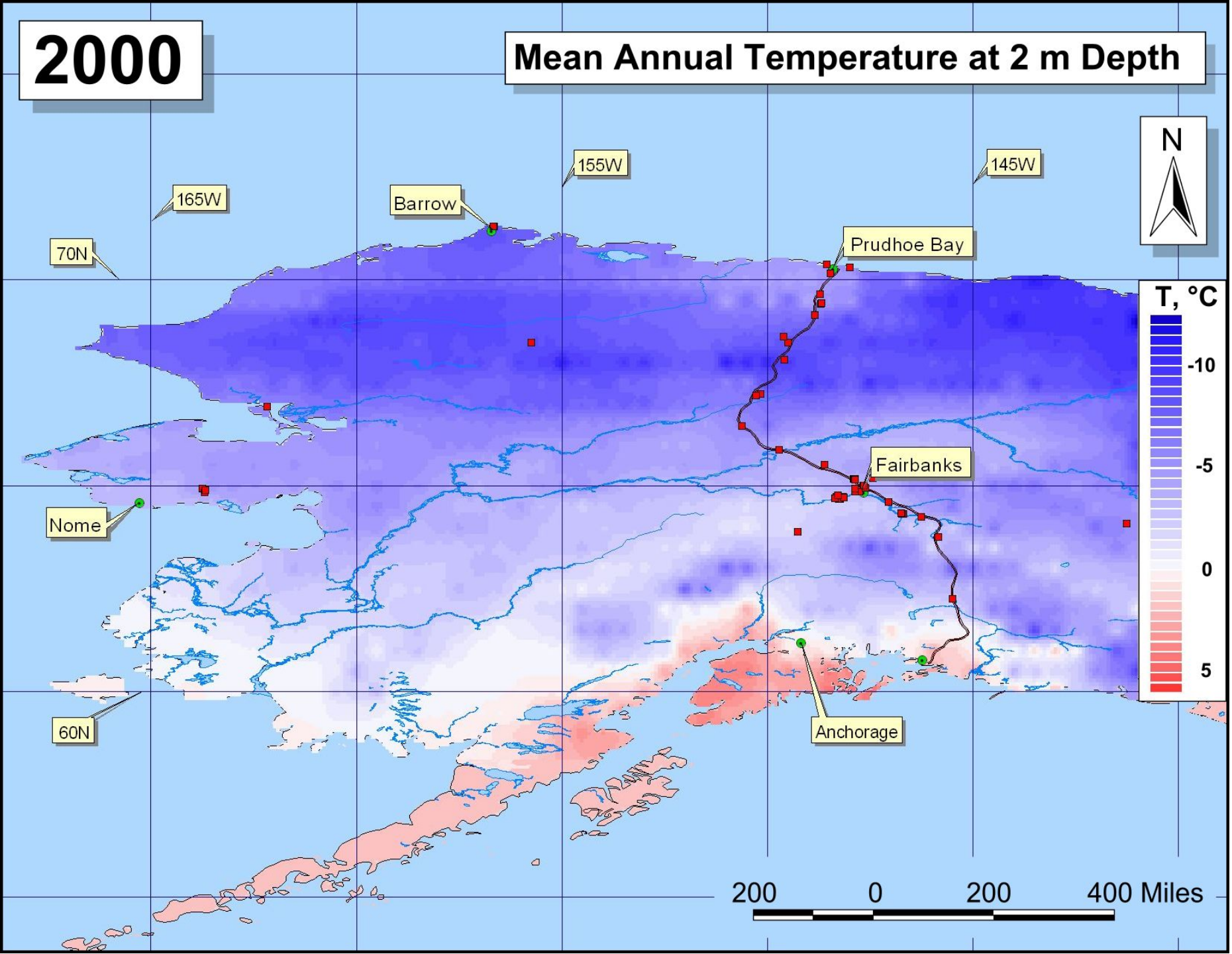

1975
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
Barrow
Prudhoe Bay
70N
Fairbanks
Nome
60N
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

