Changes in Permafrost, Observed and Modeled

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Global Terrestrial Network-Permafrost (GTN-P):
Thermal State of Permafrost (TSP)

~ 850 stations

TSP Countries

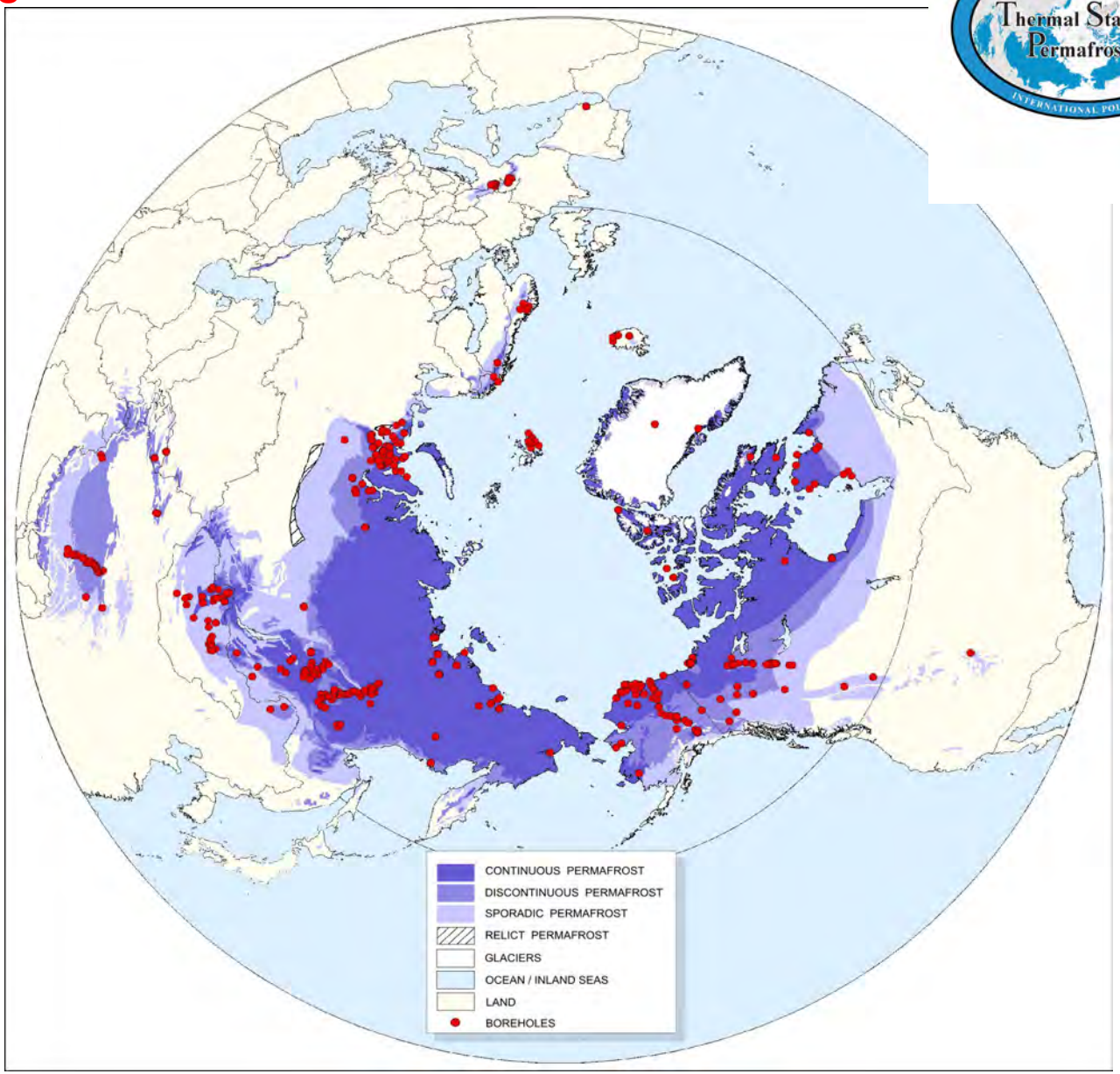
Canada
China
Denmark (Greenland)
Germany (Russia)
Iceland
Italy
Kazakhstan
Mongolia
Norway (NORPERM)
Poland
Russia
Sweden
Switzerland (PERMOS)
USA

~ 760 stations

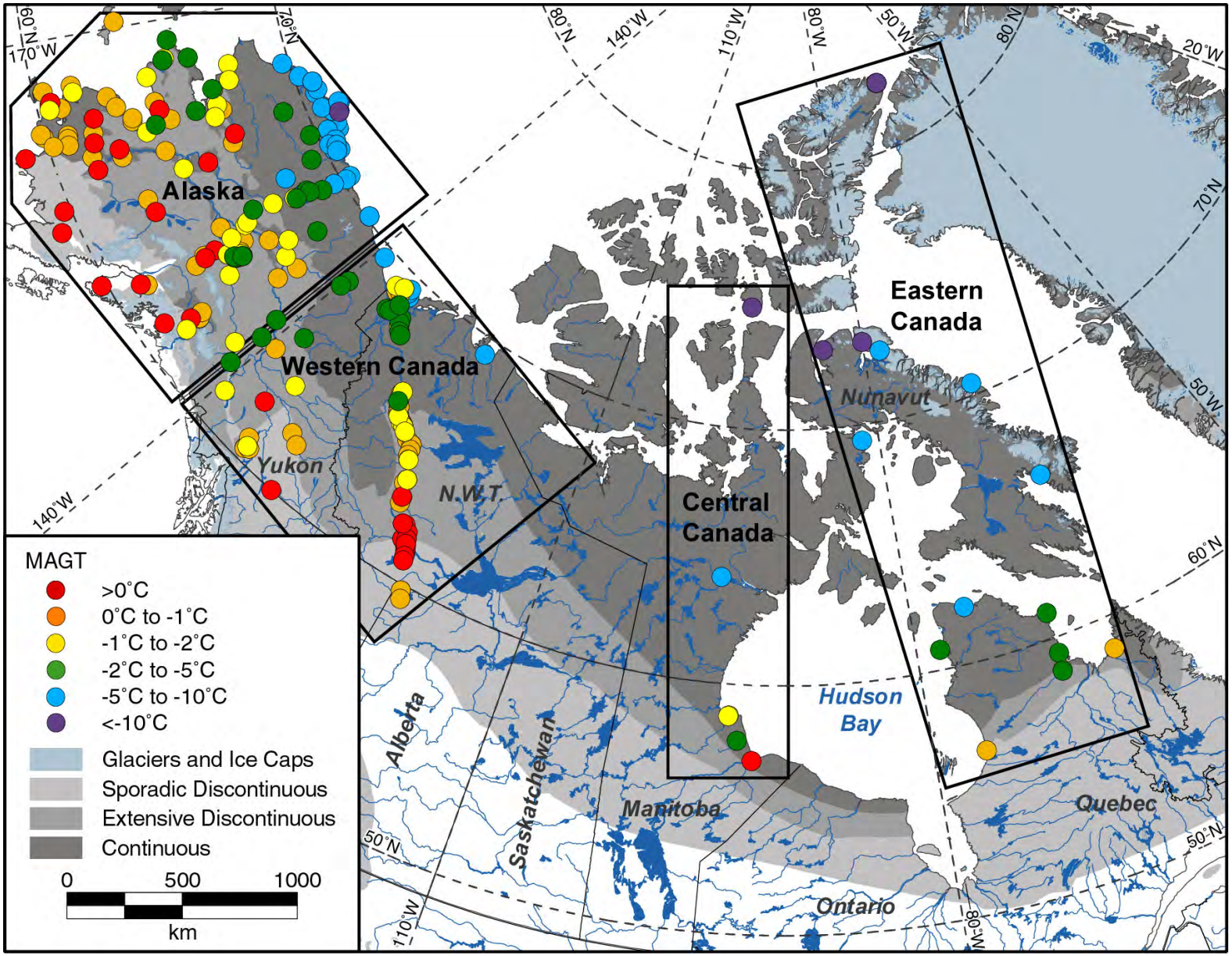
Southern Hemisphere

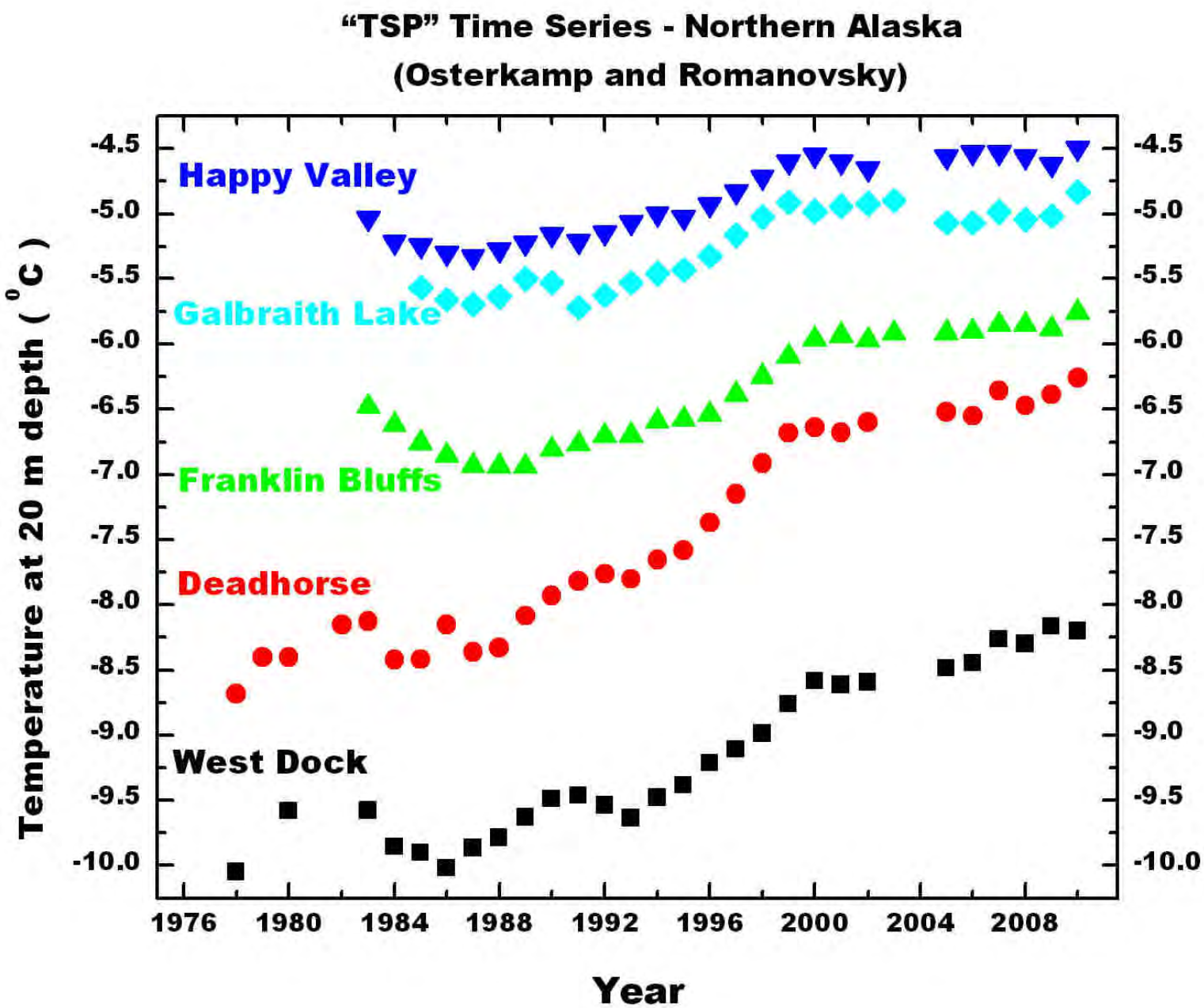
Italy
New Zealand
Portugal-Spain
Russia
USA

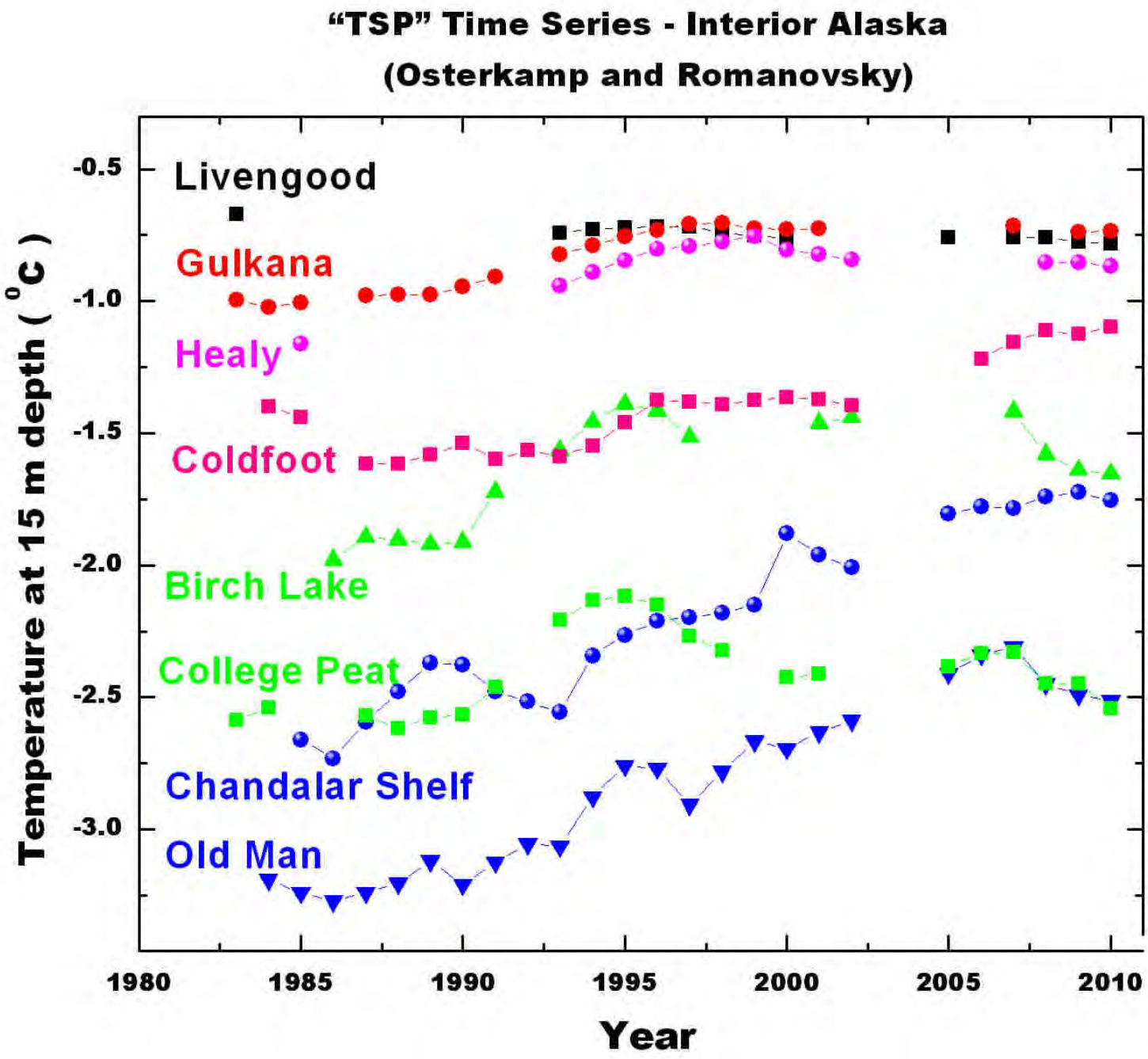
~ 90 stations



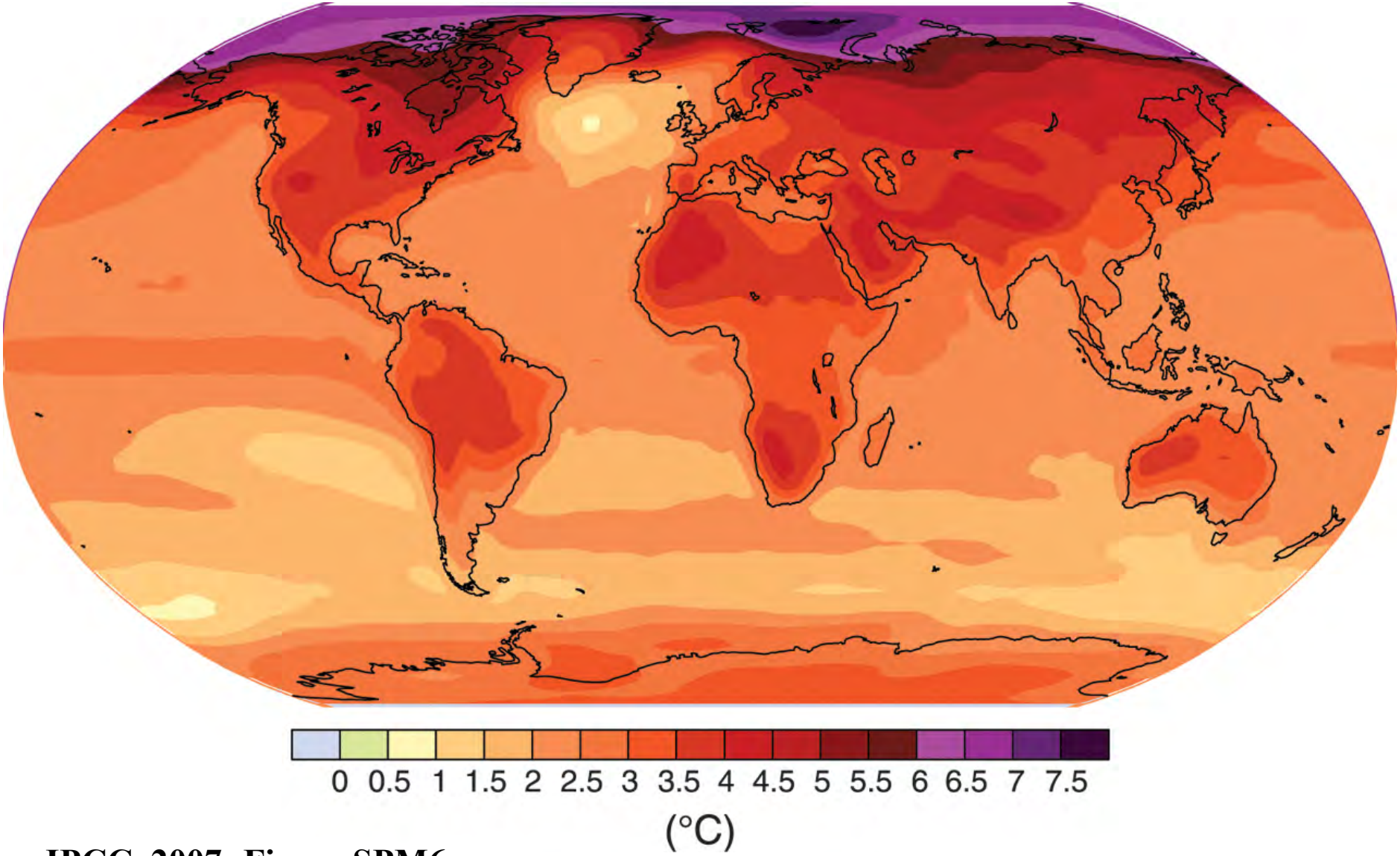
IPY TSP Snapshot



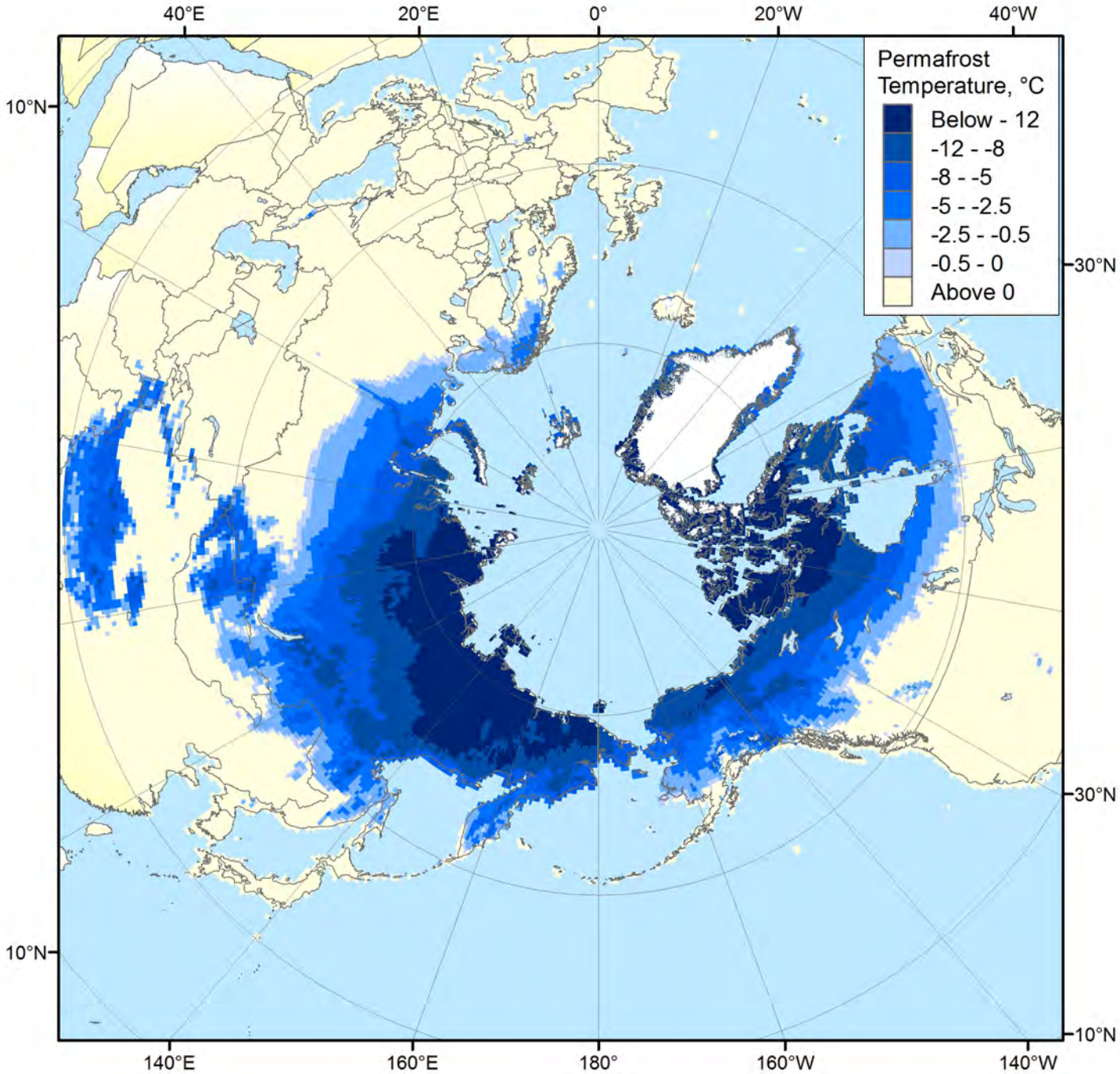

"TSP" Time Series - Northern Alaska
(Osterkamp and Romanovsky)
Happy Valley
Galbraith Lake
Franklin Bluffs
Deadhorse
West Dock
Temperature at 20 m depth (°C)
-4.5
-5.0
-5.5
-6.0
-6.5
-7.0
-7.5
-8.0
-8.5
-9.0
-9.5
-10.0
1976
1980
1984
1988
1992
1996
2000
2004
2008
Year

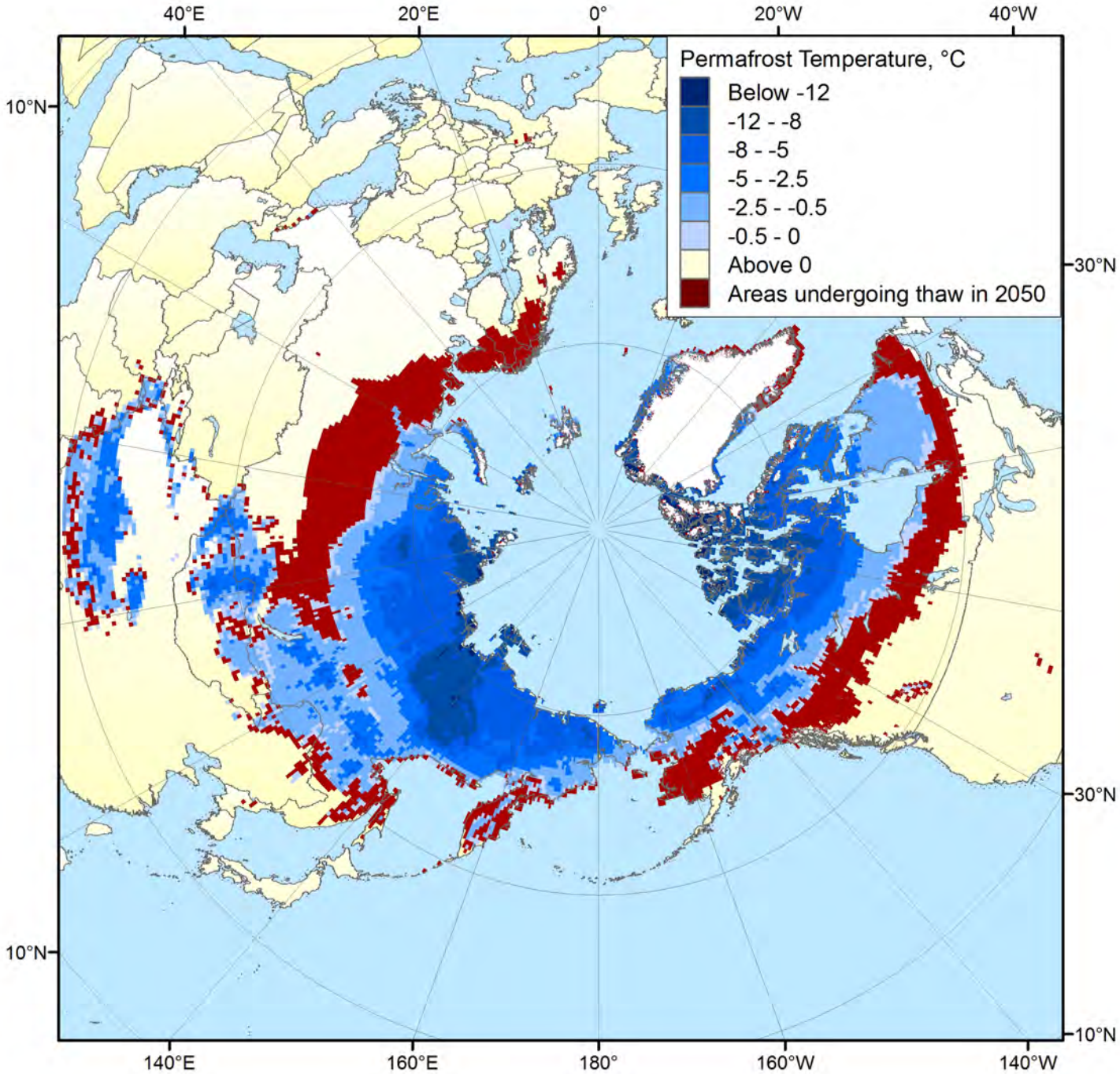

"TSP" Time Series - Interior Alaska
(Osterkamp and Romanovsky)
Livengood
Gulkana
Healy
Coldfoot
Birch Lake
College Peat
Chandalar Shelf
Old Man
Temperature at 15 m depth (°C)
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
1980
1985
1990
1995
2000
2005
2010
Year

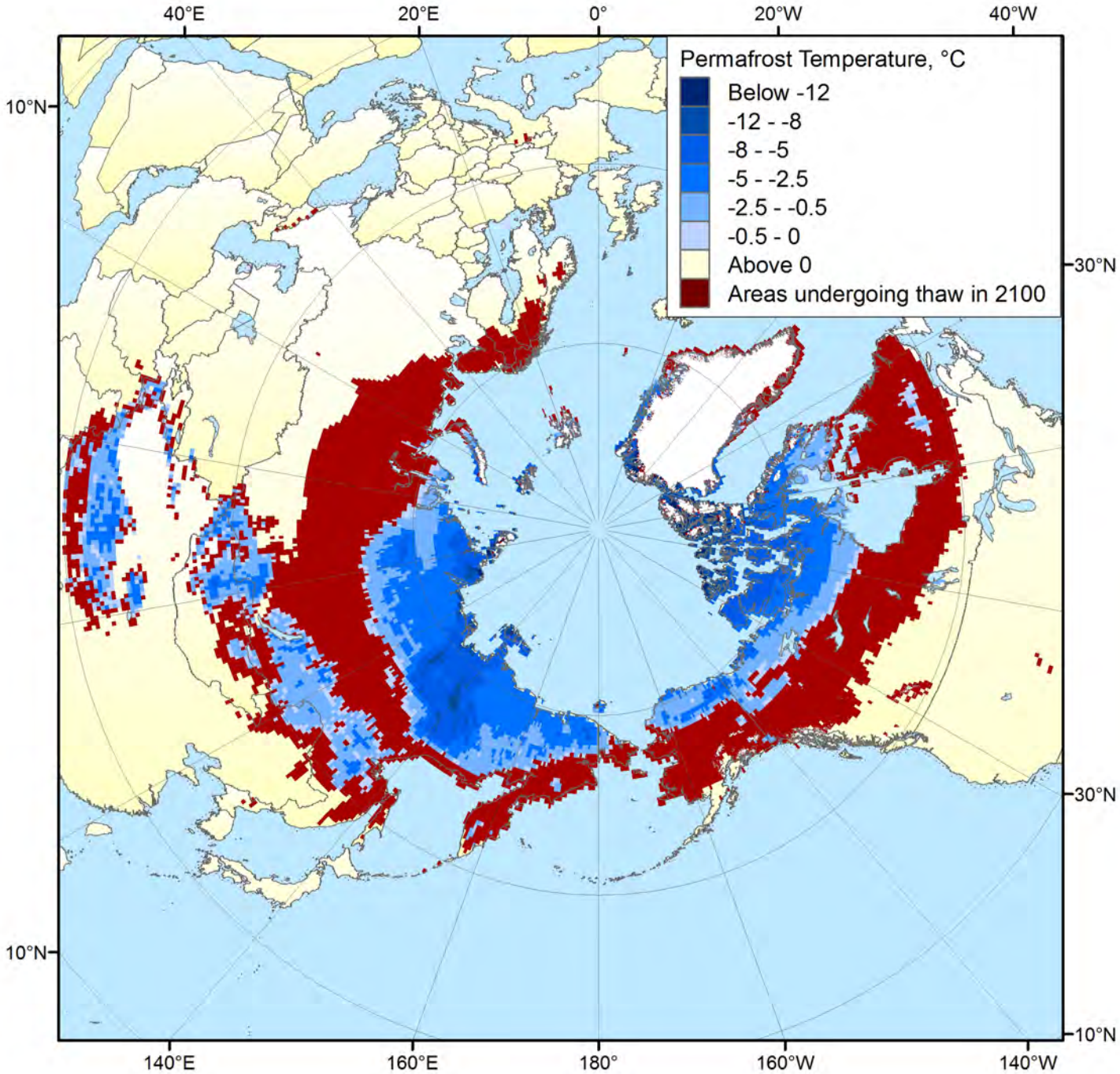
Projected surface air temperature (2090-2099 relative to 1980-1999)