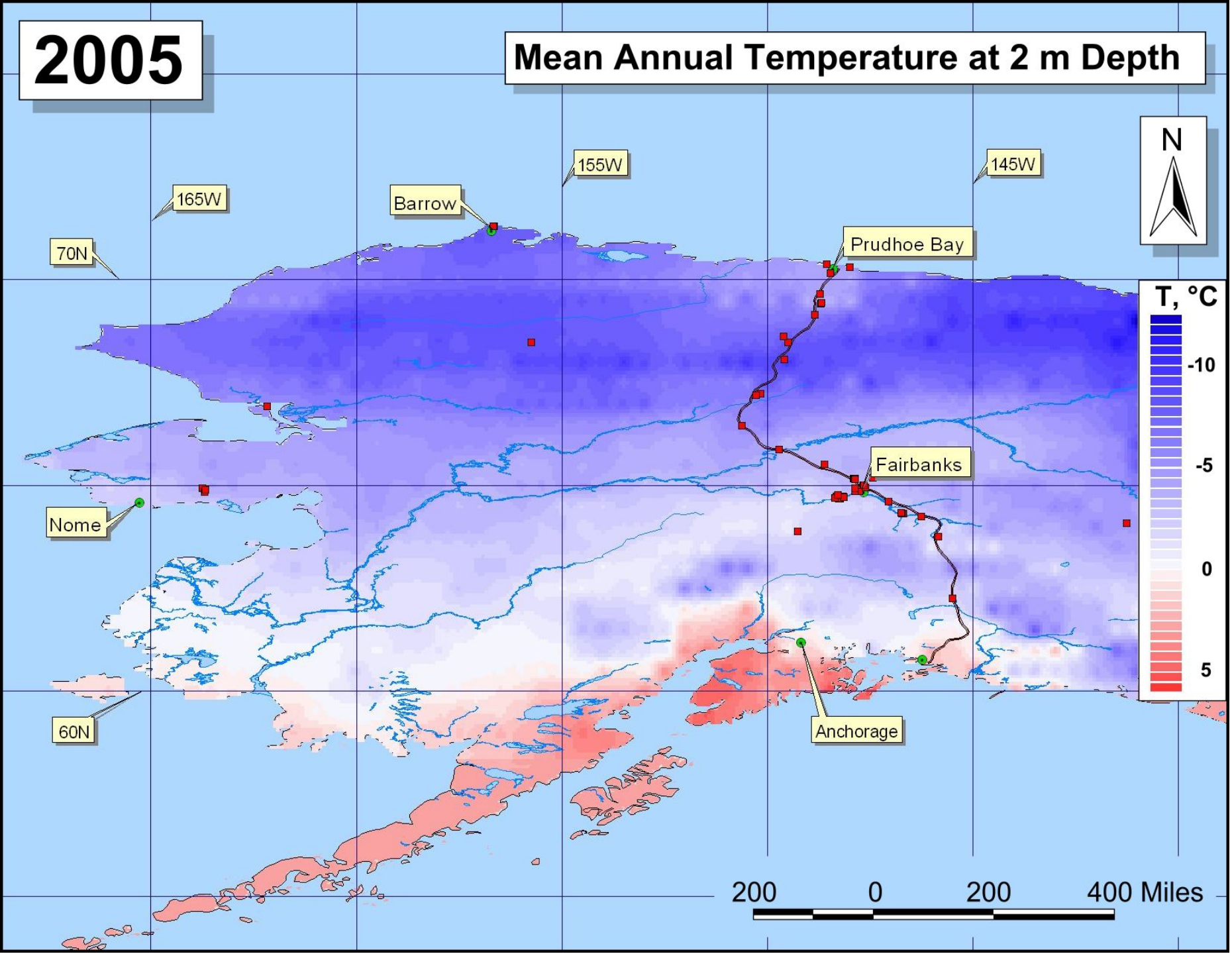

1980
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

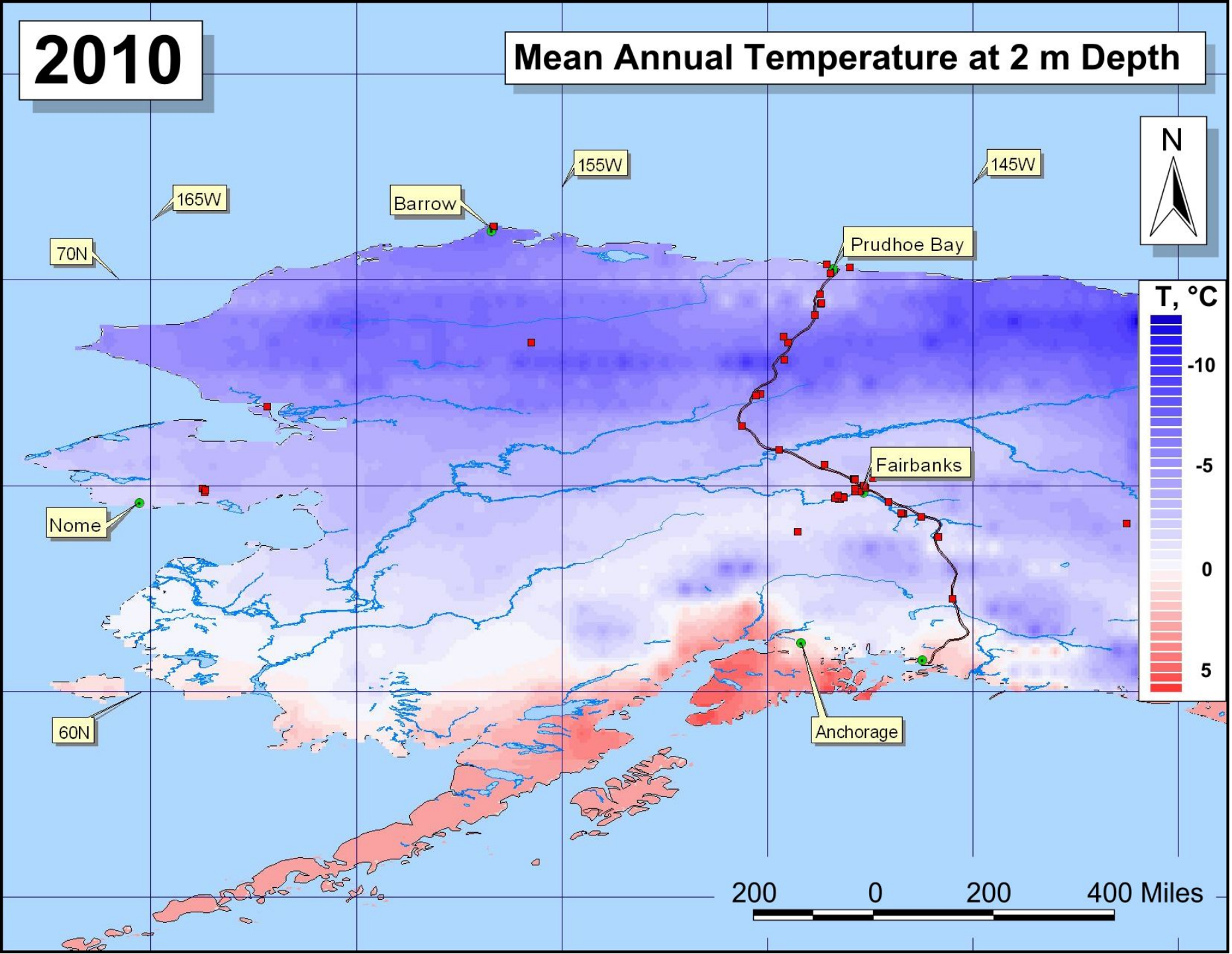

1985
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

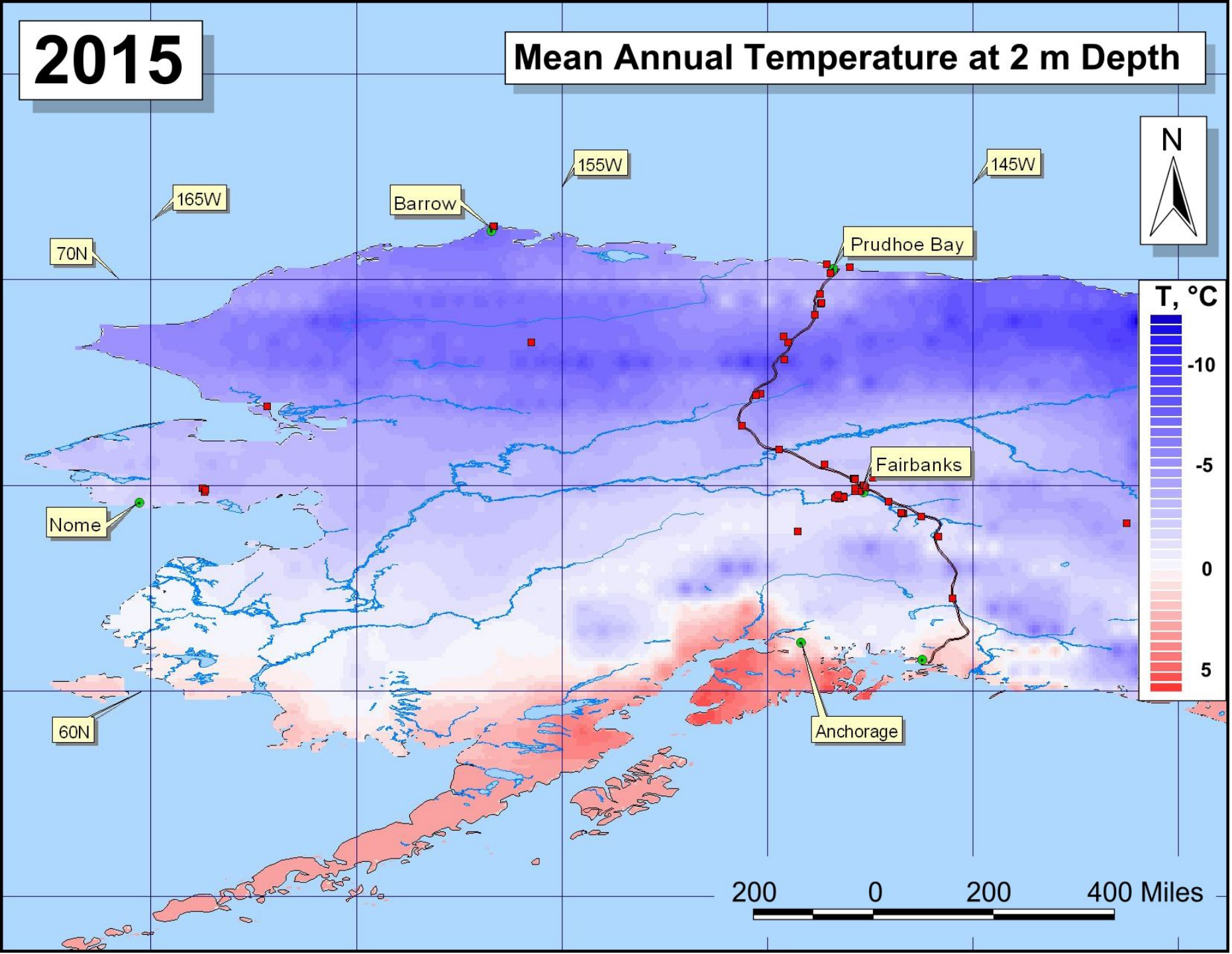

1990
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
Barrow
Prudhoe Bay
70N
T, °C
-10
-5
0
5
Fairbanks
Nome
60N
Anchorage
200
0
200
400 Miles

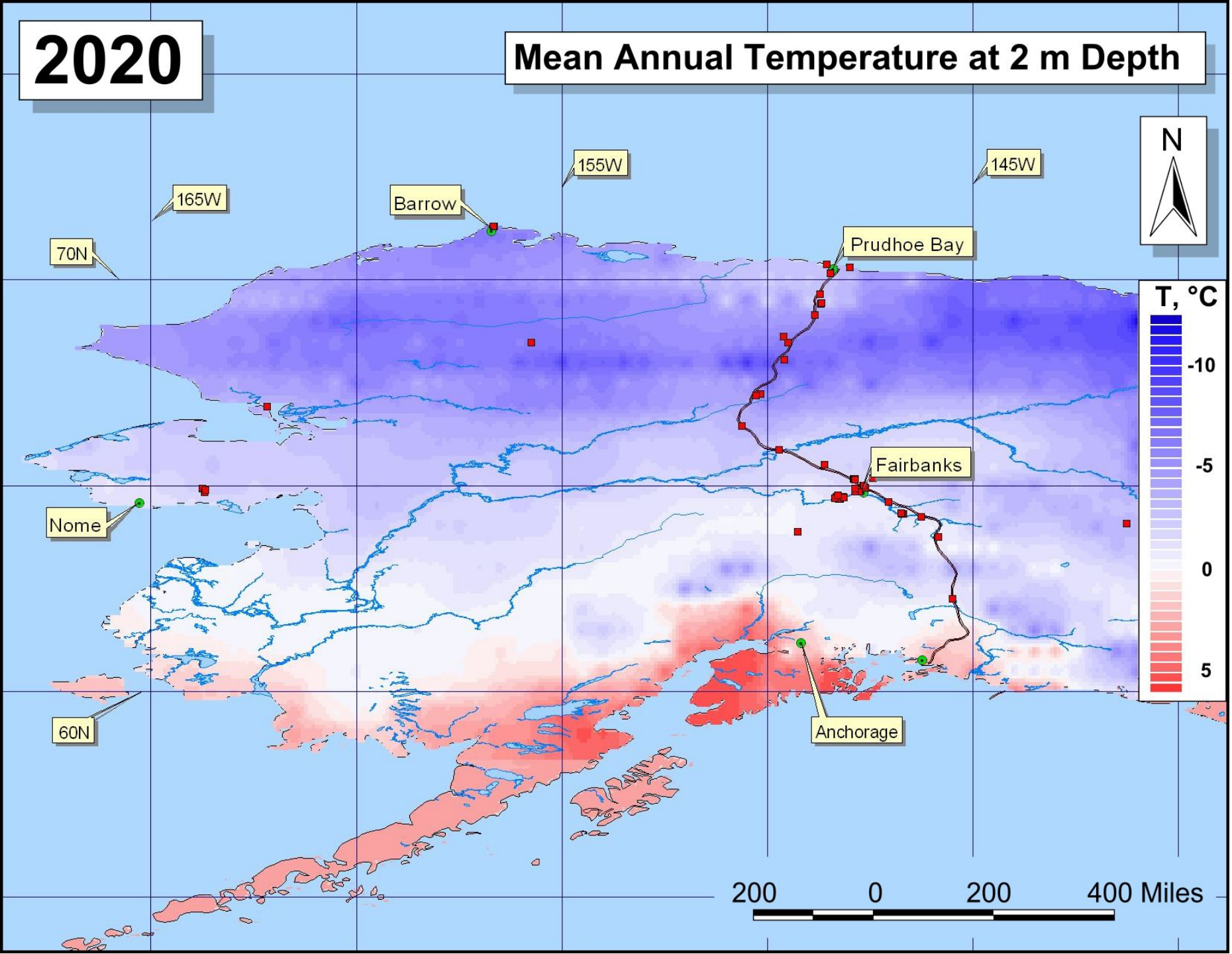

1995
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
Barrow
Prudhoe Bay
70N
T, °C
-10
-5
0
5
Fairbanks
Nome
60N
Anchorage
200
0
200
400 Miles

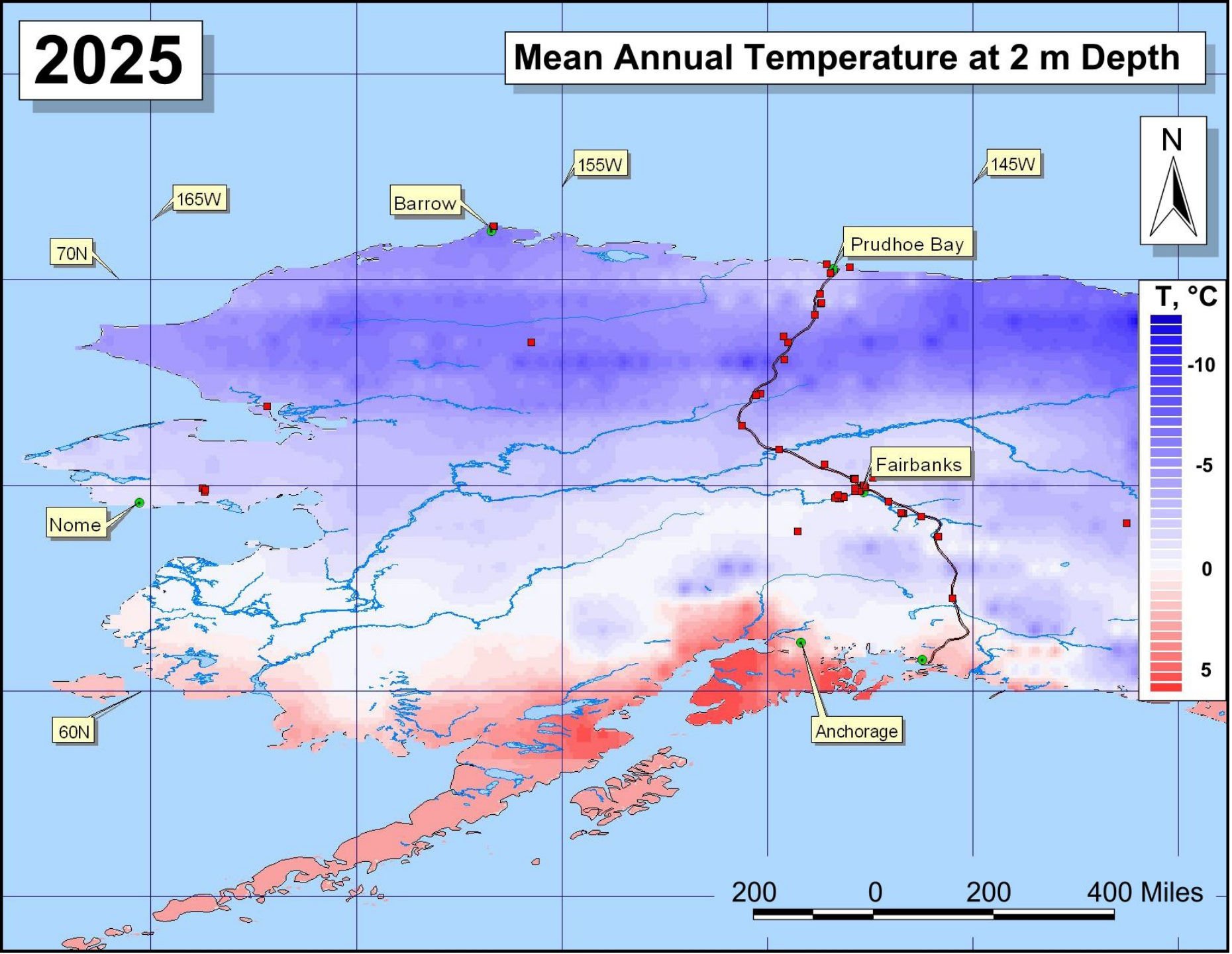

2000
Mean Annual Temperature at 2 m Depth
N
155W
145W
165W
Barrow
Prudhoe Bay
70N
T, °C
-10
-5
Fairbanks
Nome
0
5
60N
Anchorage
200
0
200
400 Miles