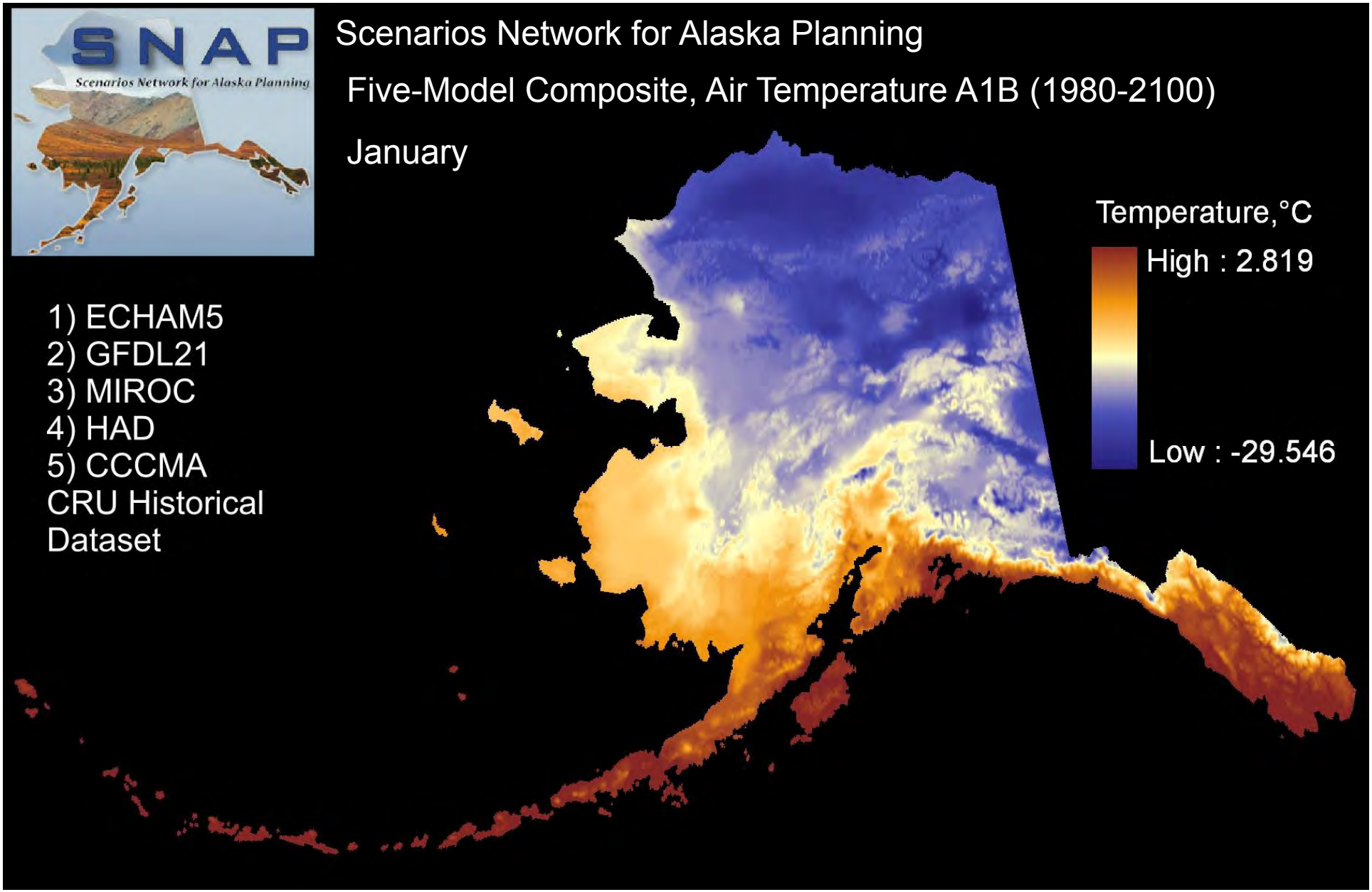


IPCC, 2007; Figure SPM6

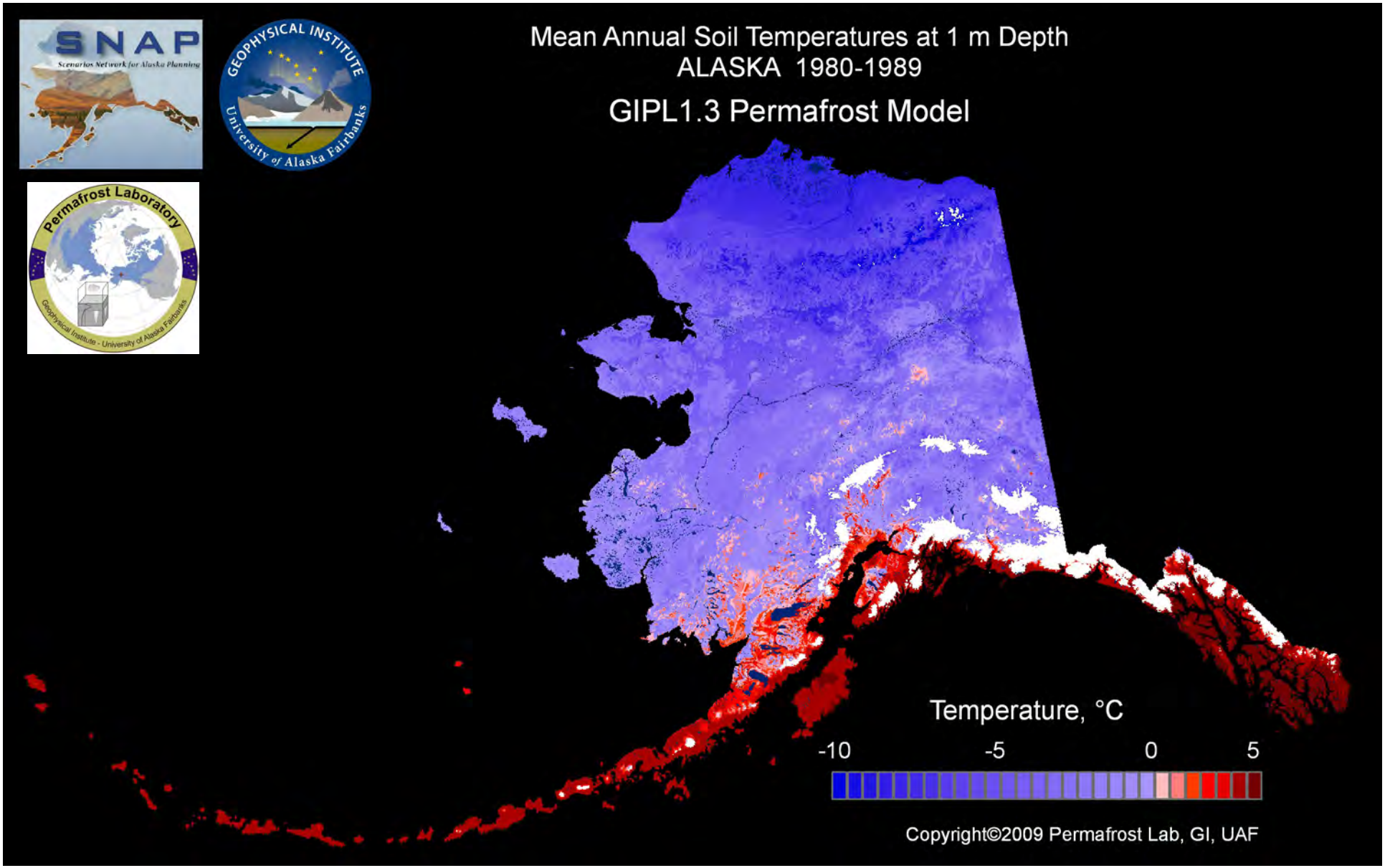

Permafrost Temperature, °C
Below - 12
-12 - -8
-8 - -5
-5 - -2.5
-2.5 - -0.5
-0.5 - 0
Above 0
40°E
20°E
0°
20°W
40°W
10°N
30°N
30°N
10°N
10°N
140°E
160°E
180°
160°W
140°W

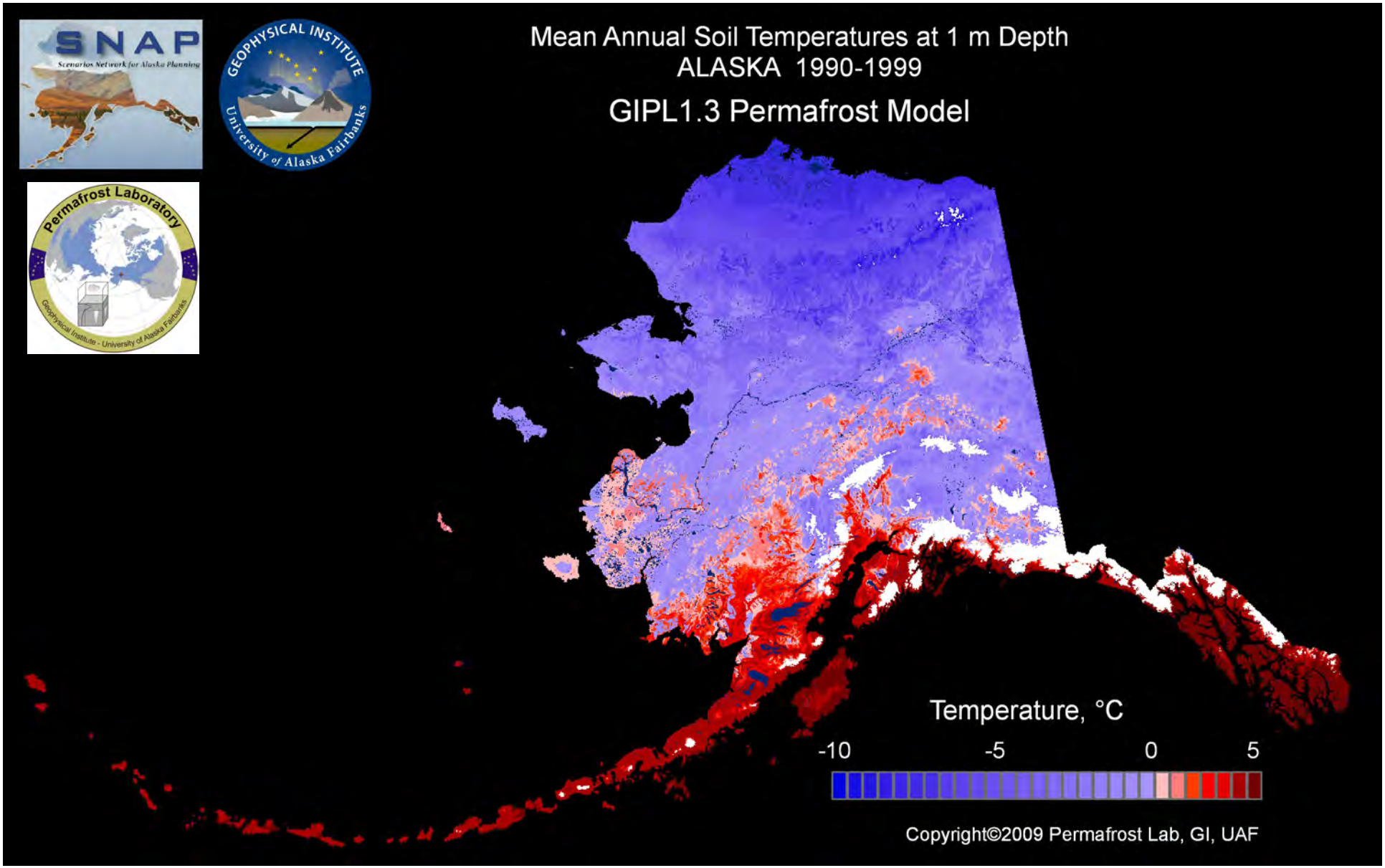

Permafrost Temperature, °C
Below -12
-12 - -8
-8 - -5
-5 - -2.5
-2.5 - -0.5
-0.5 - 0
Above 0
Areas undergoing thaw in 2050
40°E
20°E
0°
20°W
40°W
10°N
30°N
30°N
10°N
10°N
140°E
160°E
180°
160°W
140°W

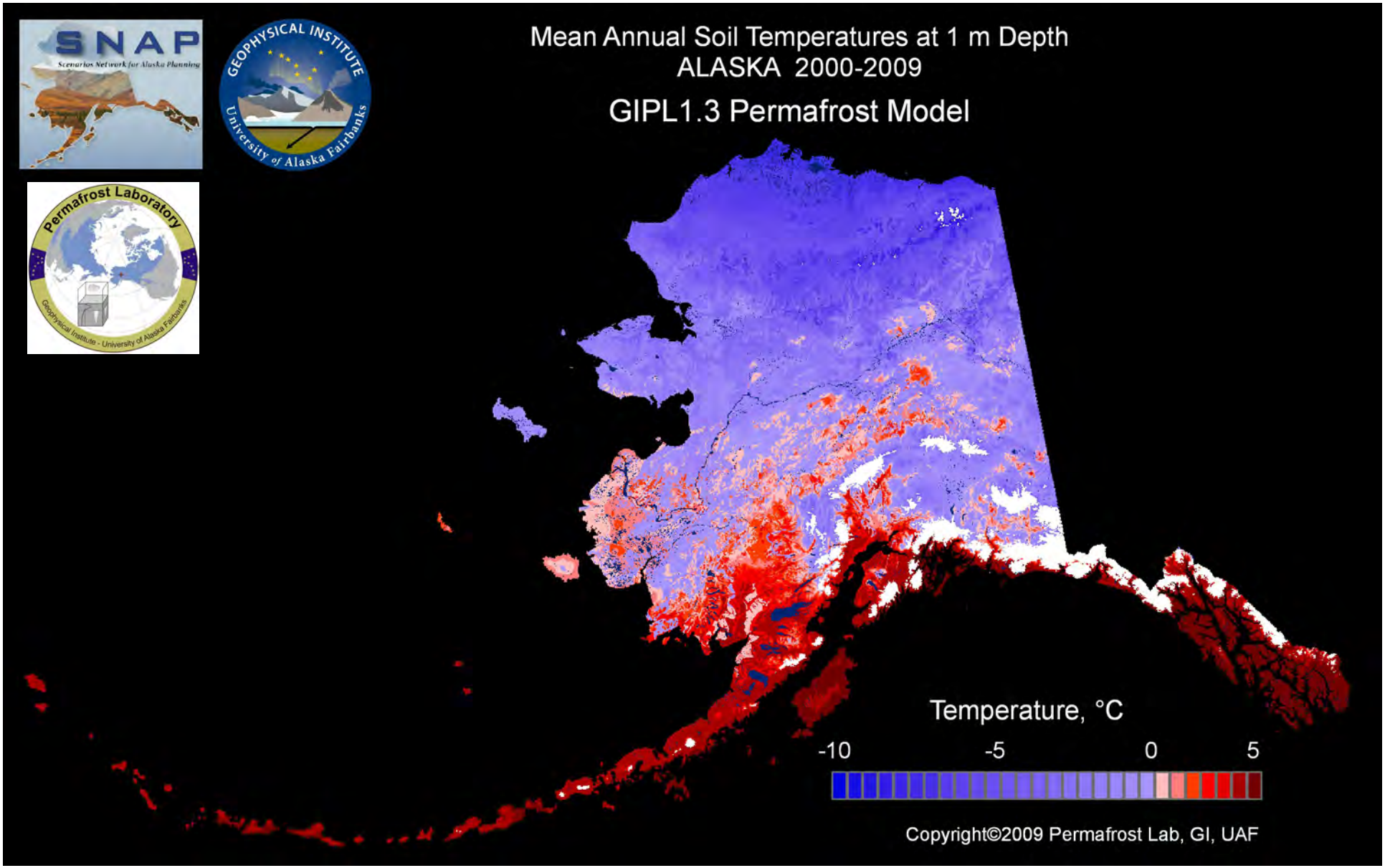

Permafrost Temperature, °C
Below -12
-12 - -8
-8 - -5
-5 - -2.5
-2.5 - -0.5
-0.5 - 0
Above 0
Areas undergoing thaw in 2100
40°E
20°E
0°
20°W
40°W
10°N
30°N
30°N
10°N
10°N
140°E
160°E
180°
160°W
140°W