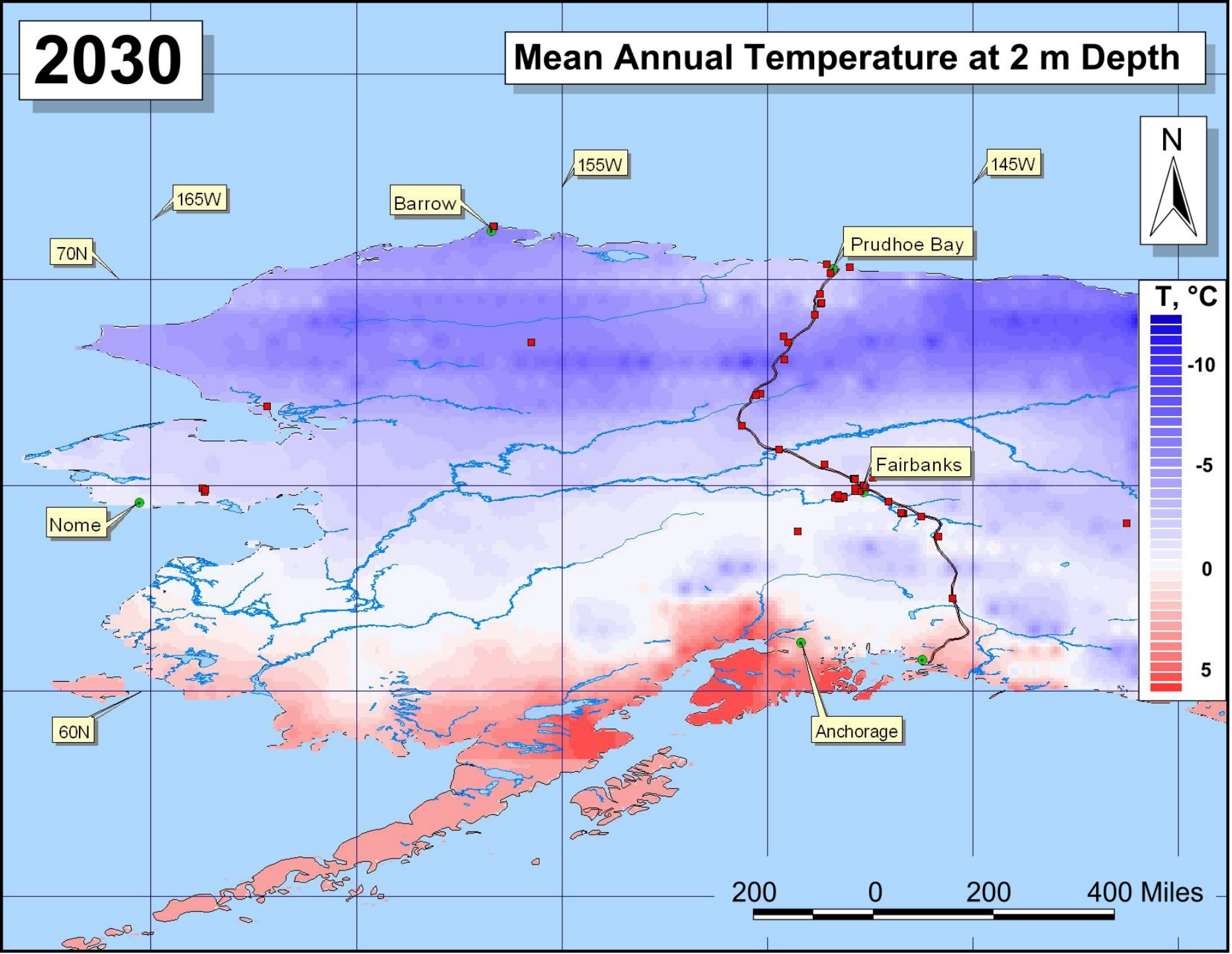

2005
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

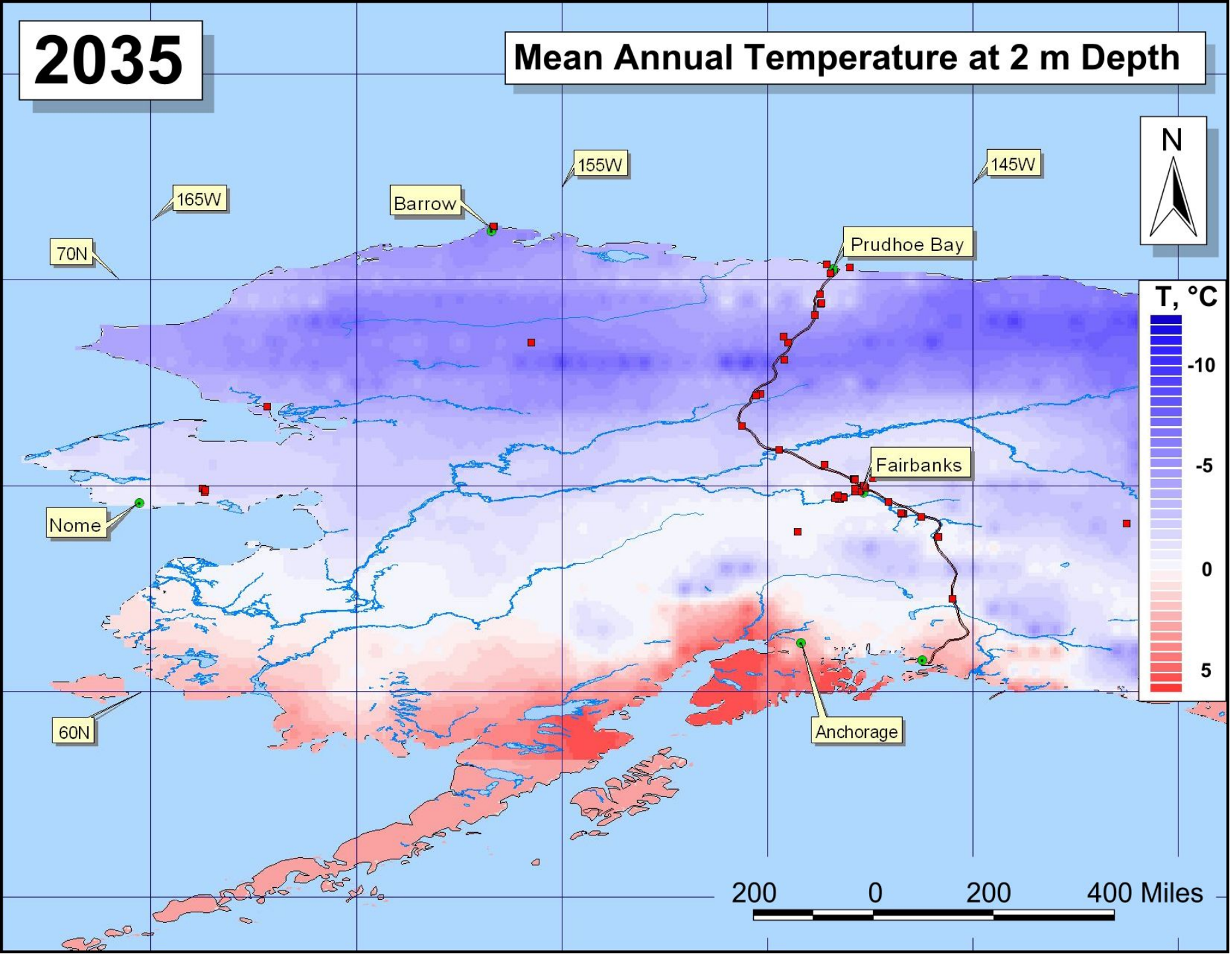

2010
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

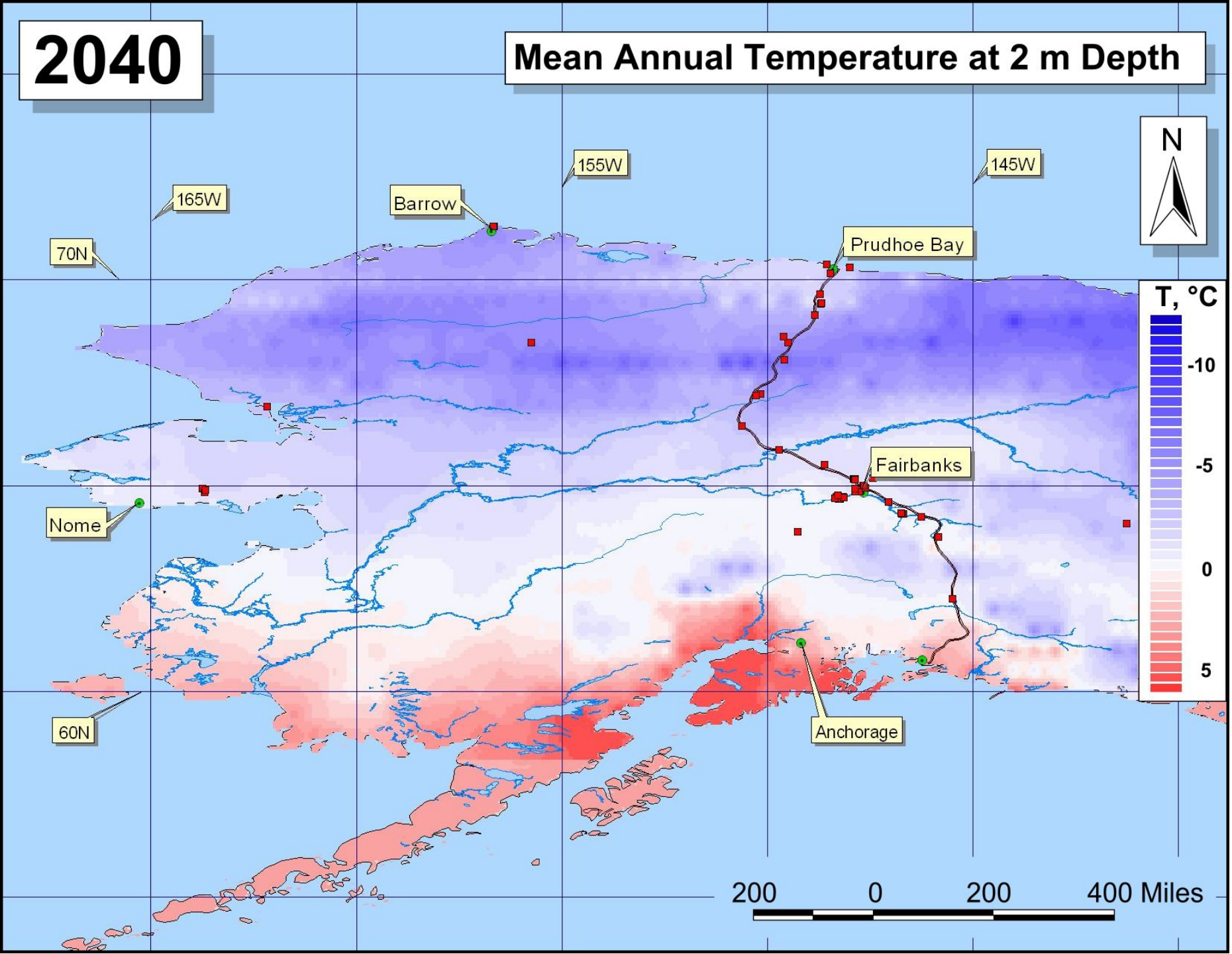

2015
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

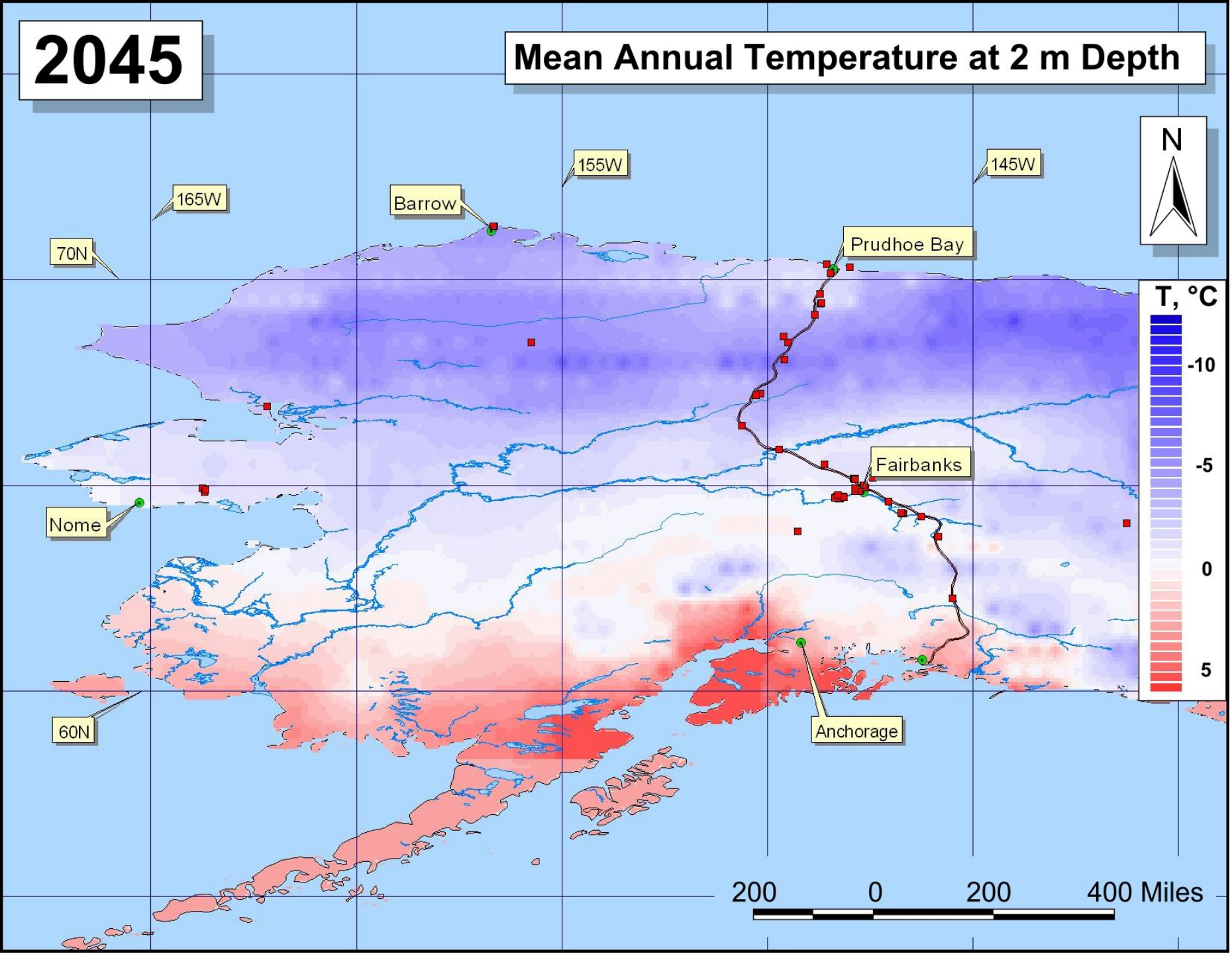

2020
Mean Annual Temperature at 2 m Depth
N
155W
145W
165W
Barrow
70N
Prudhoe Bay
T, °C
-10
-5
Fairbanks
Nome
0
5
60N
Anchorage
200
0
200
400 Miles