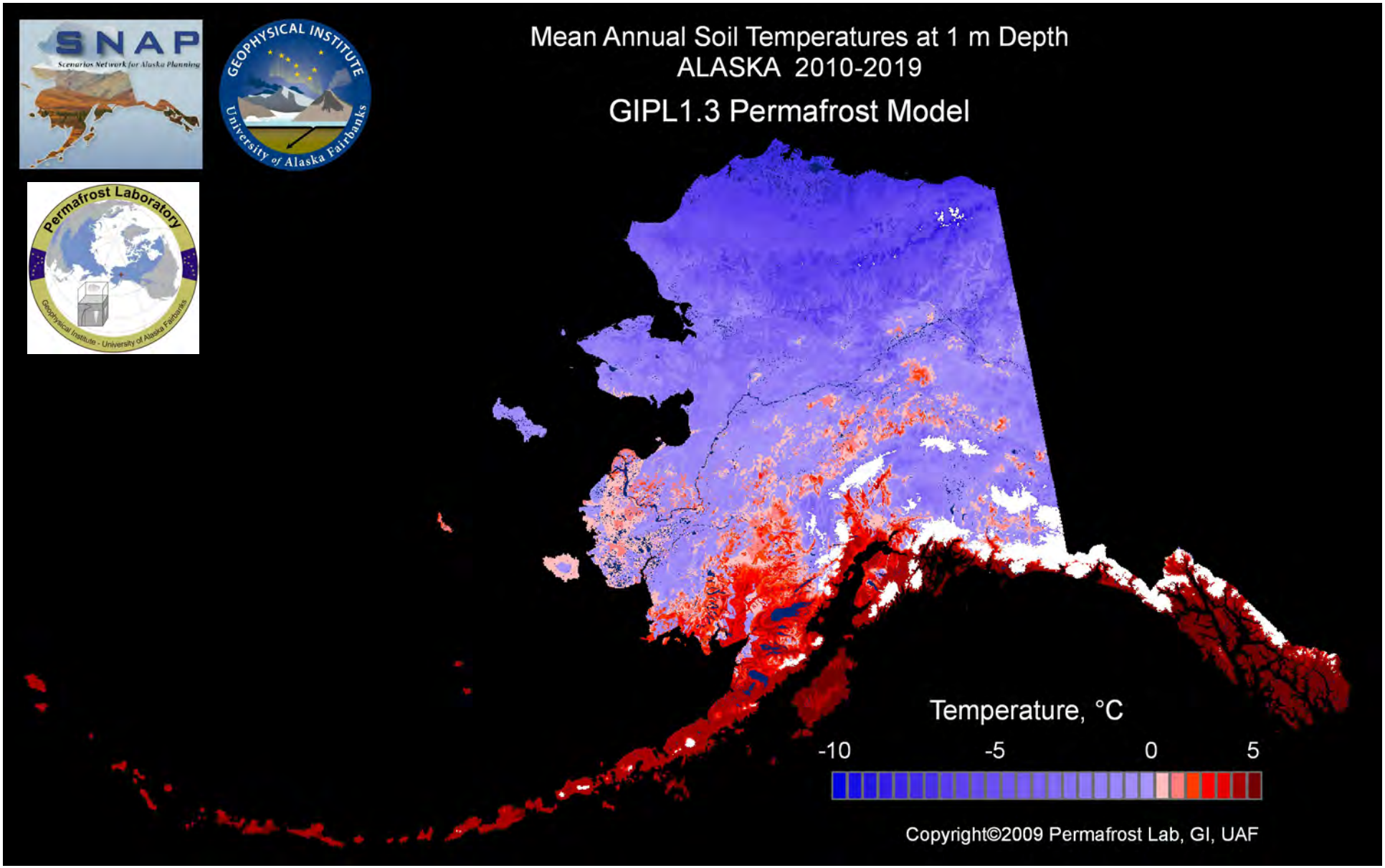


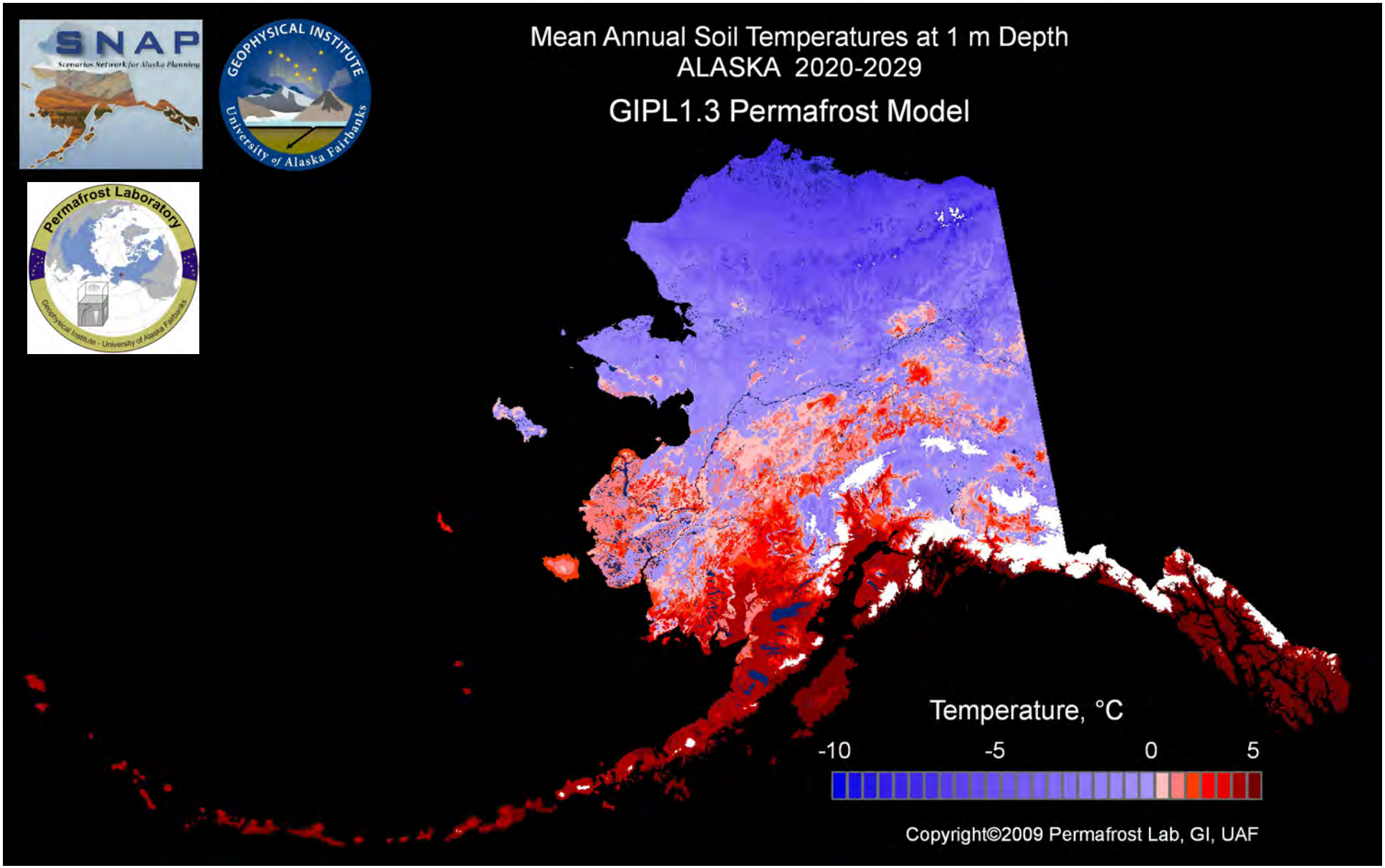
Temperature data (representing the A1B mid-range climate scenario as defined by the International Panel on Climate Change) down-scaled at the 2 km grid resolution (410,205 grid points).

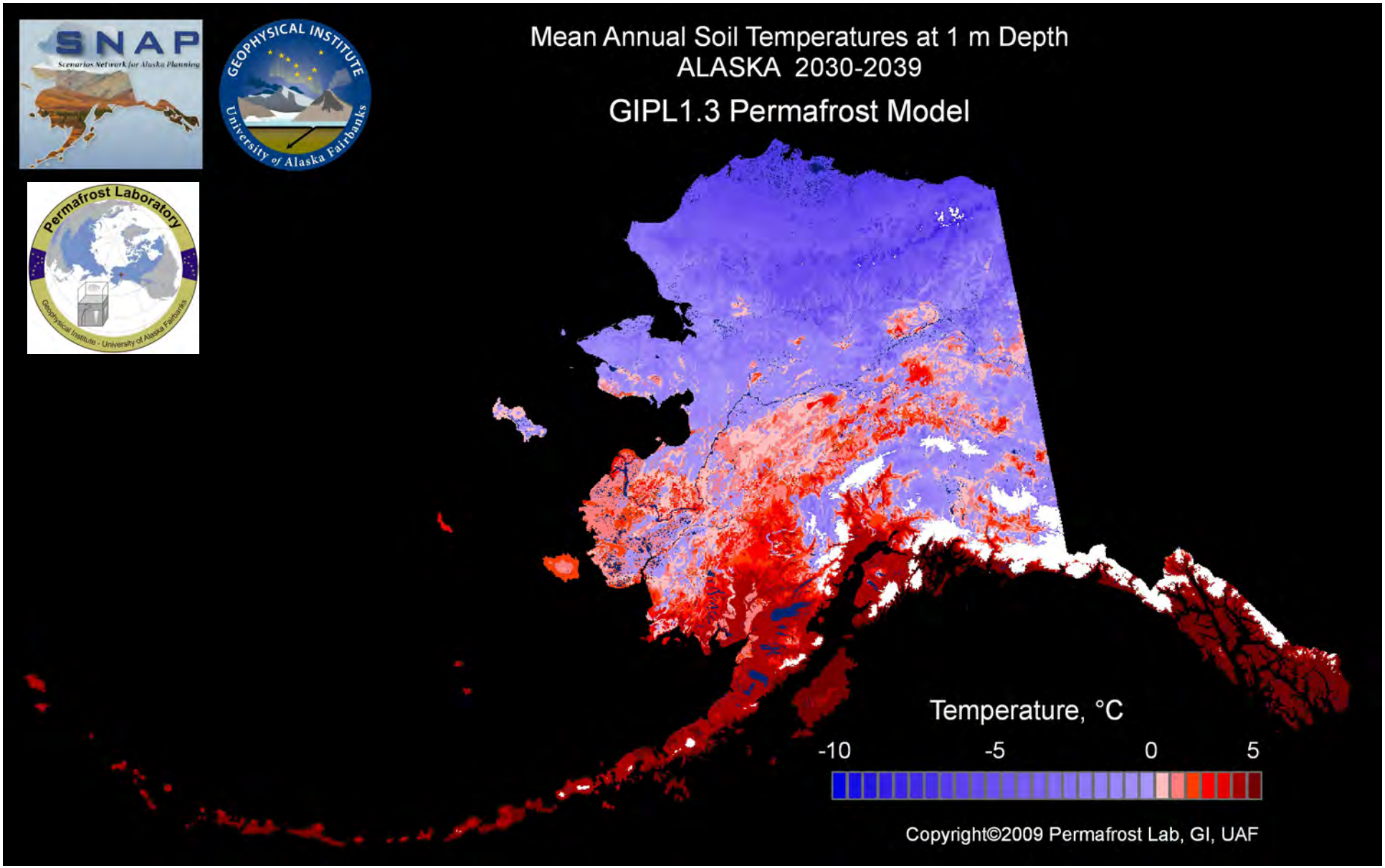

Mean Annual Soil Temperatures at 1 m Depth
ALASKA 1980-1989
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
Copyright©2009 Permafrost Lab, GI, UAF


Mean Annual Soil Temperatures at 1 m Depth
ALASKA 1990-1999
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
Copyright©2009 Permafrost Lab, GI, UAF


Mean Annual Soil Temperatures at 1 m Depth
ALASKA 2000-2009
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
Copyright©2009 Permafrost Lab, GI, UAF


Mean Annual Soil Temperatures at 1 m Depth
ALASKA 2010-2019
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
Copyright©2009 Permafrost Lab, GI, UAF


Mean Annual Soil Temperatures at 1 m Depth
ALASKA 2020-2029
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
Copyright©2009 Permafrost Lab, GI, UAF


Mean Annual Soil Temperatures at 1 m Depth
ALASKA 2030-2039
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
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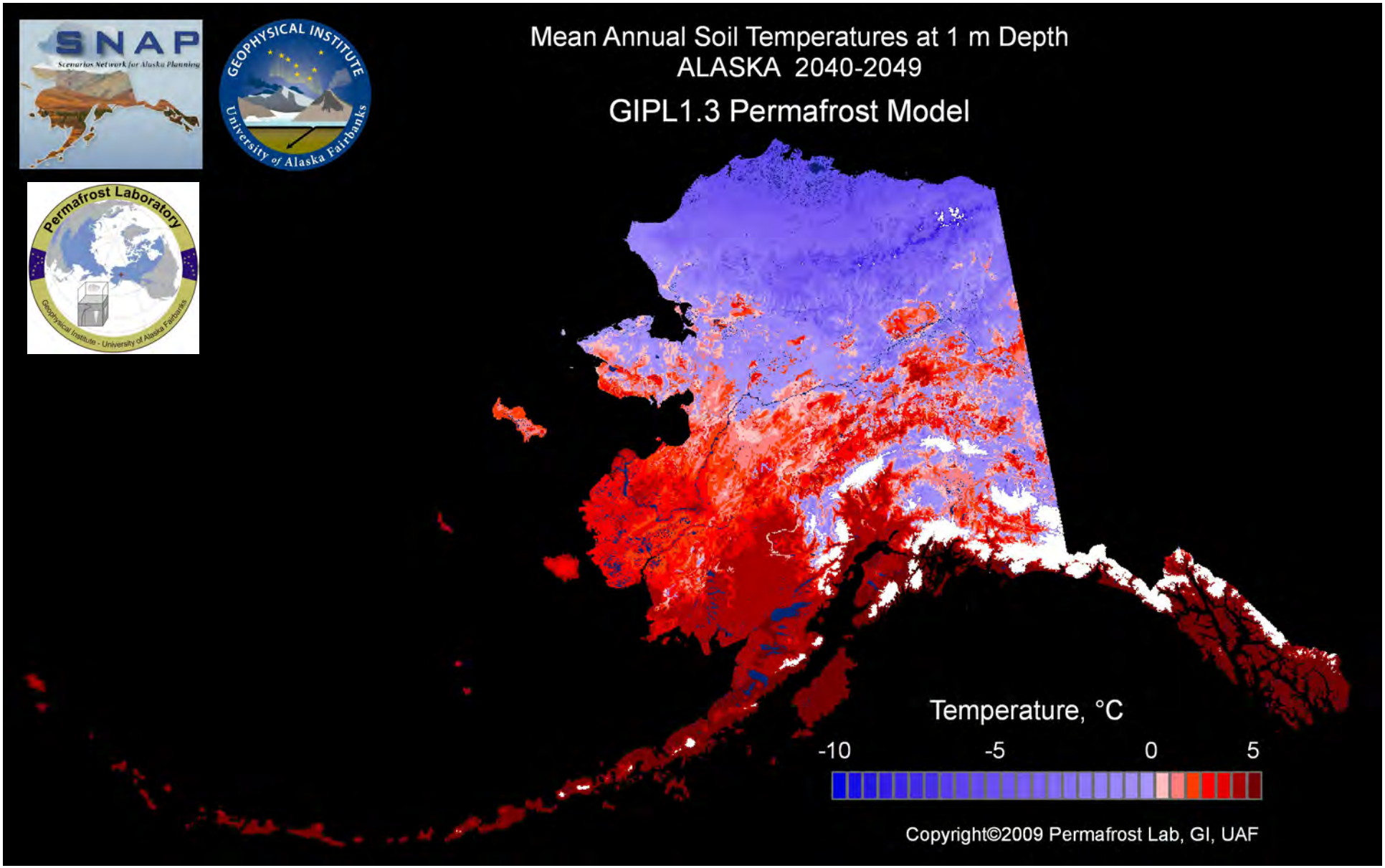
Mean Annual Soil Temperatures at 1 m Depth
ALASKA 2040-2049
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
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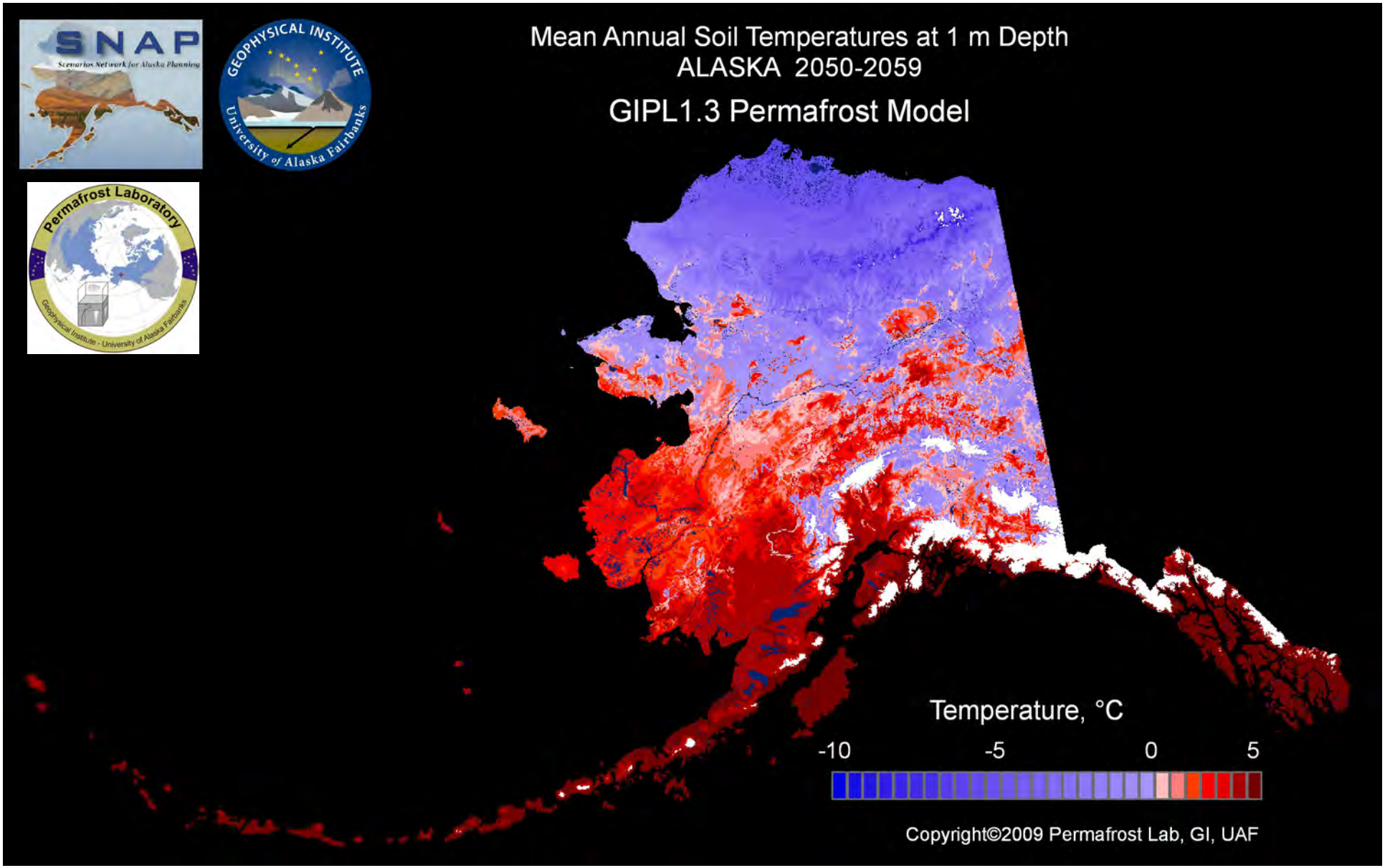
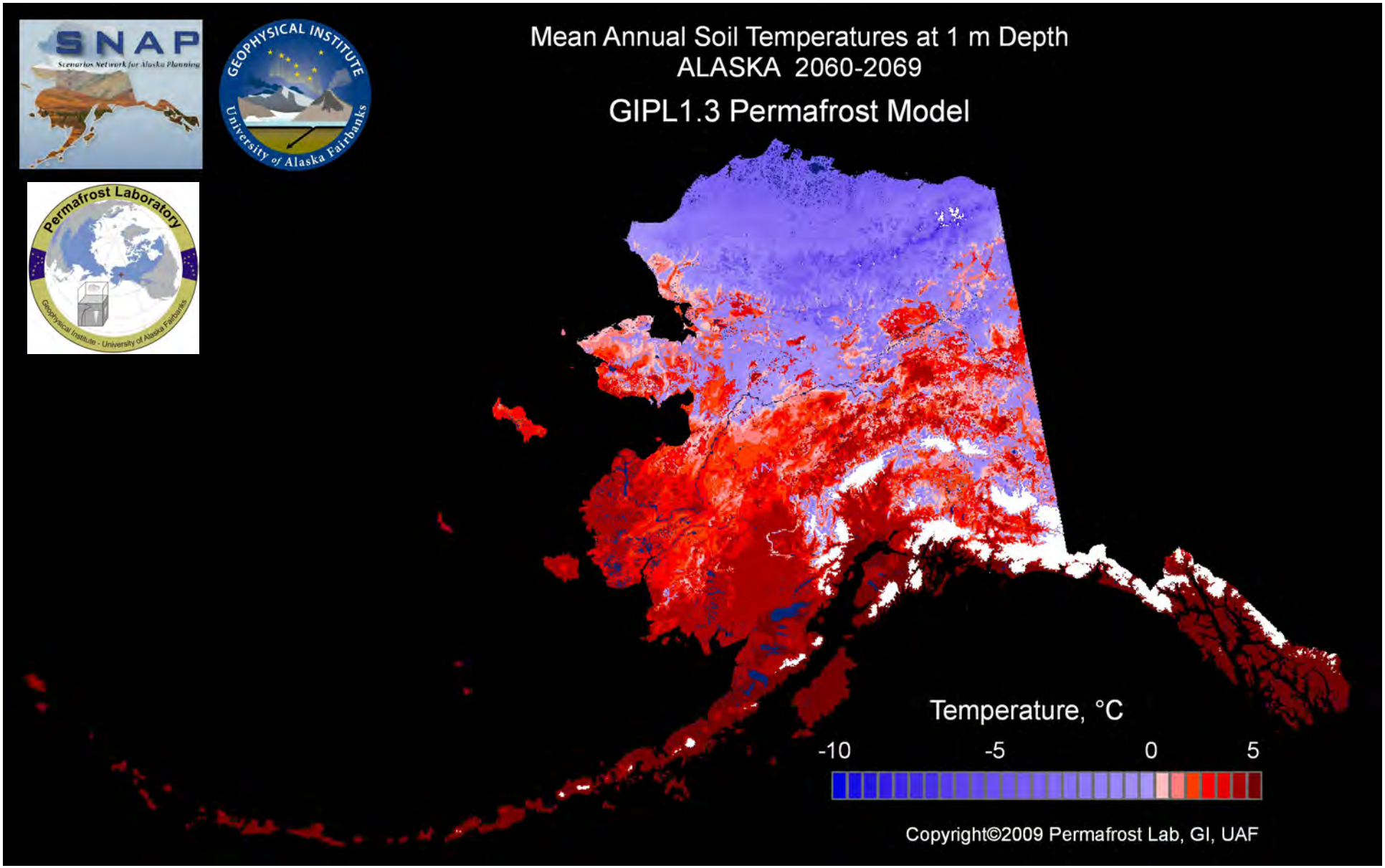

Mean Annual Soil Temperatures at 1 m Depth
ALASKA 2050-2059
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
Copyright©2009 Permafrost Lab, GI, UAF


Mean Annual Soil Temperatures at 1 m Depth
ALASKA 2060-2069
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
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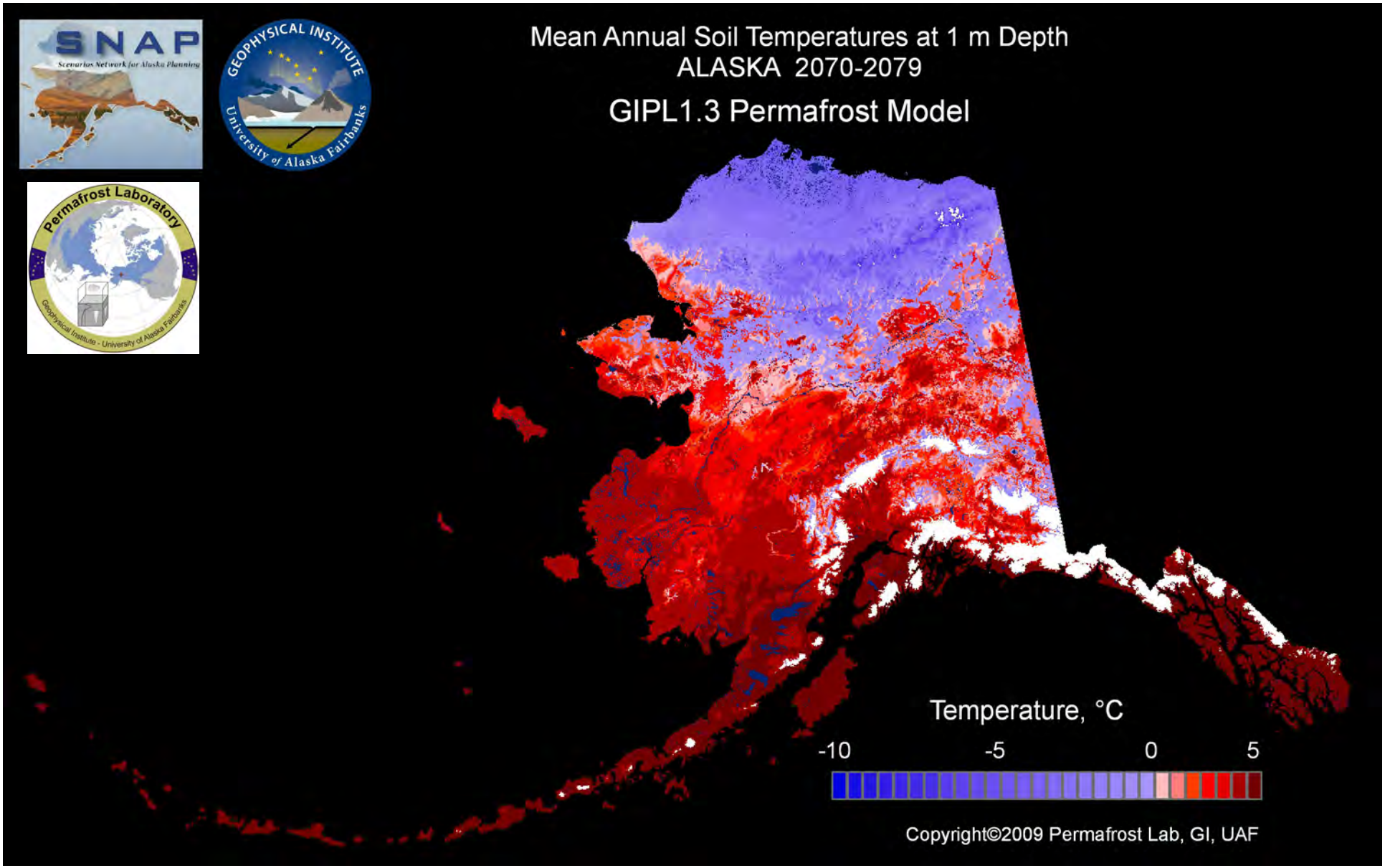
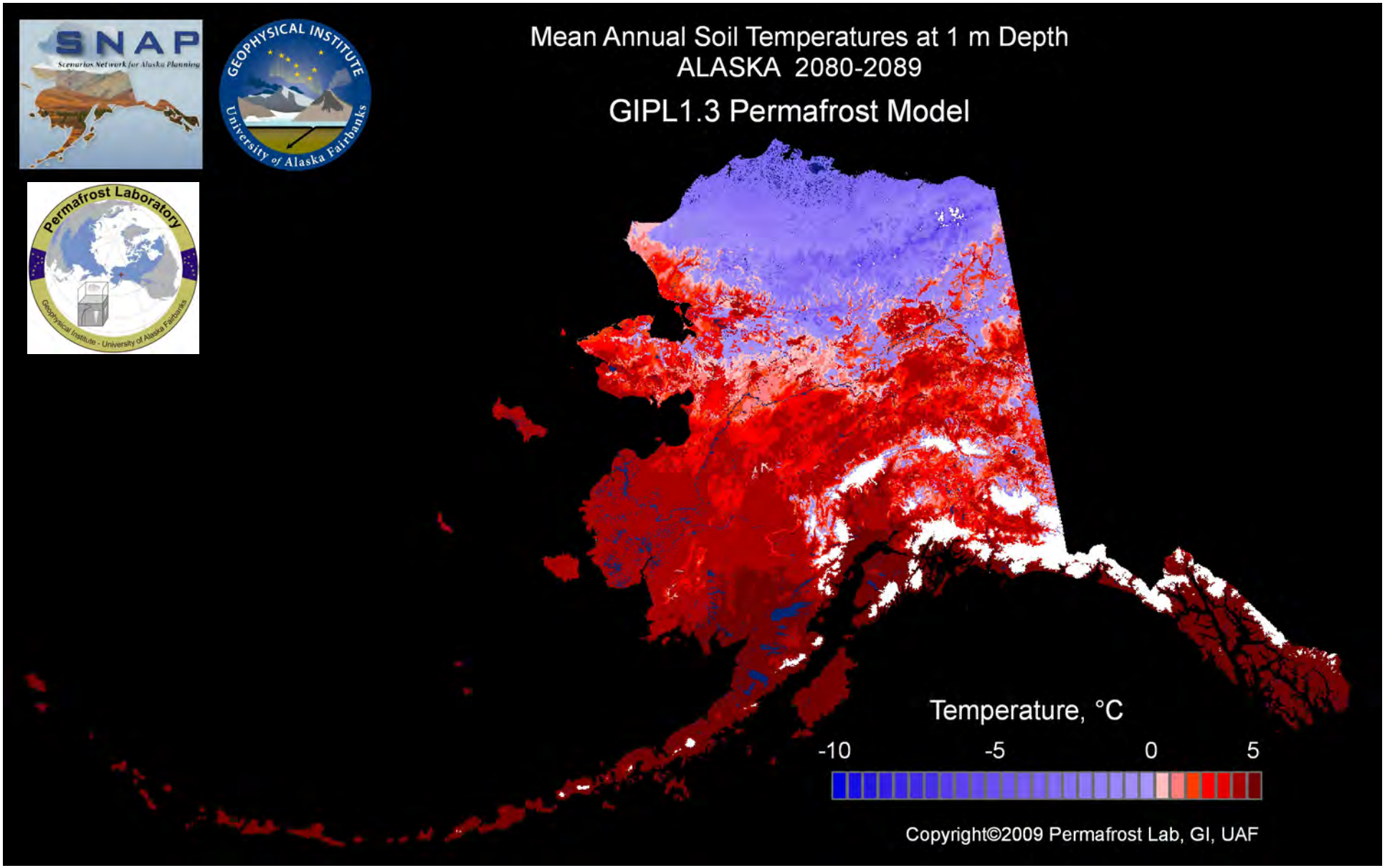
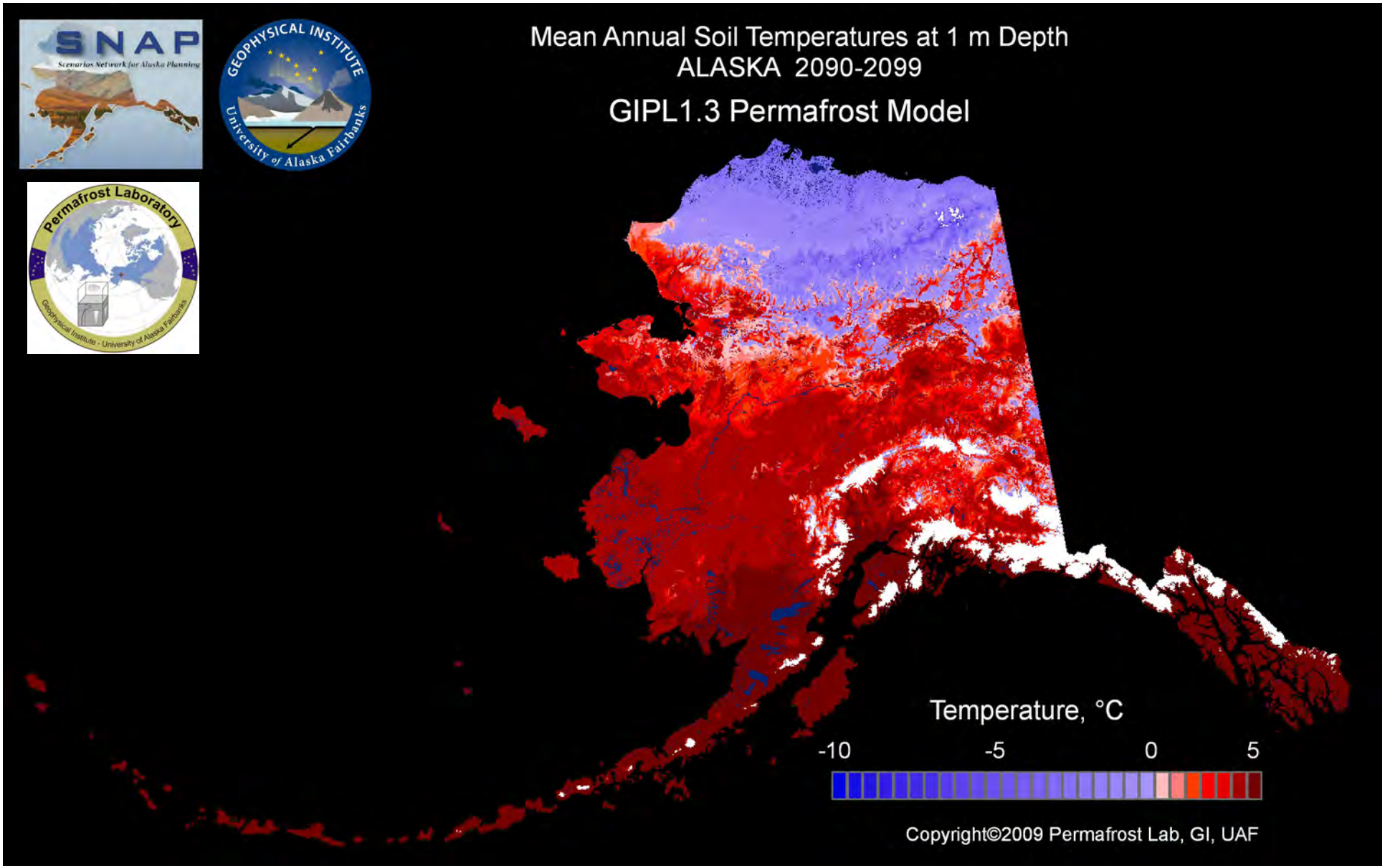
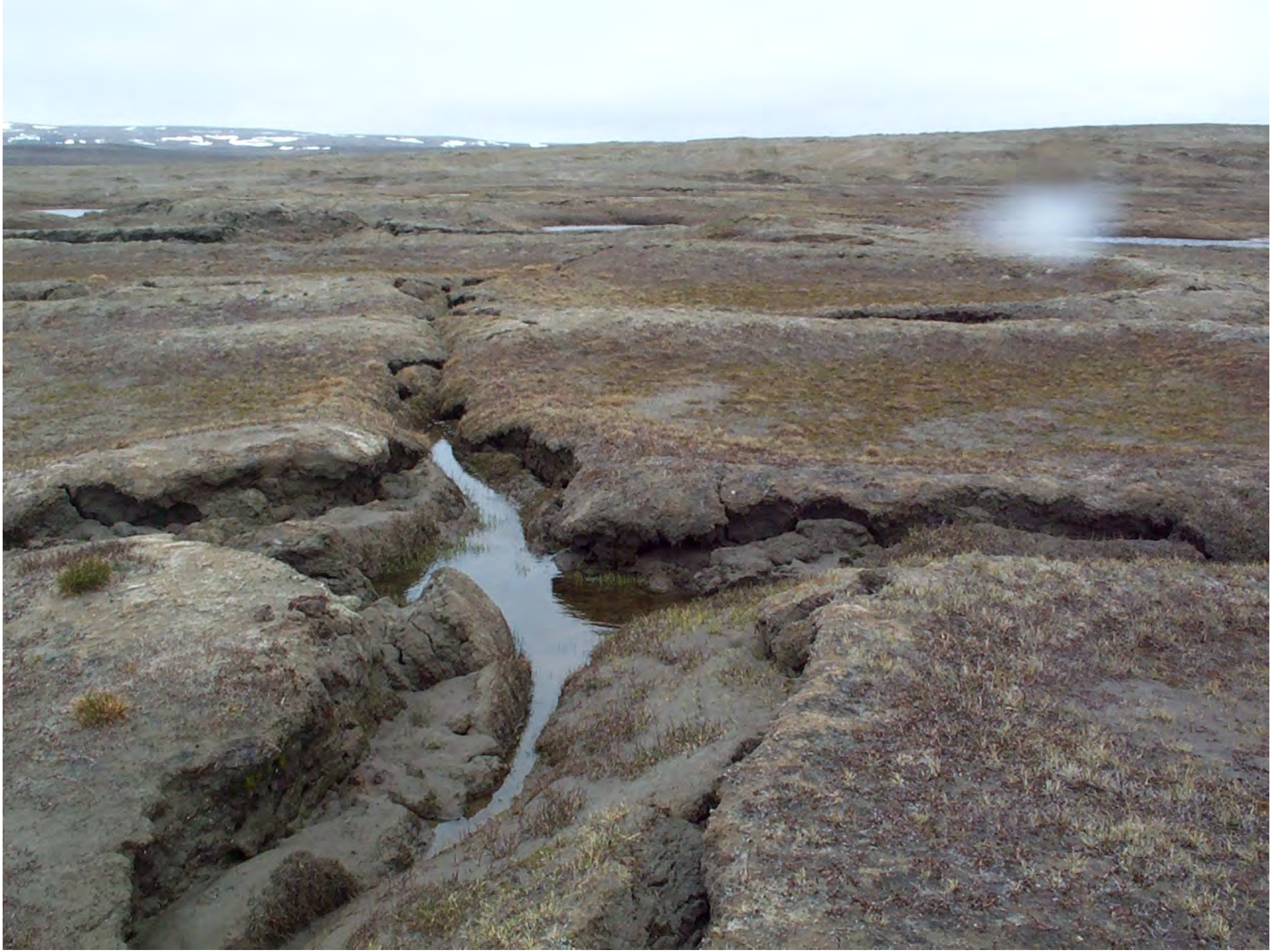
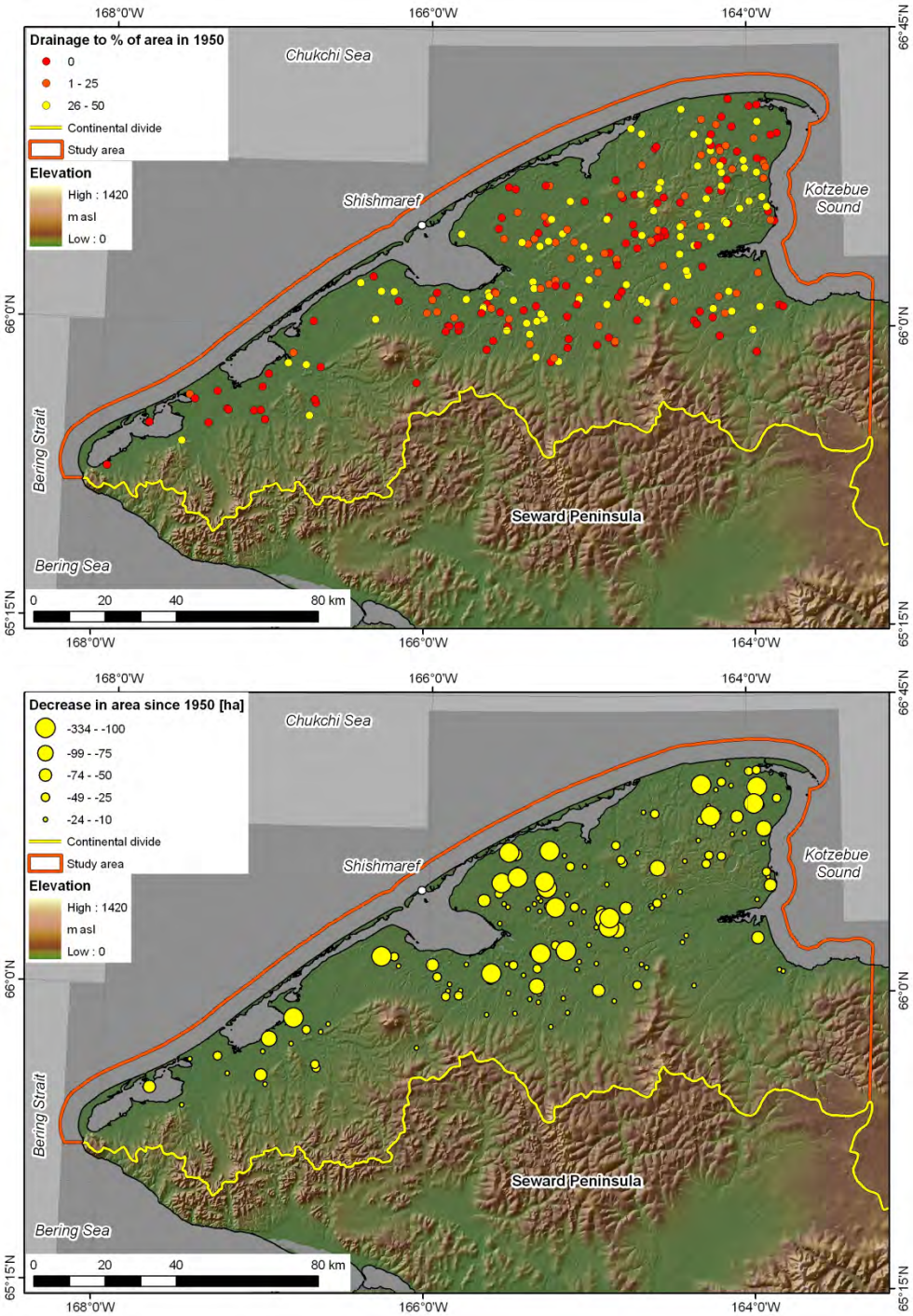