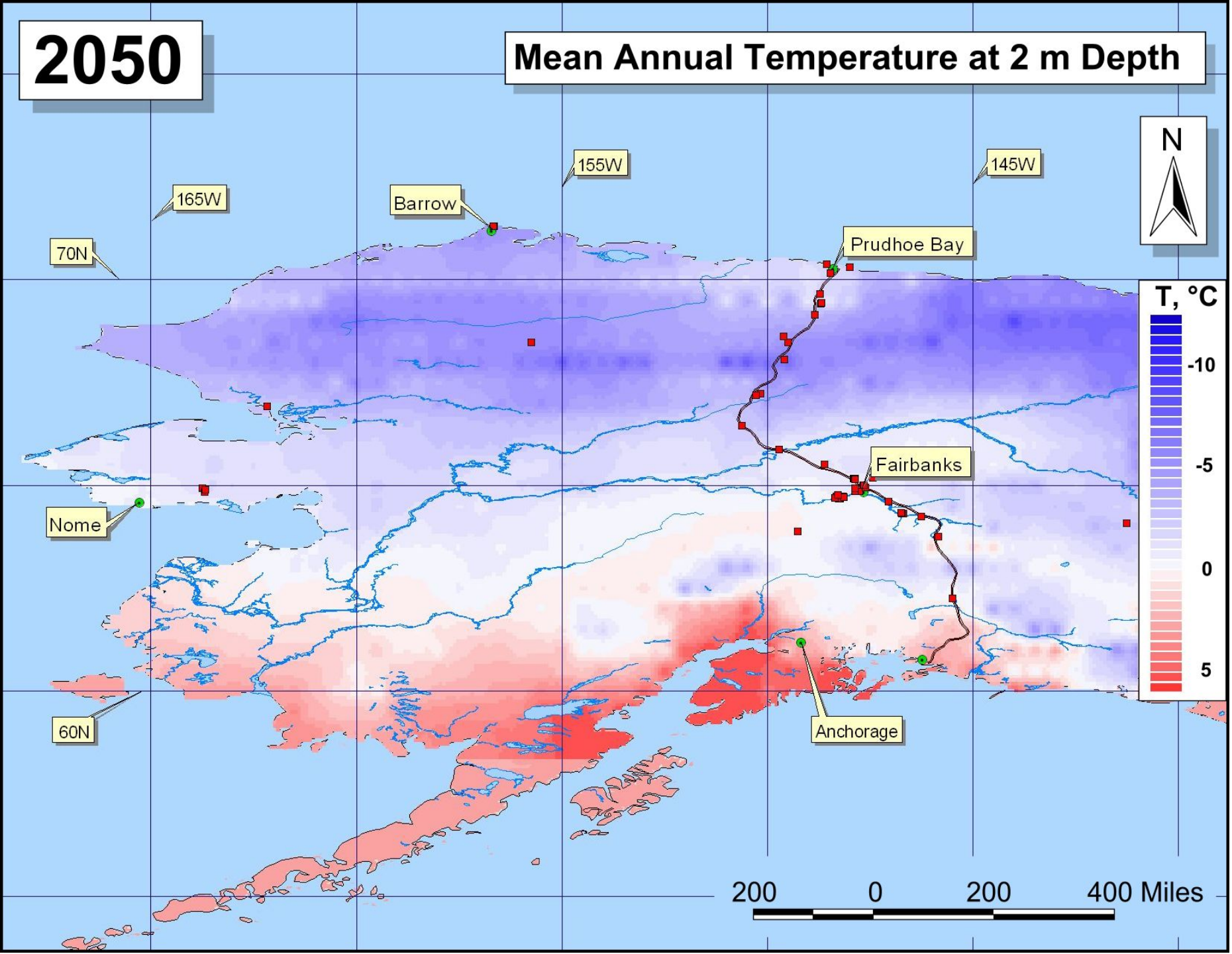

2025
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

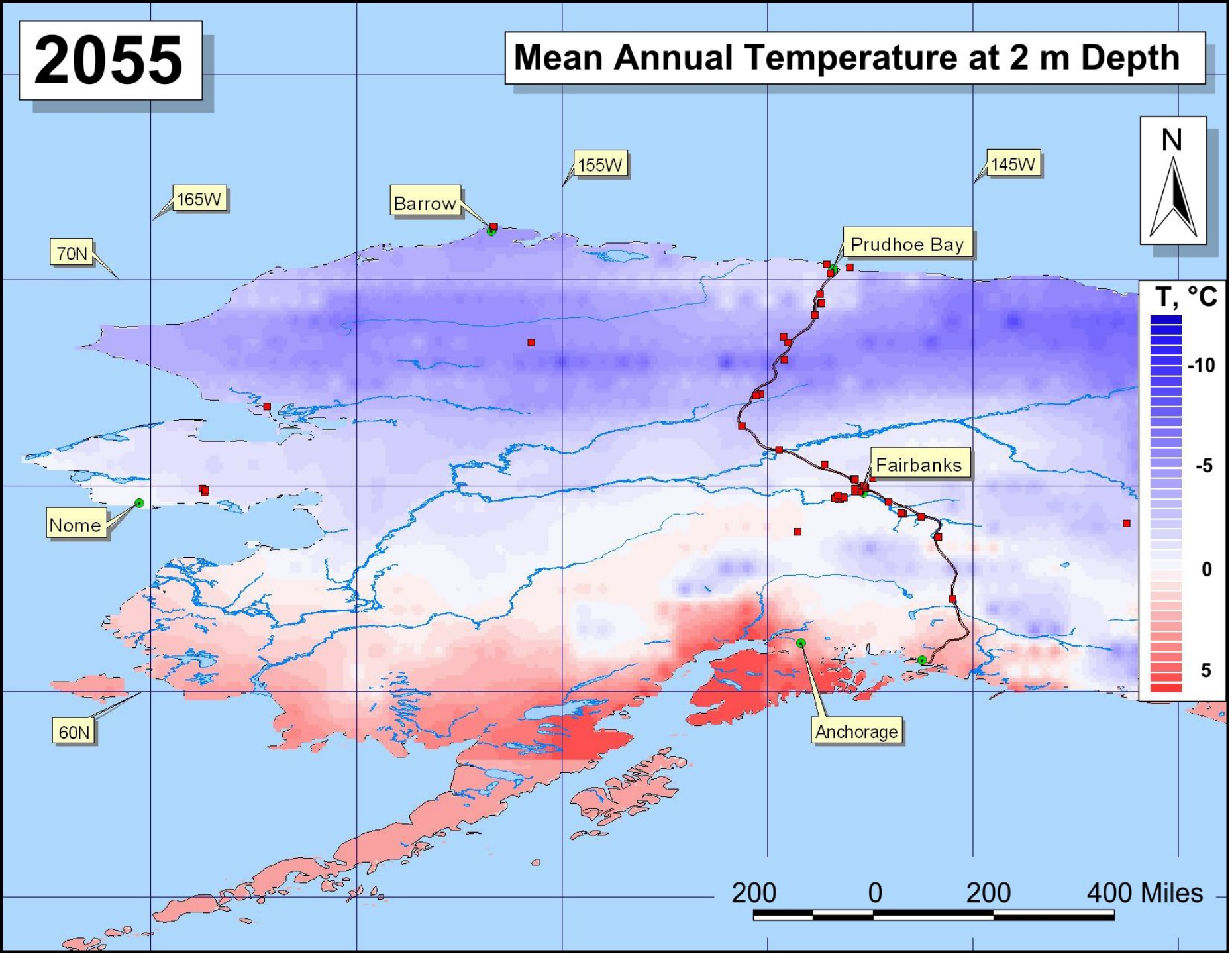

2030
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

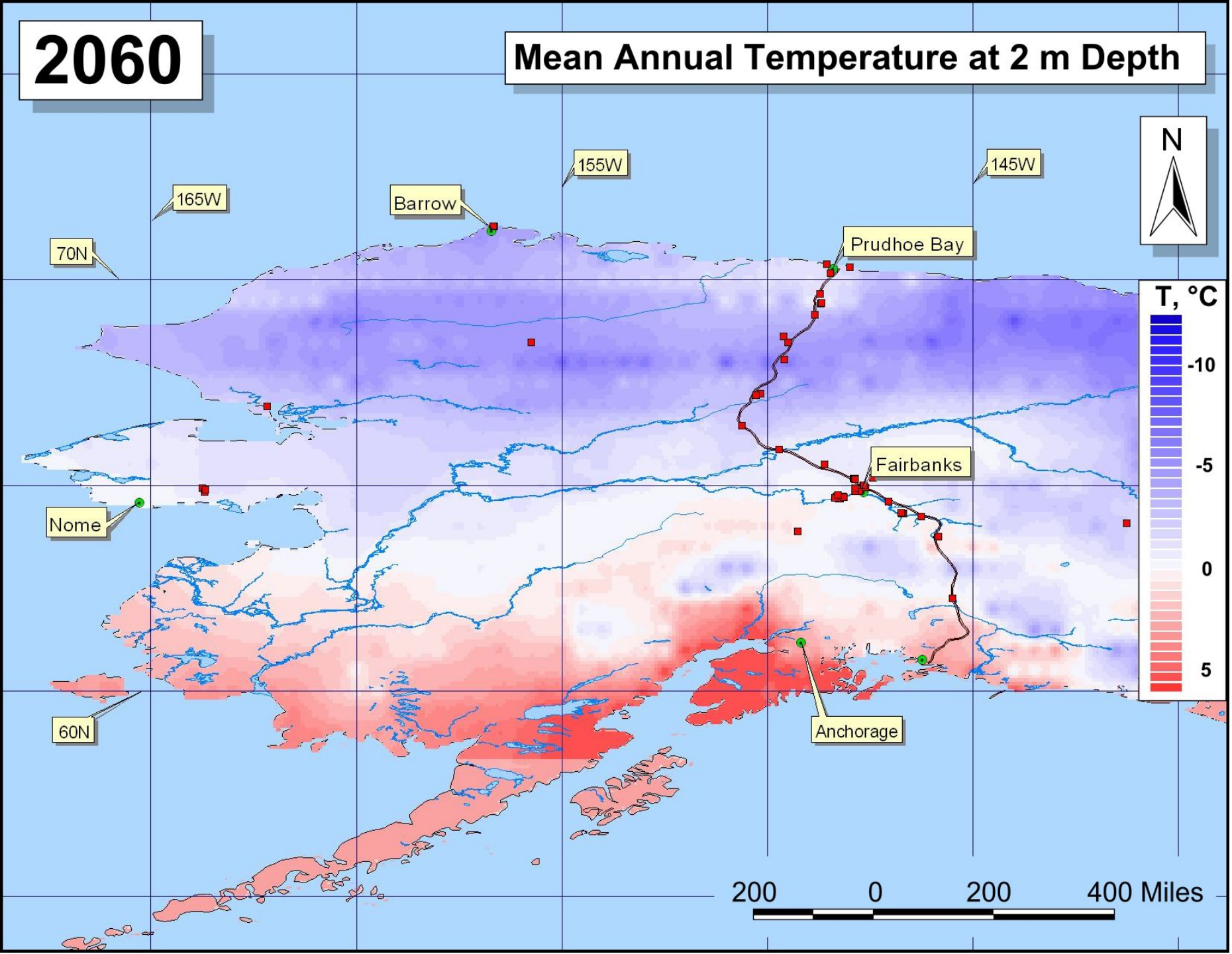

2035
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

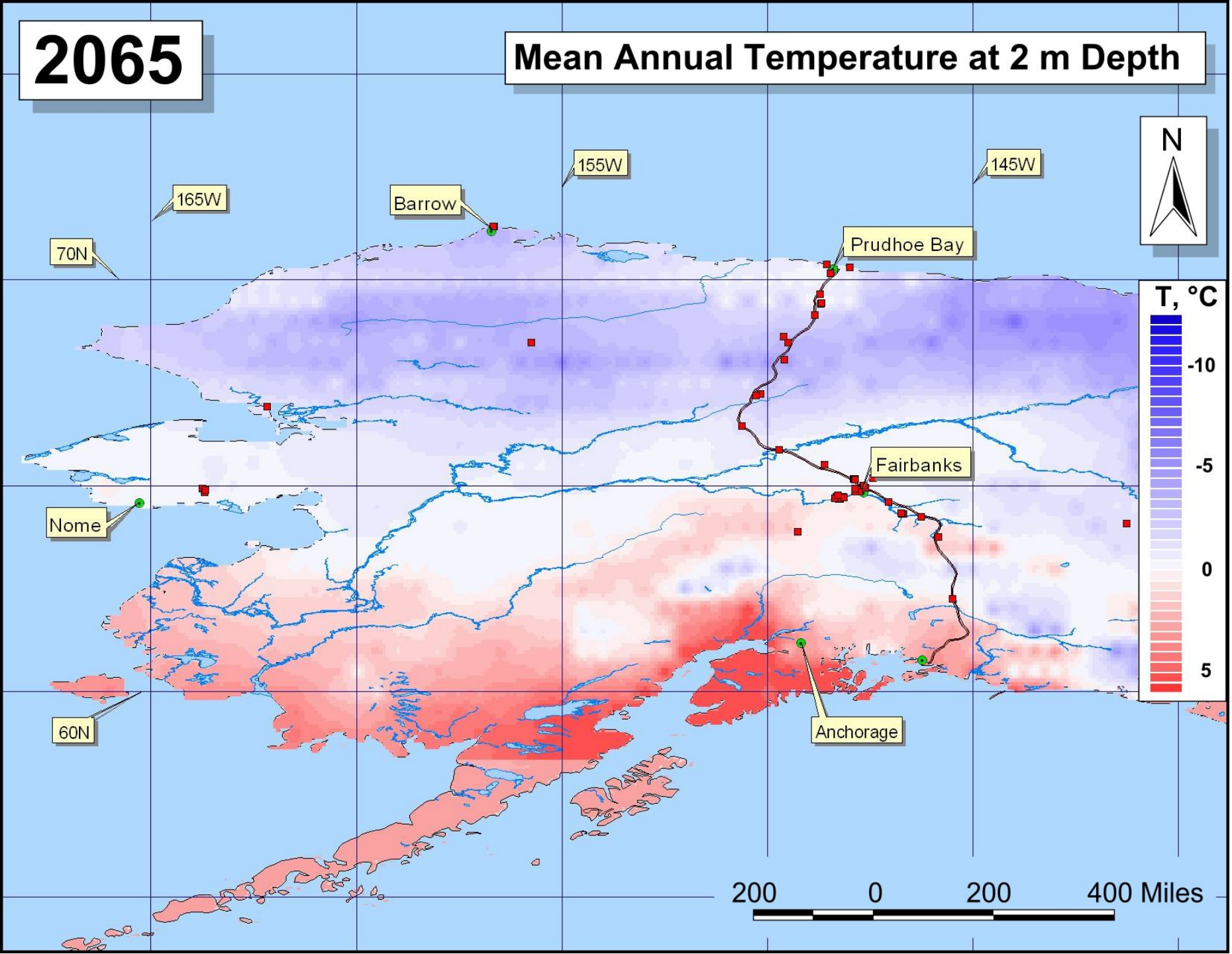

2040
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

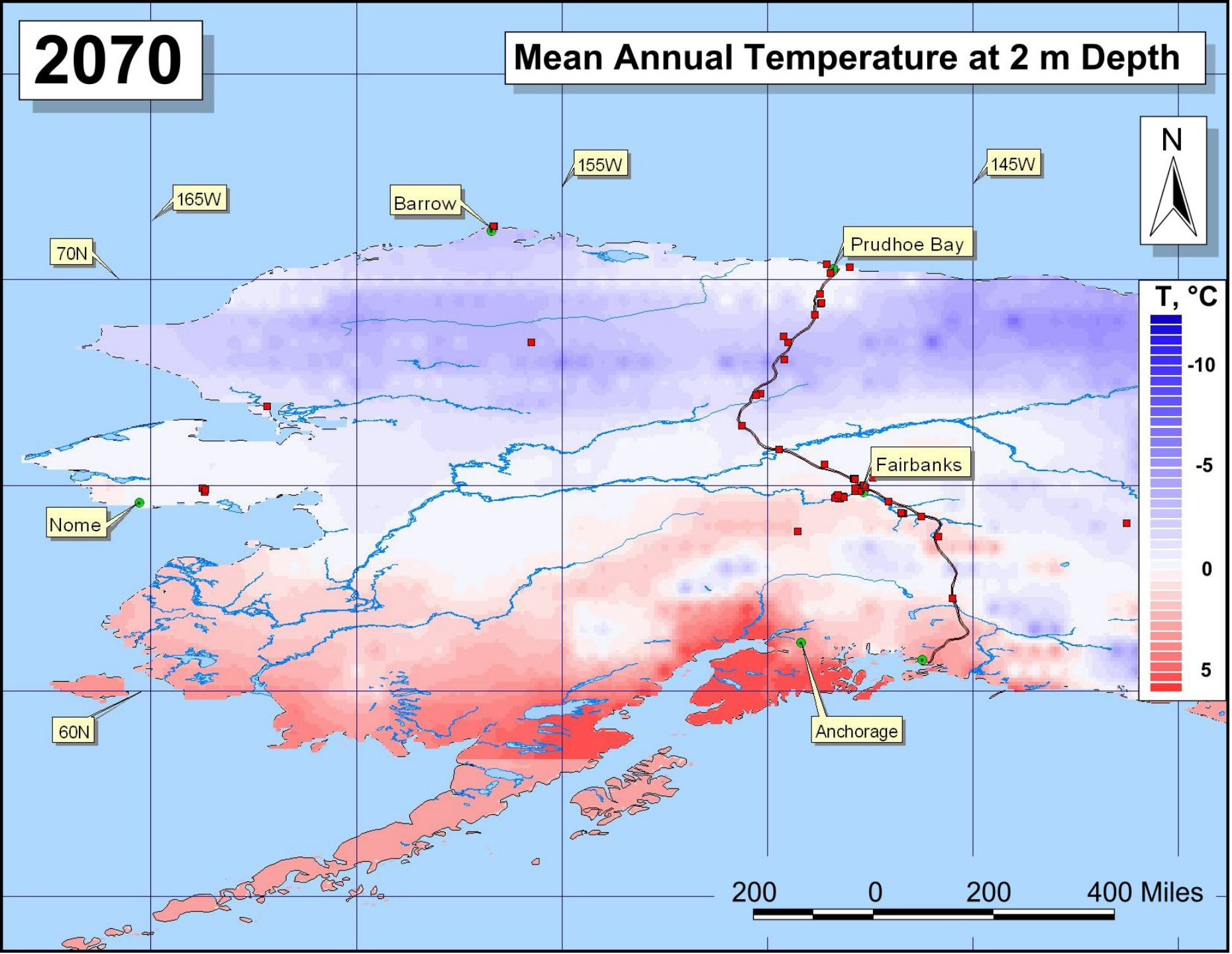

2045
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

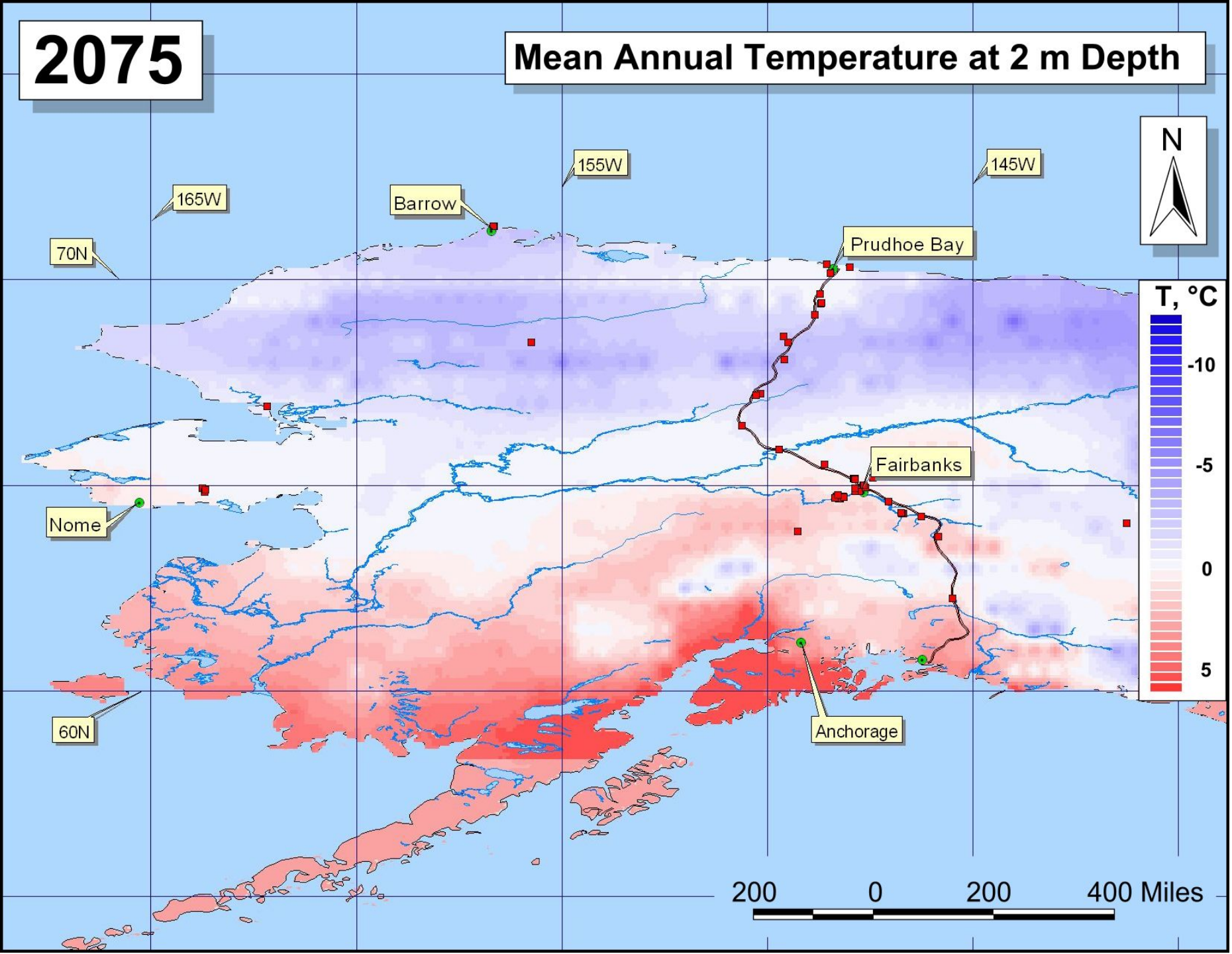

2050
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

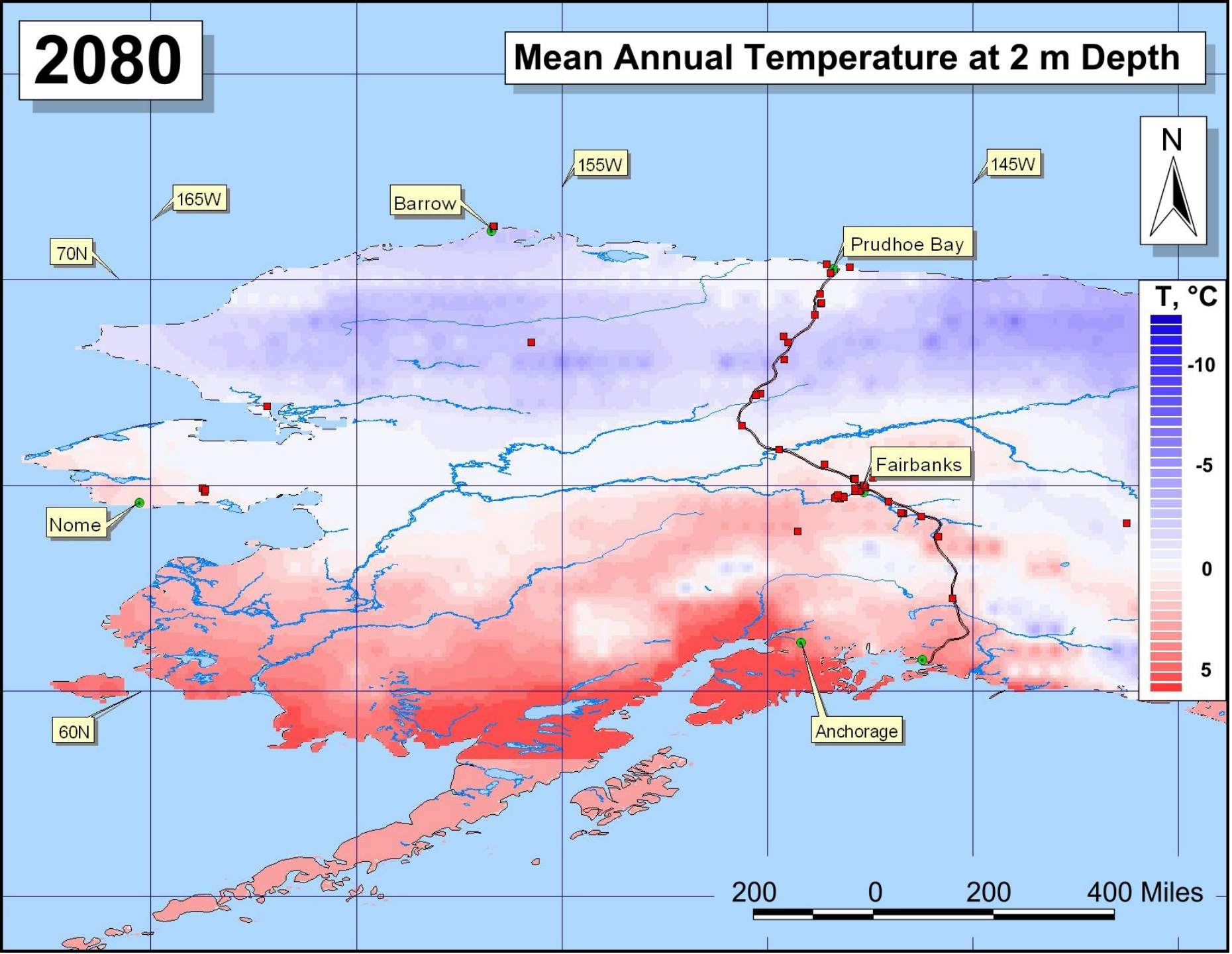

2055
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

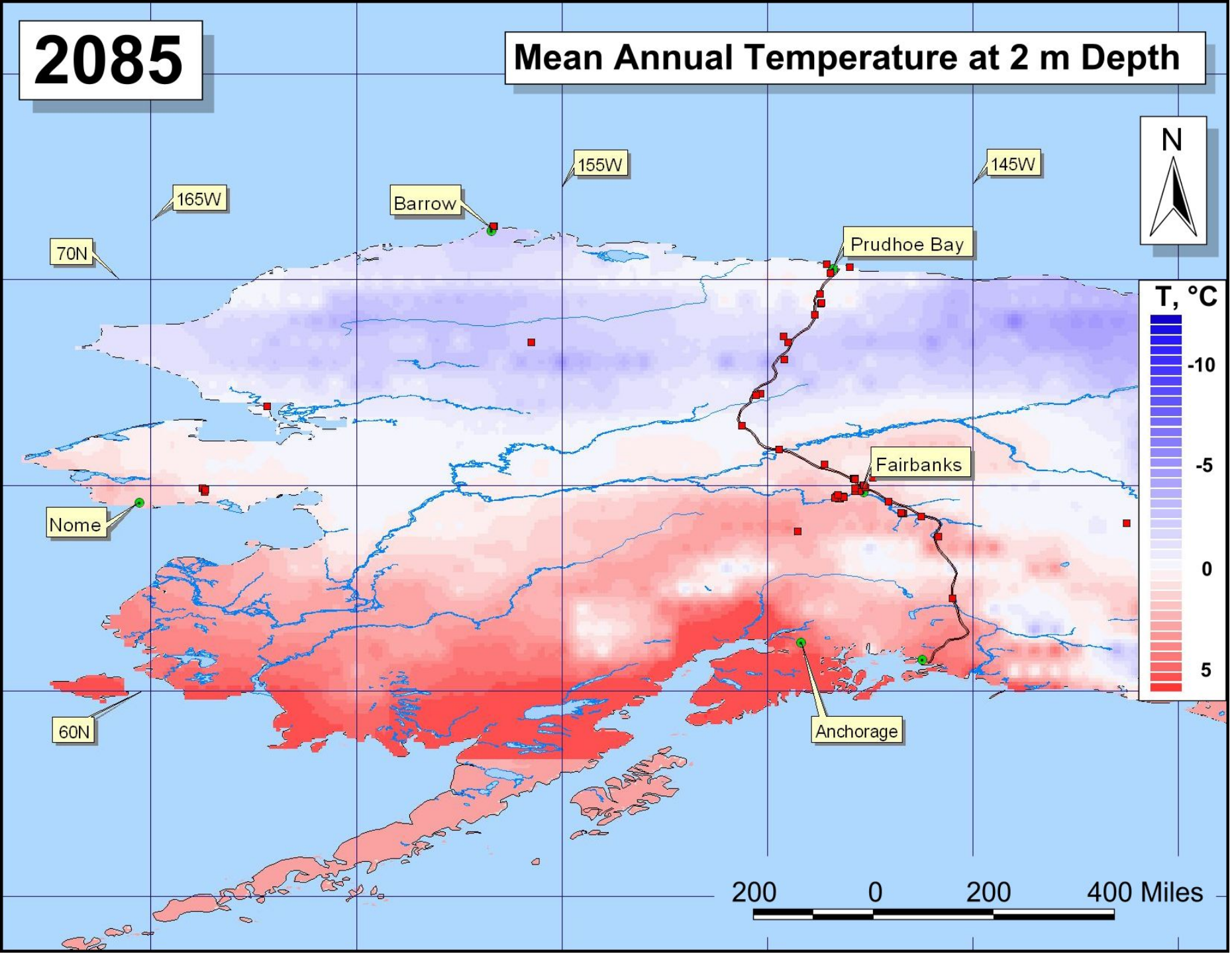

2060
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

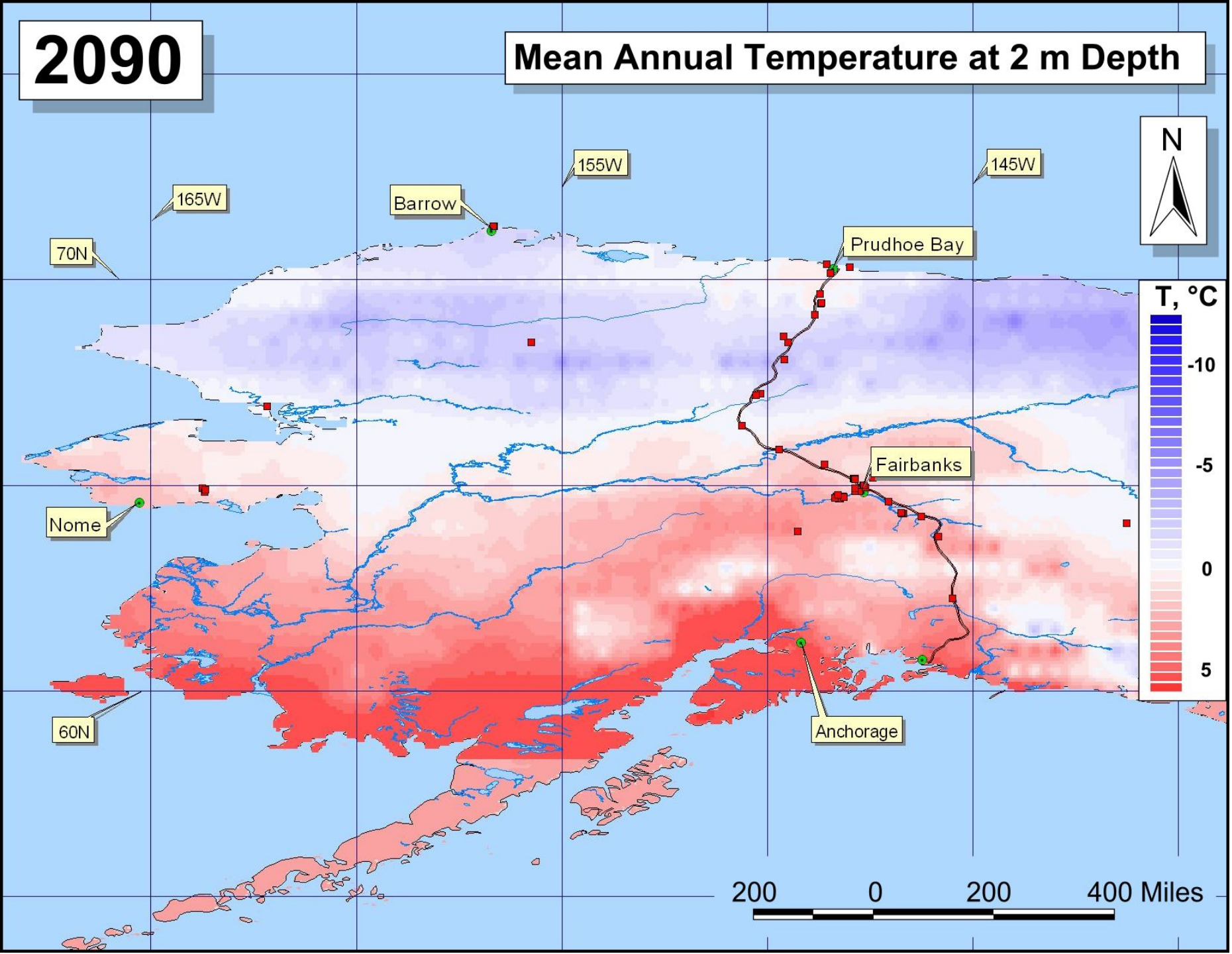

2065
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

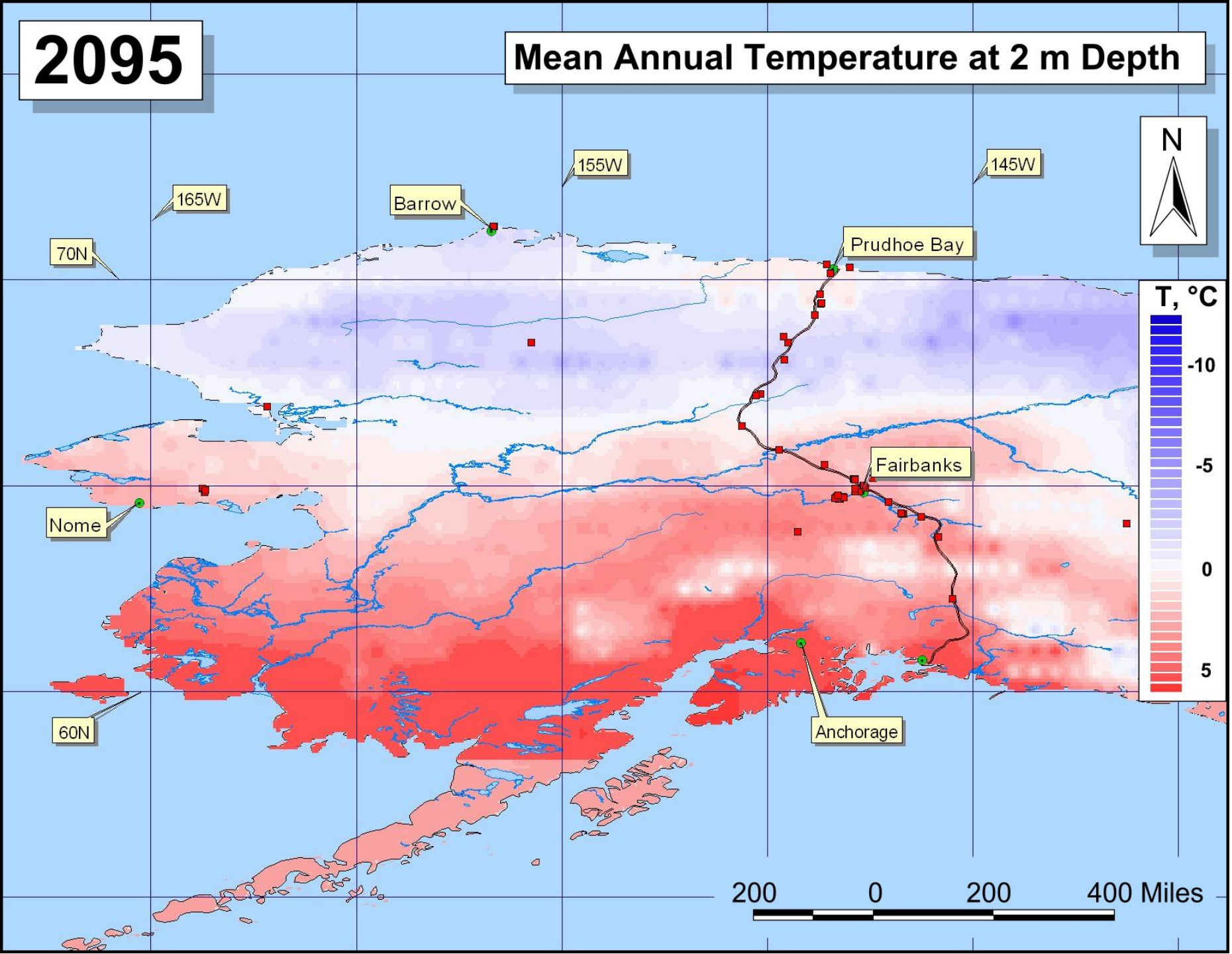

2070
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