Mean Annual Soil Temperatures at 1 m Depth
ALASKA 2070-2079
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
Copyright©2009 Permafrost Lab, GI, UAF


Mean Annual Soil Temperatures at 1 m Depth
ALASKA 2080-2089
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
Copyright©2009 Permafrost Lab, GI, UAF


Mean Annual Soil Temperatures at 1 m Depth
ALASKA 2090-2099
GIPL1.3 Permafrost Model
Temperature, °C
-10
-5
0
5
Copyright©2009 Permafrost Lab, GI, UAF





Seward Peninsula study area (NW Alaska)

1950-2008

- 118 (8.2%) drained completely (-100% in area)

- 523 (36.3%) largely or considerably (-99% to -10%)

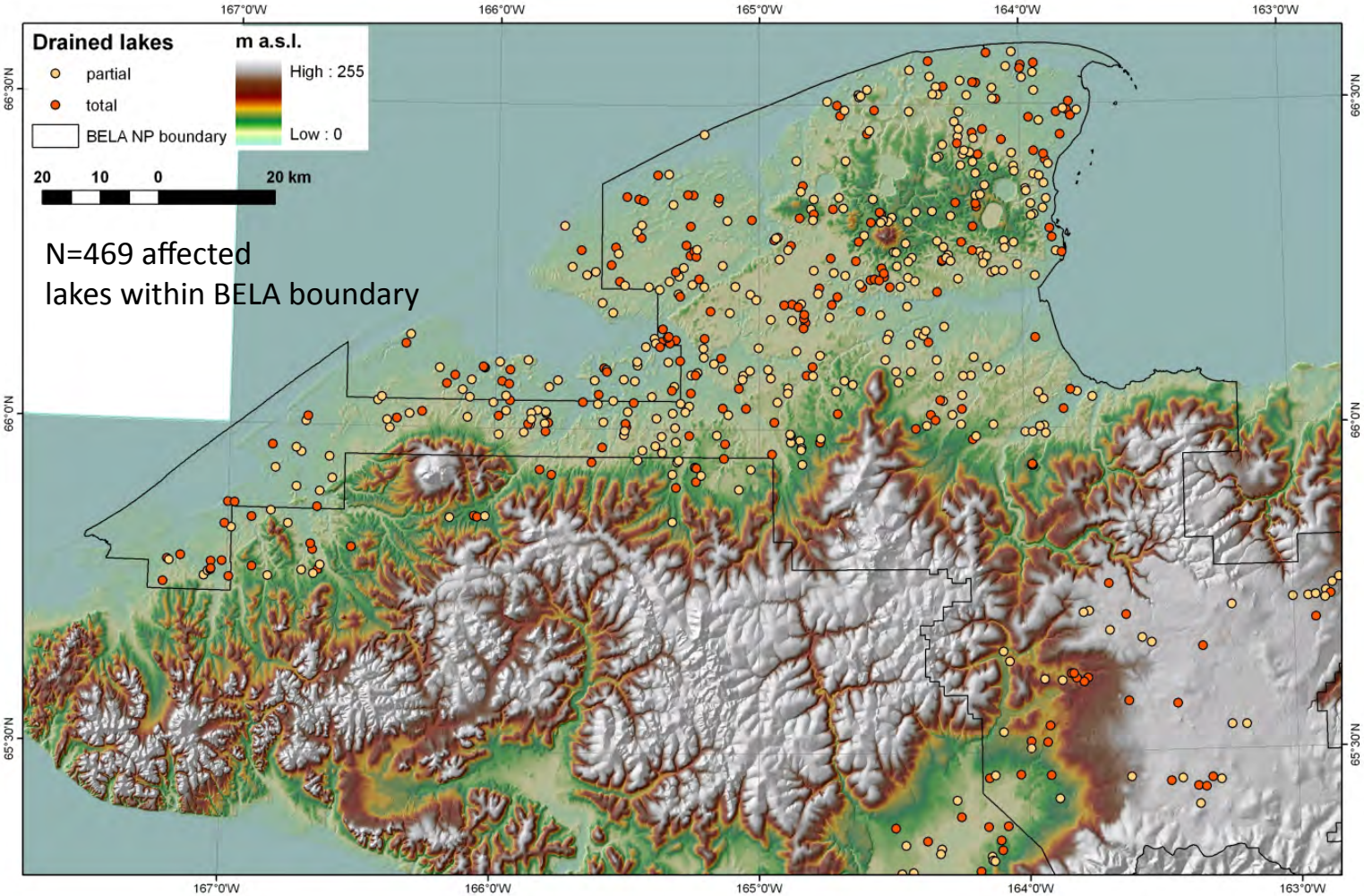
-Lake area of 8,611 ha was lost over the 58 year period within these two classes, equaling 22% of the total TKL area (39,156 ha) in 1950.

- 273 TKL (18.9%) show area increase (>+10%), while 529 TKL (36.7%) remained relatively stable (-10% to +10%).

-Continuous expansion of most lakes at rates of up to 1.5 m/yr did not offset the area loss from drainage.

Grosse et al. (in prep.)

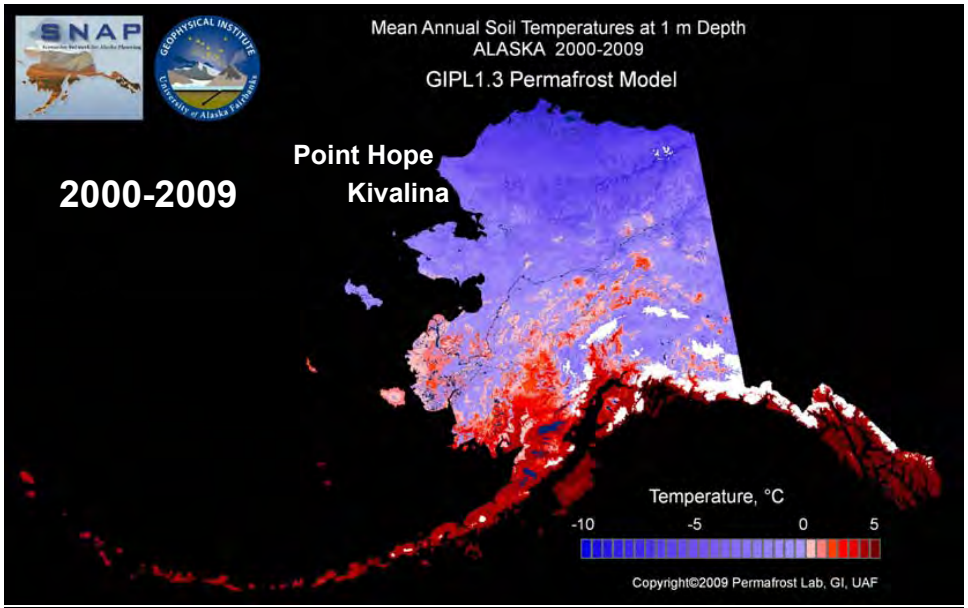
Spatial distribution of lake drainage

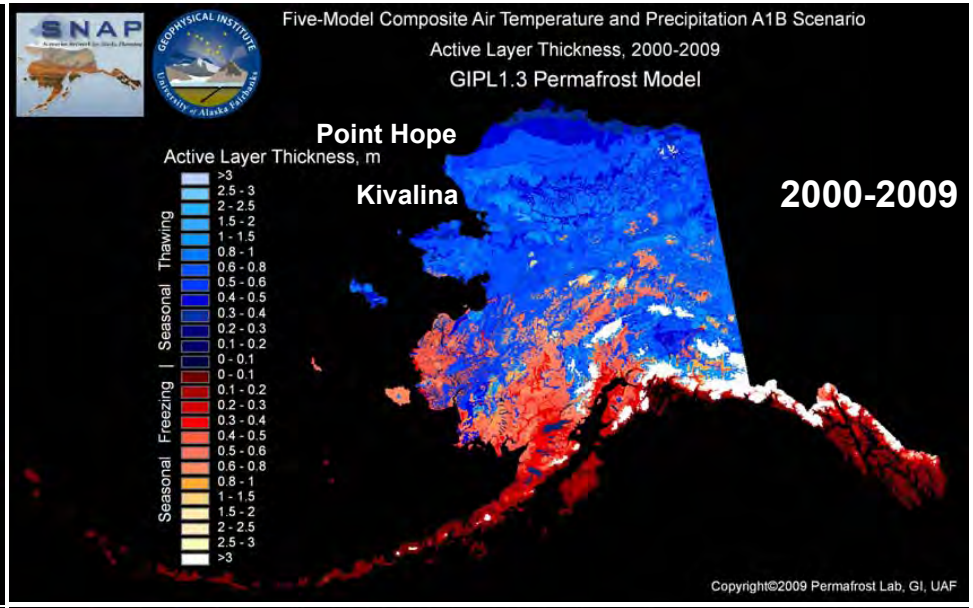


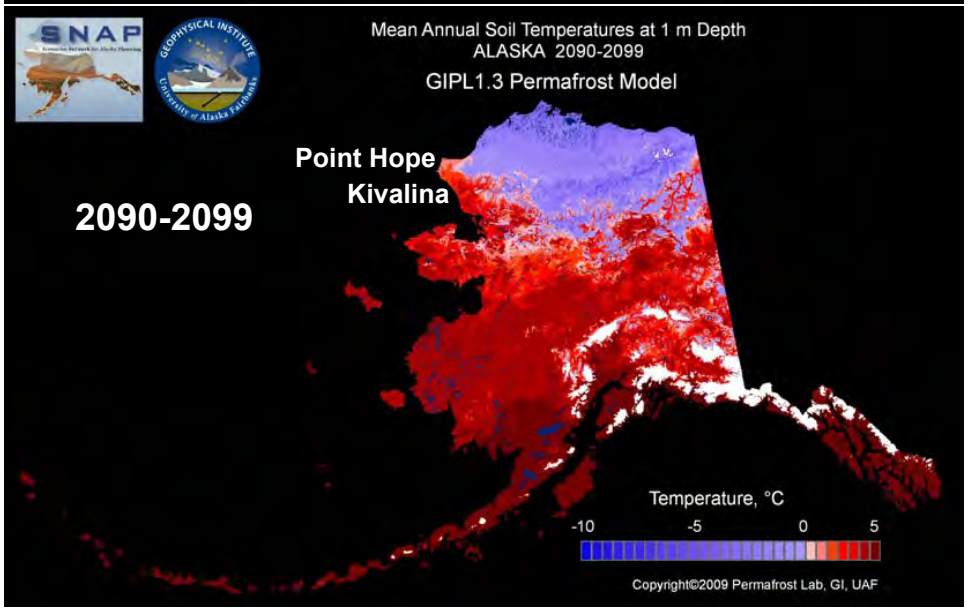
Based on 1950 Topographic maps and
2008 Landsat ETM data (58 years)

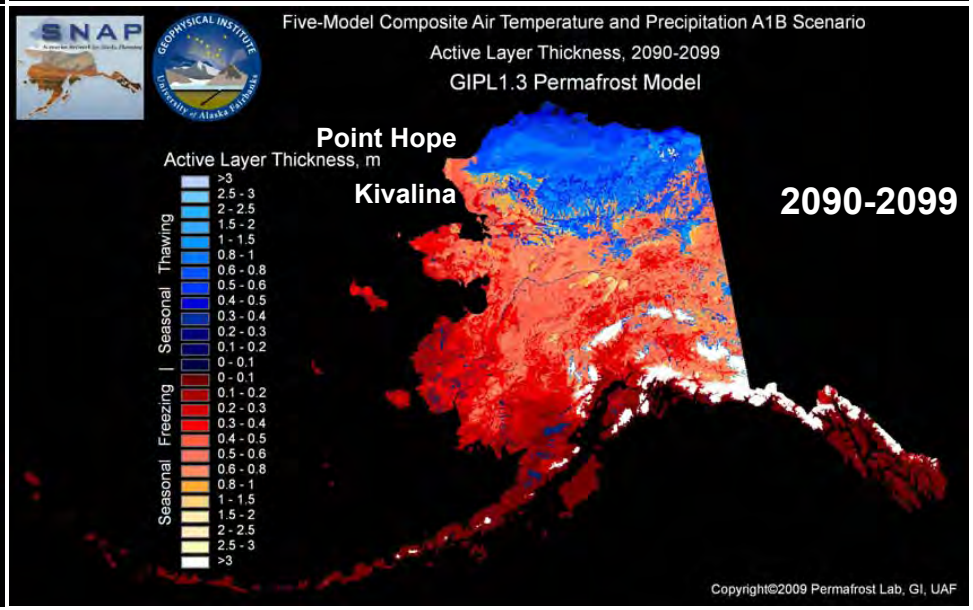
Thawing permafrost and melting ice lenses are adding turbidity to the Wulik River


2006
2007
2008
2009





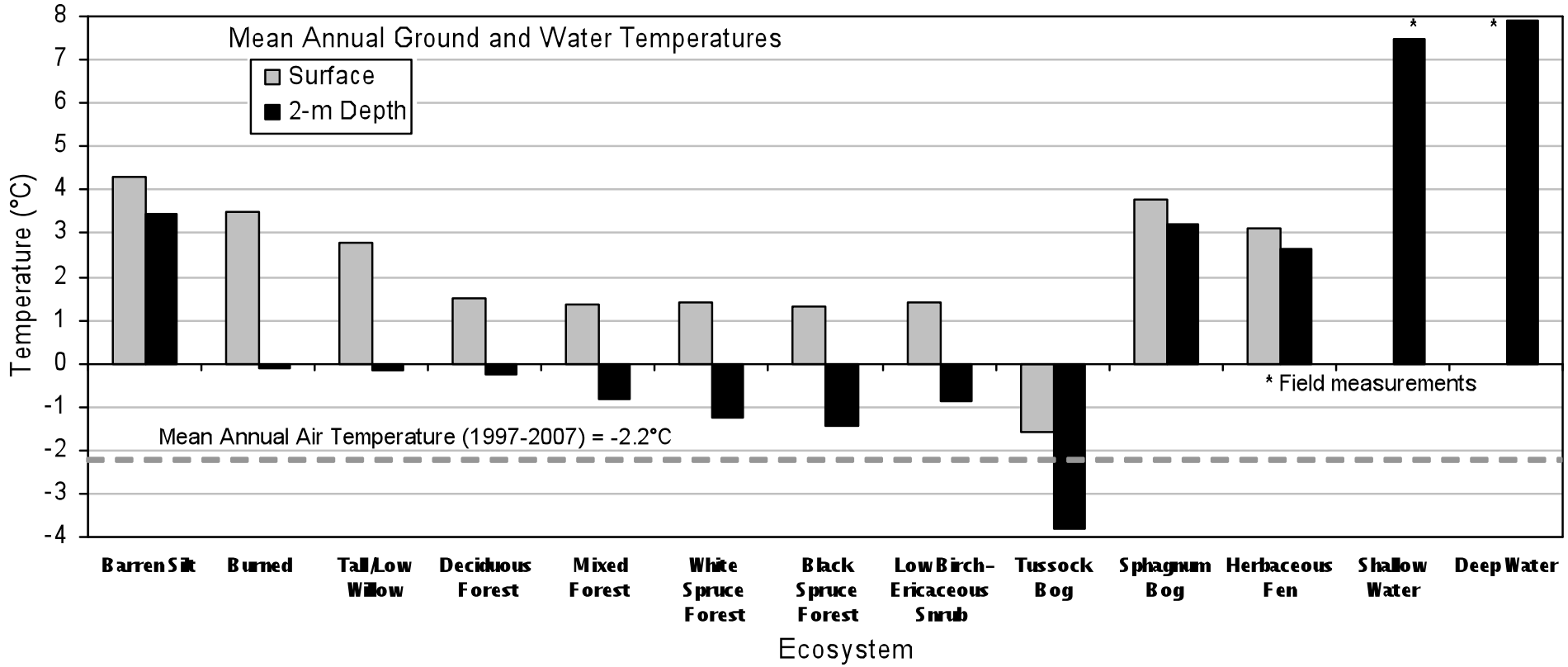


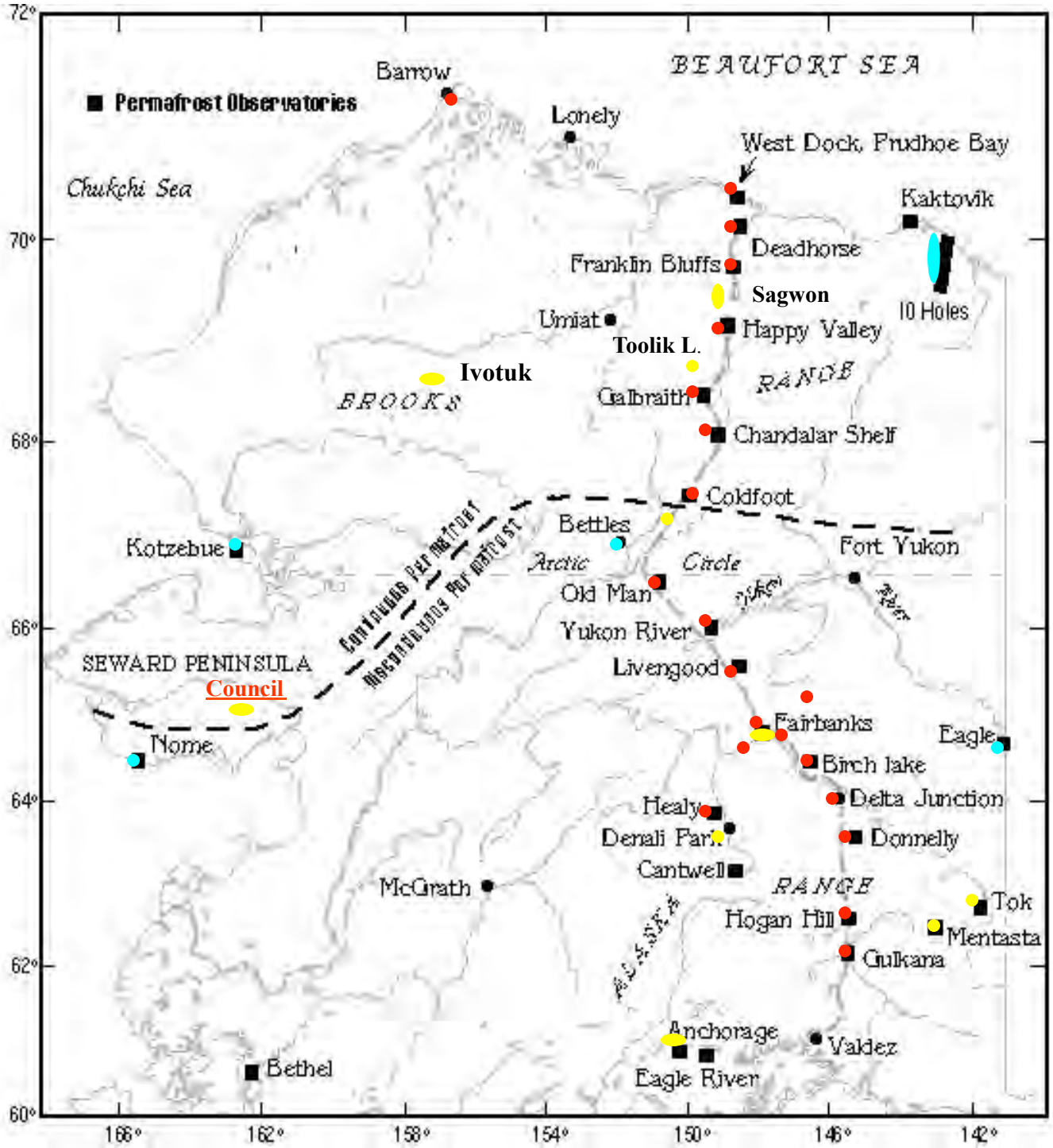


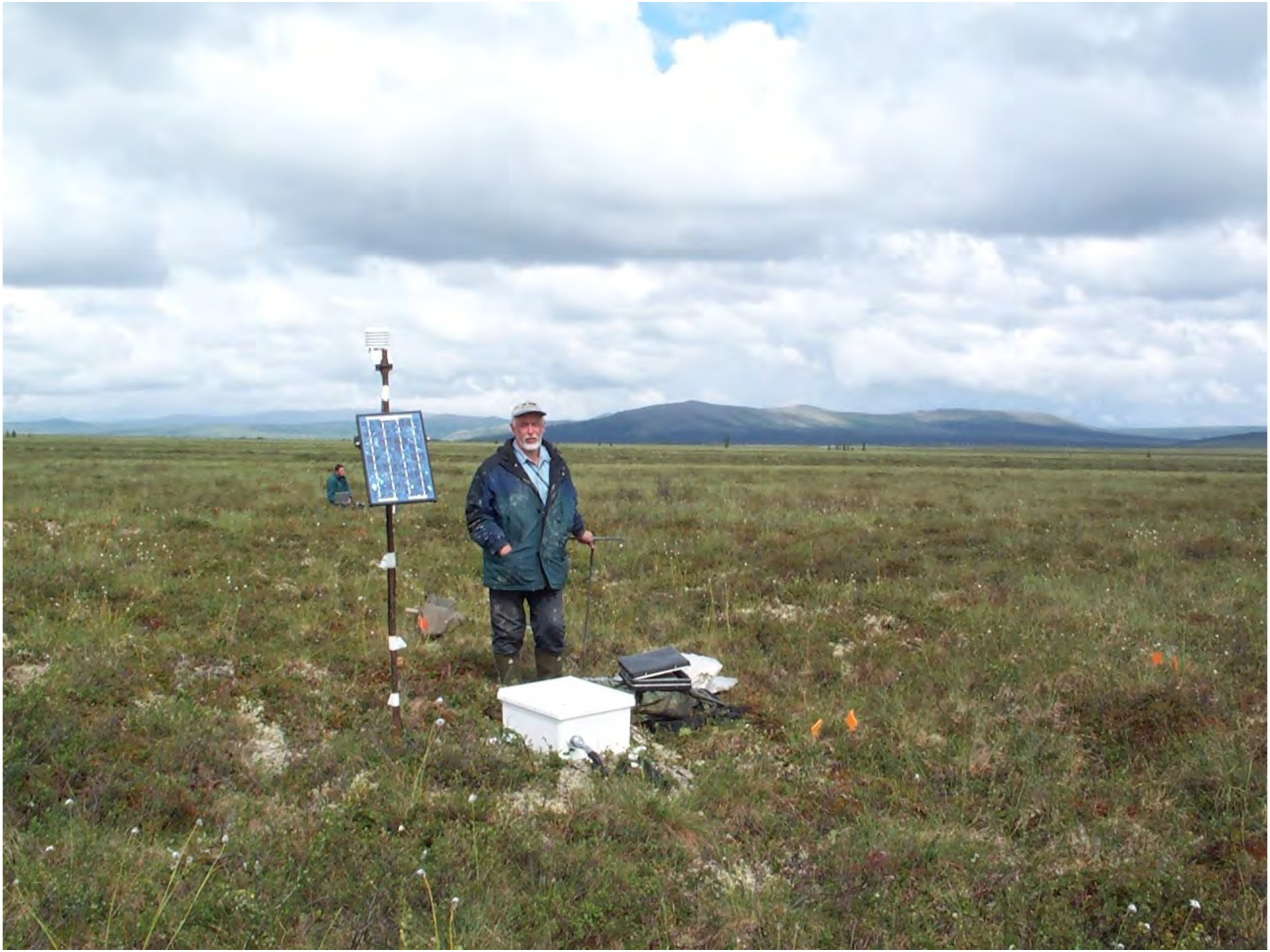
Simulated ground temperatures at 1 meter depth for Alaska for the periods 2000-09 (above) and 2090-99 (below)