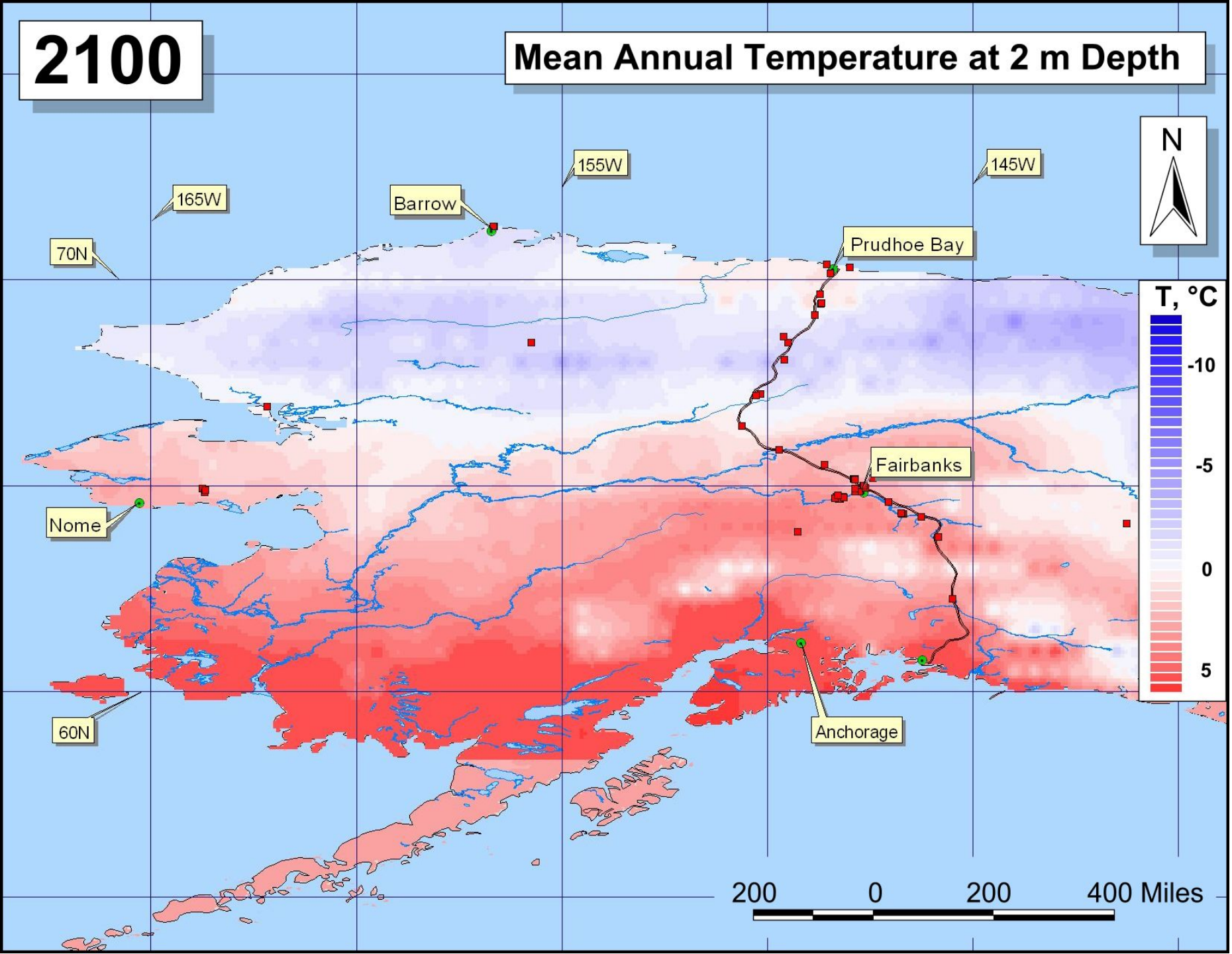

2075
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
Barrow
Prudhoe Bay
70N
Fairbanks
Nome
60N
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles


2080
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles


2085
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles


2090
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles


2095
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

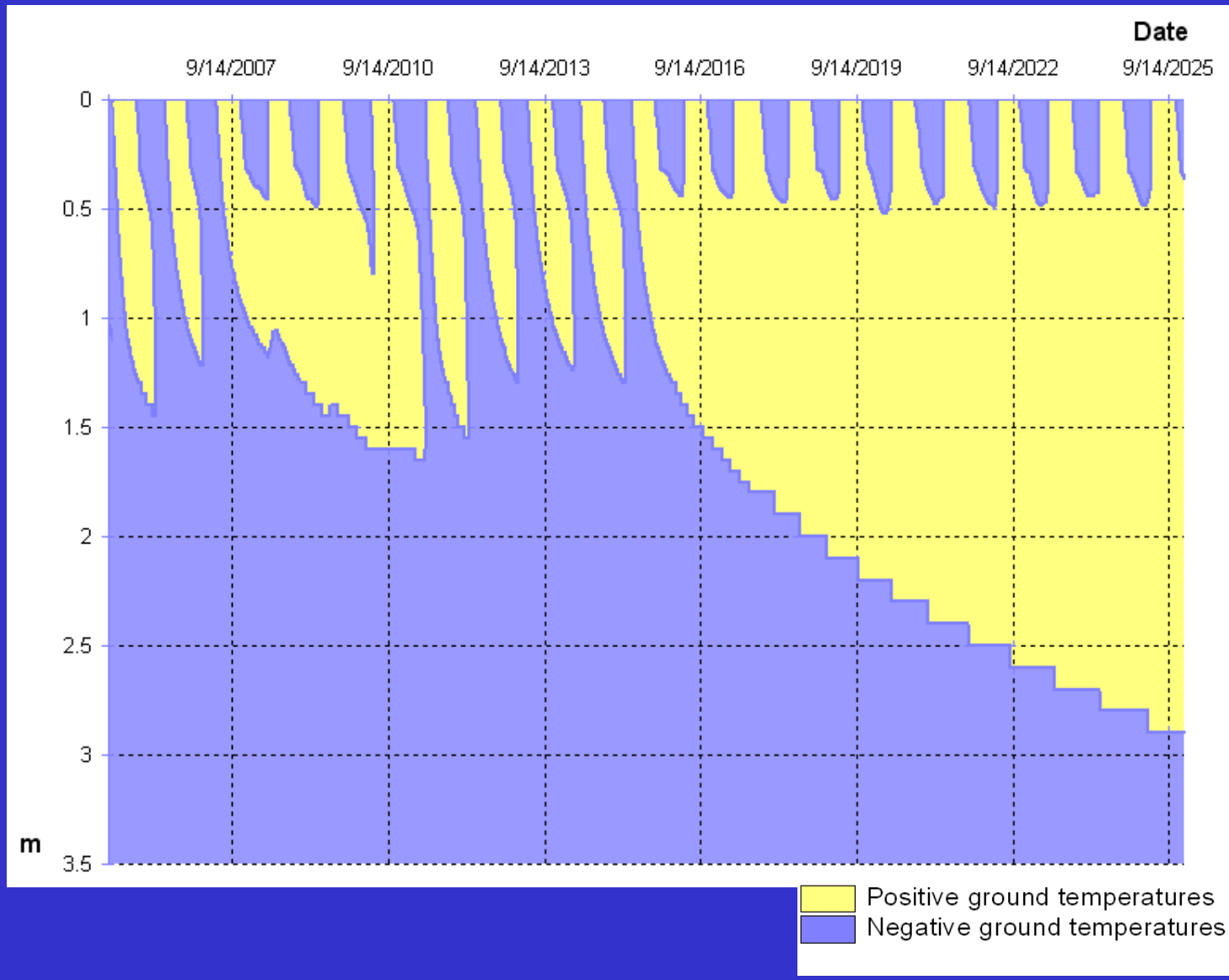

2100
Mean Annual Temperature at 2 m Depth
N
165W
155W
145W
70N
60N
Barrow
Prudhoe Bay
Fairbanks
Nome
Anchorage
T, °C
-10
-5
0
5
200
0
200
400 Miles

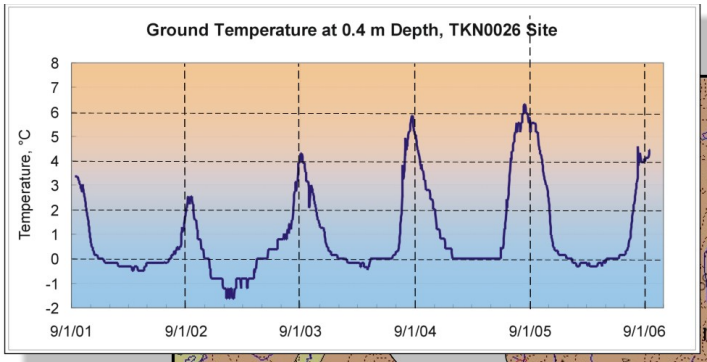
The nature and rate of permafrost degradation are different for regions with continuous and discontinuous permafrost

Permafrost Degradation

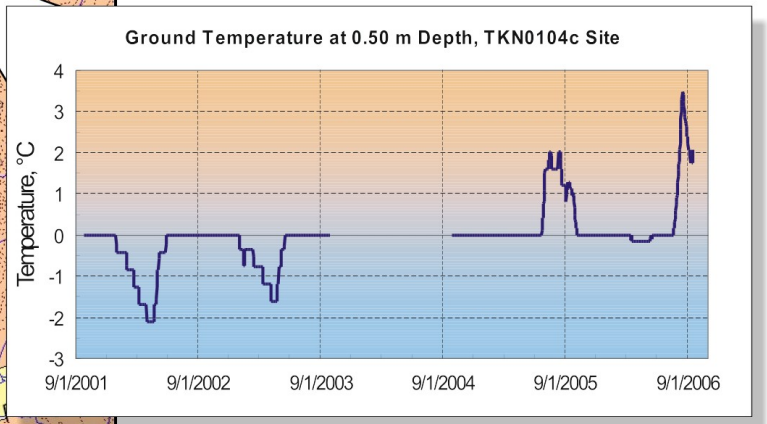
When temperature on the surface is getting warmer, the active layer does not freeze up during the winter, and permafrost degradation starts.

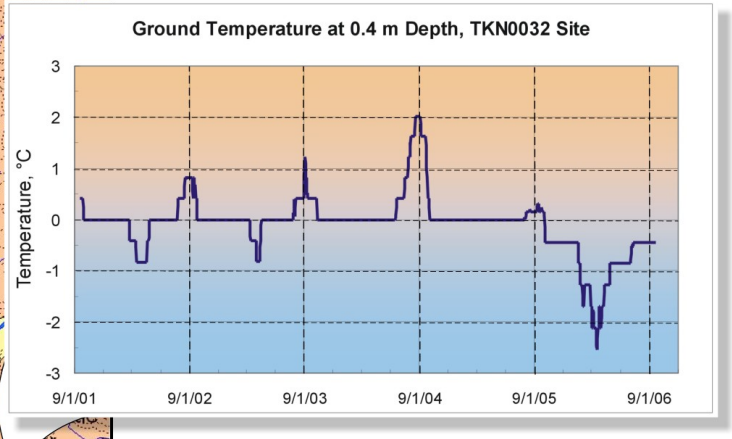
Active layer dynamics in Fairbanks




Ground Temperature at 0.4 m Depth, TKN0026 Site
Temperature, °C
8
7
6
5
4
3
2
1
0
-1
-2
9/1/01
9/1/02
9/1/03
9/1/04
9/1/05
9/1/06

NOME CREEK
CHATANIKA RIVER
Washington Creek
BABE CREEK
North aspect profile
Fox site
Goldstream Creek
(Romanovsky's
Smith
Potato Field
FAIRBANKS
CHENA
LTER-1
TANANA RIVER
EAFB
East
Delta


Ground Temperature at 0.50 m Depth, TKN0104c Site
Temperature, °C
4
3
2
1
0
-1
-2
-3
9/1/2001
9/1/2002
9/1/2003
9/1/2004
9/1/2005
9/1/2006

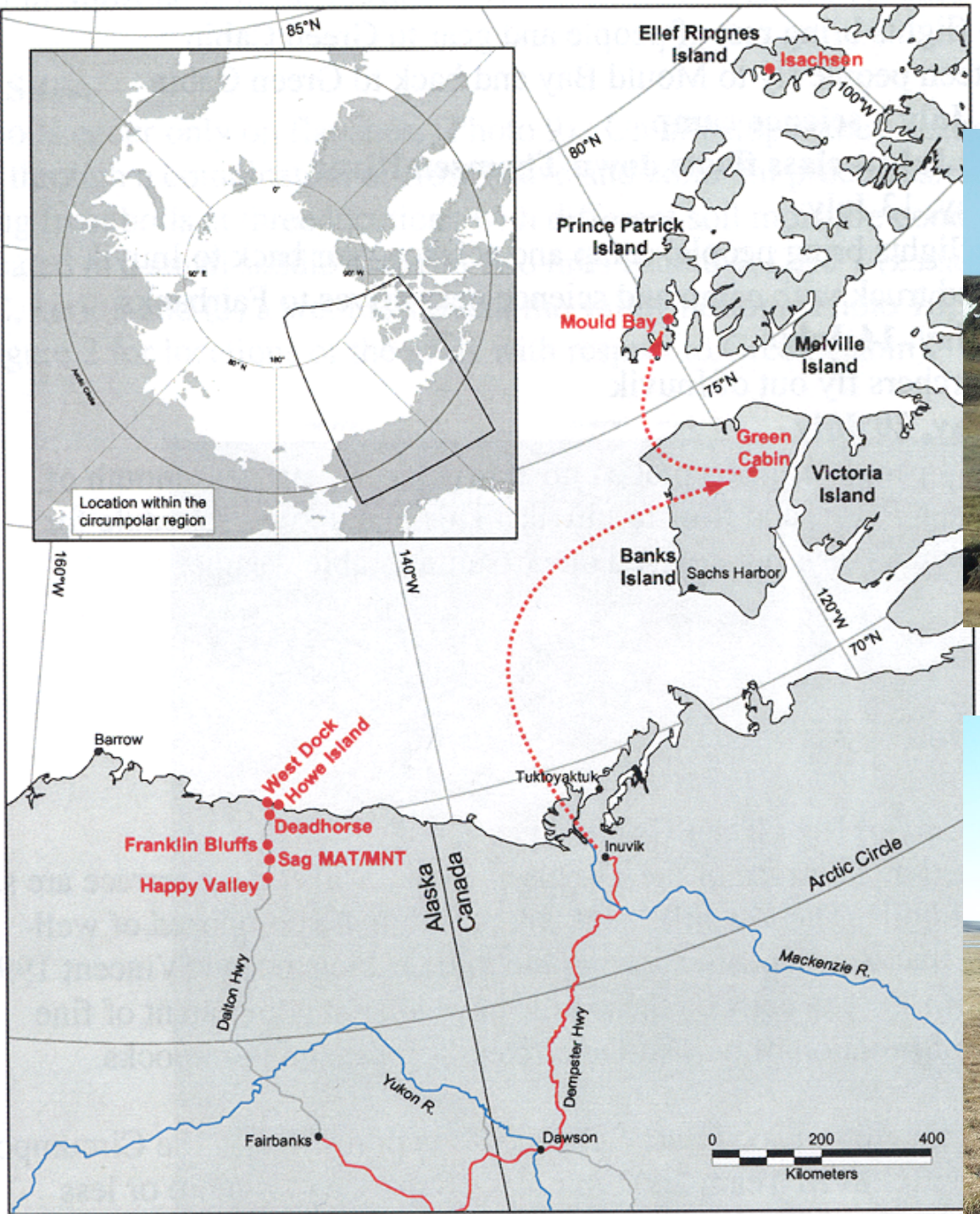

Ground Temperature at 0.4 m Depth, TKN0032 Site
Temperature, °C
3
2
1
0
-1
-2
-3
9/1/01
9/1/02
9/1/03
9/1/04
9/1/05
9/1/06

Ground Temperature at 0.4 m Depth, TKN0026 Site
Temperature, °C
4
2
0
-2
-4
-6
-8
9/1/2001
9/1/2002
9/1/2003
9/1/2004
9/1/2005

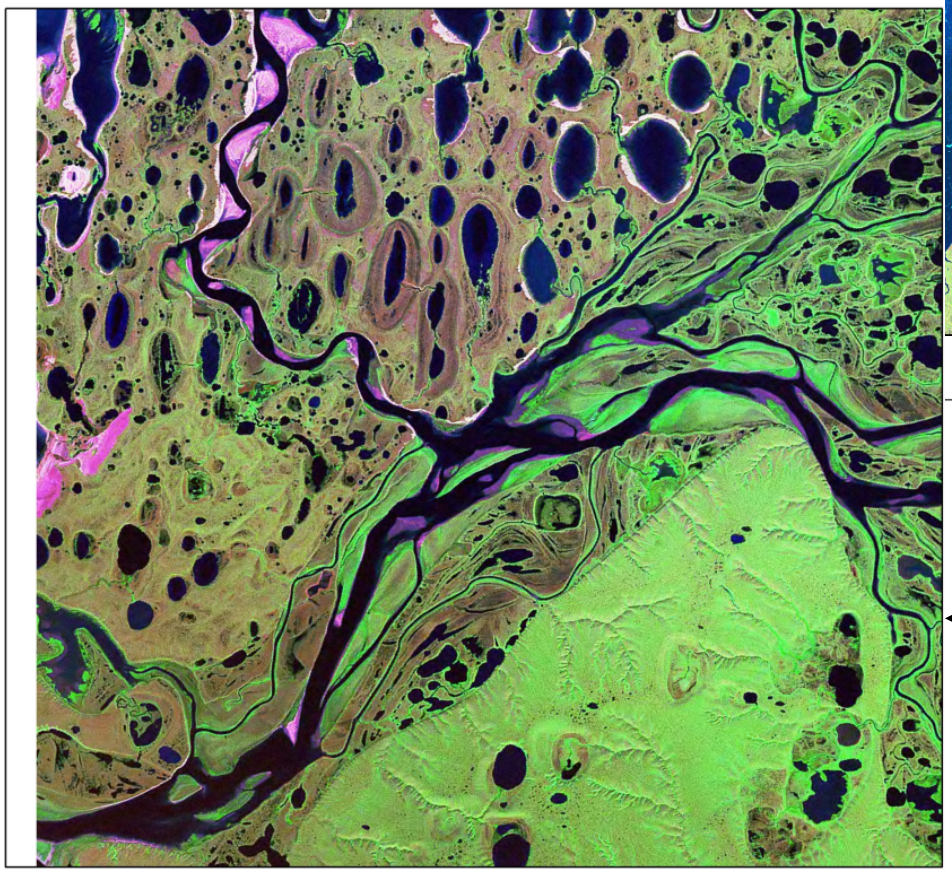
Photograph by T. Jorgenson

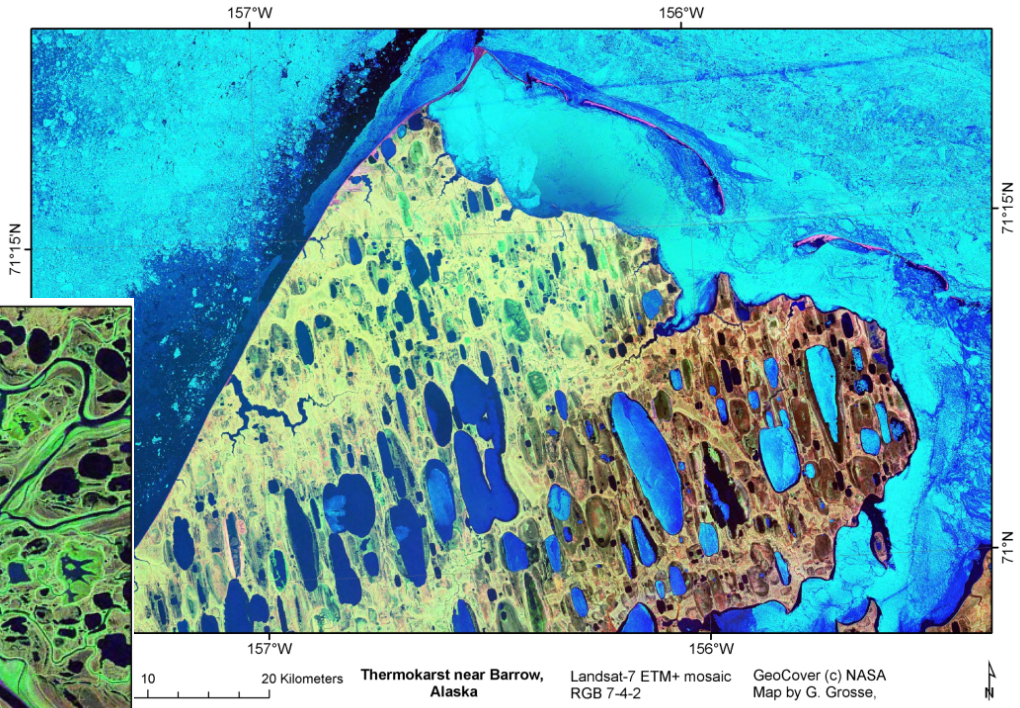
In the area of “wet thermokarst” formation, new and significant sources of CH_4 production will be developing. There will be a considerable difference in greenhouse production from degrading permafrost depending on a different type of substrate and soil carbon quantity and quality.

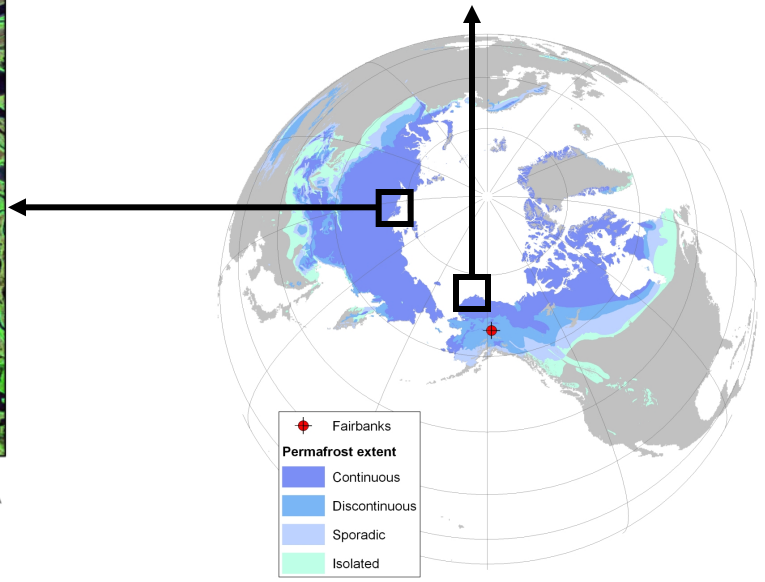

Photo by Ken Tape


85°N
Ellef Ringnes Island
Isachsen
100°W
80°N
Prince Patrick Island
Mould Bay
Melville Island
75°N
Green Cabin
Victoria Island
Banks Island
Sachs Harbor
120°W
70°N
160°W
140°W
Location within the circumpolar region
Barrow
West Dock
Howe Island
Deadhorse
Franklin Bluffs
Sag MAT/MNT
Happy Valley
Tuktoyaktuk
Inuvik
Alaska
Canada
Arctic Circle
Dalton Hwy
Mackenzie R.
Yukon R.
Dempster Hwy
Fairbanks
Dawson
0
200
400
Kilometers

Examples for Arctic landscapes affected by massive permafrost degradation (thermokarst)







Thank you very much !

www.gi.alaska.edu/snowice/Permafrost-lab