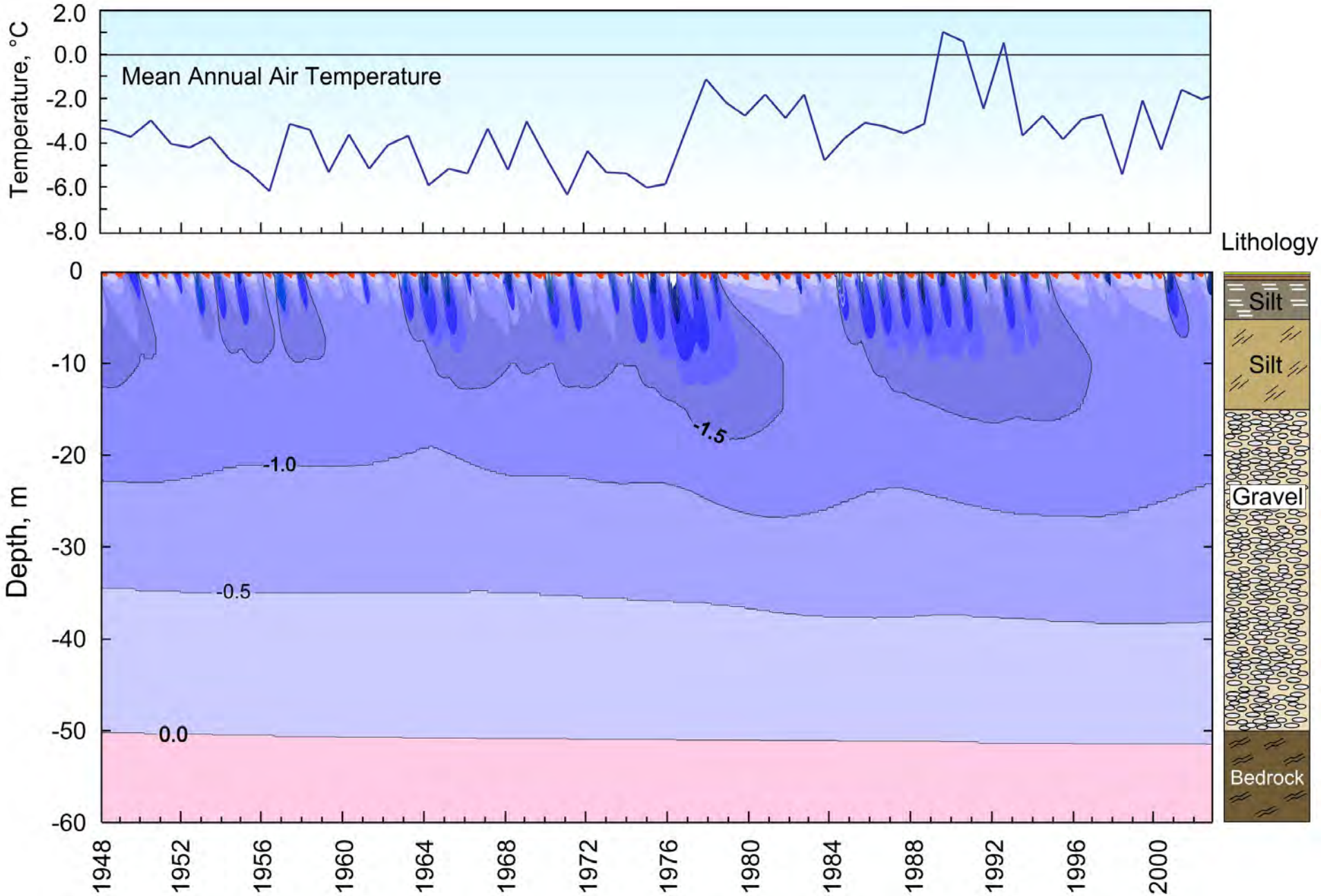
Simulated active layer depth for Alaska for the periods 2000-09 (above) and 2090-99 (below)

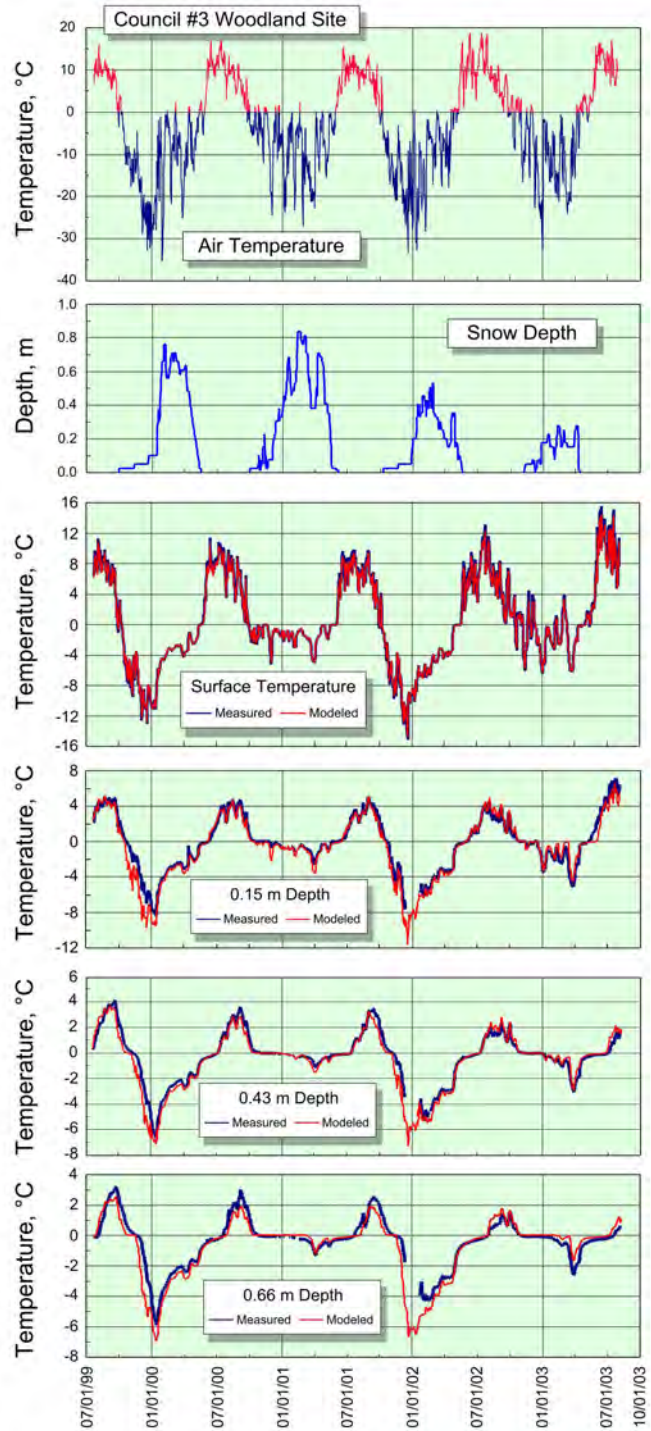
It is projected that communities of Point Hope and Kivalina will lose their permafrost by 2100

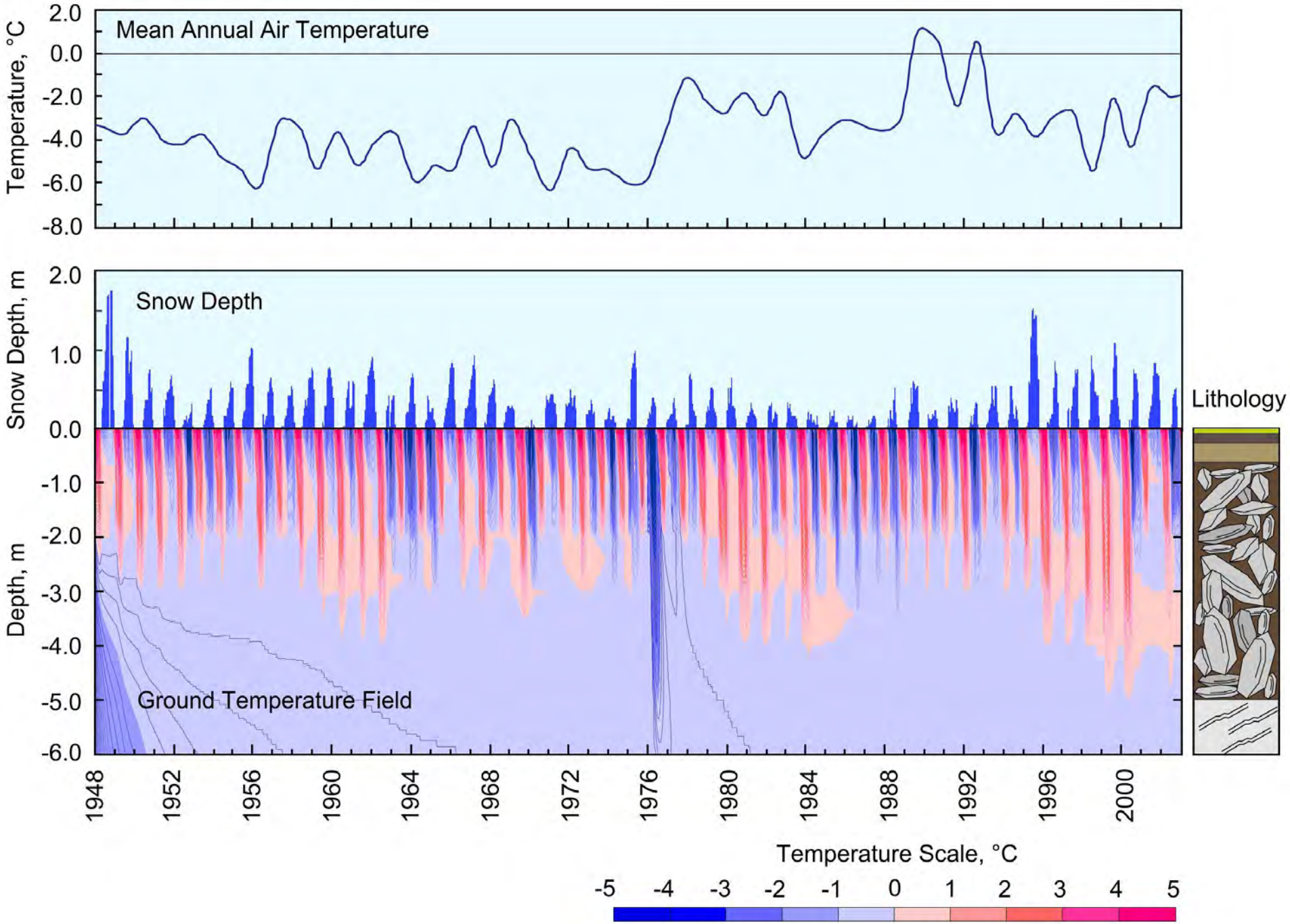

Mean Annual Ground and Water Temperatures
Surface
2-m Depth
Temperature (°C)
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
Mean Annual Air Temperature (1997-2007) = -2.2°C
* Field measurements
*
*
Barren Silt
Burned
Tall/Low Willow
Deciduous Forest
Mixed Forest
White Spruce Forest
Black Spruce Forest
Low Birch-Ericaceous Shrub
Tussock Bog
Sphagnum Bog
Herbaceous Fen
Shallow Water
Deep Water
Ecosystem

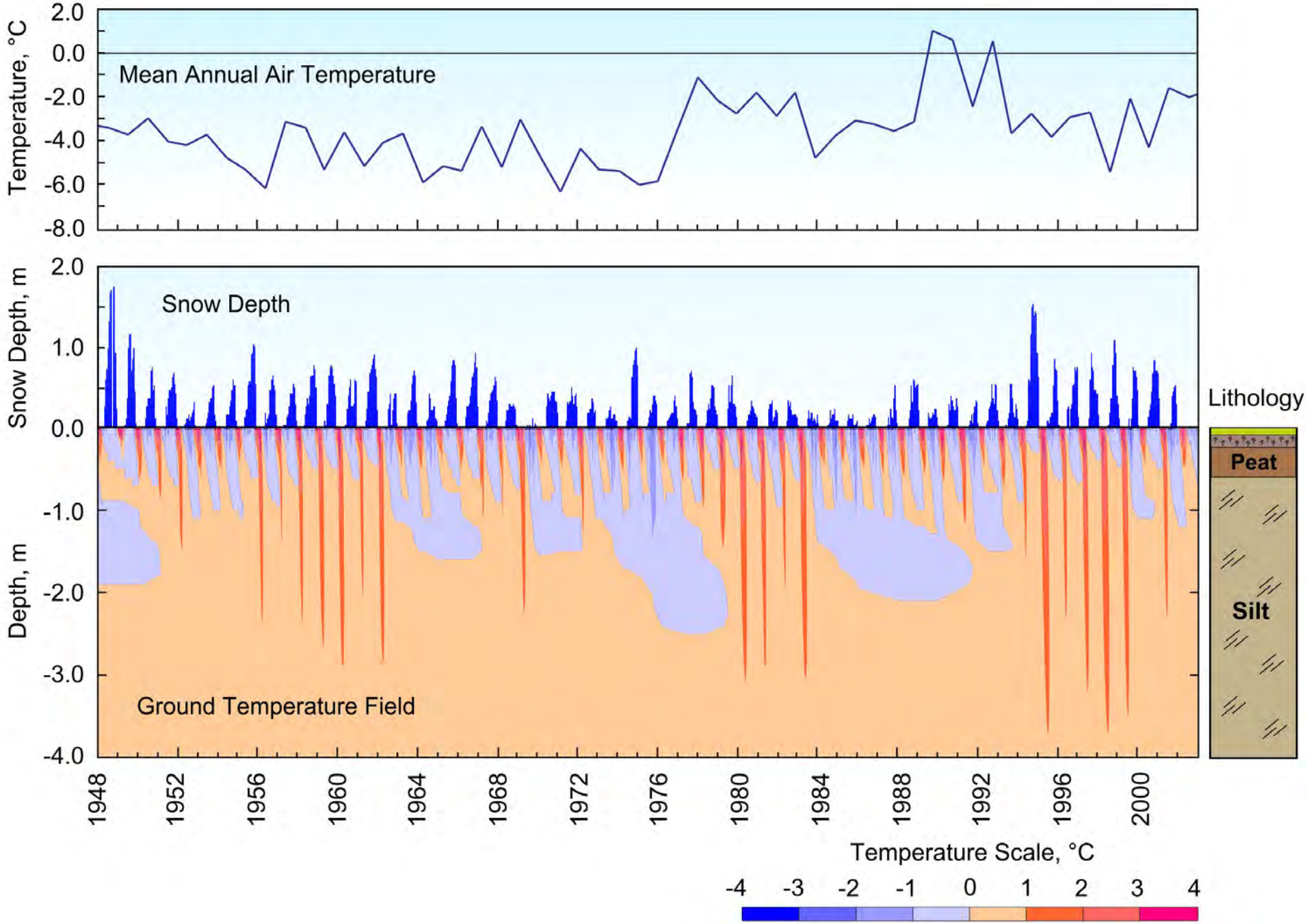

Permafrost Observatories
BEAUFORT SEA
Chukchi Sea
Barrow
Lonely
West Dock, Prudhoe Bay
Kaktovik
Deadhorse
Franklin Bluffs
Sagwon
10 Holes
Umiat
Happy Valley
Toolik L.
Ivotuk
BROOKS
RANGE
Galbraith
Chandalar Shelf
Coldfoot
Bettles
Fort Yukon
Kotzebue
Arctic
Circle
Old Man
Yukon River
Livengood
SEWARD PENINSULA
Council
Nome
Fairbanks
Eagle
Birch lake
Delta Junction
Healy
Denali Park
Donnelly
Cantwell
McGrath
RANGE
Tok
Hogan Hill
Mentasta
Gulkana
Anchorage
Valdez
Eagle River
Bethel
72°
70°
68°
66°
64°
62°
60°
166°
162°
158°
154°
150°
146°
142°

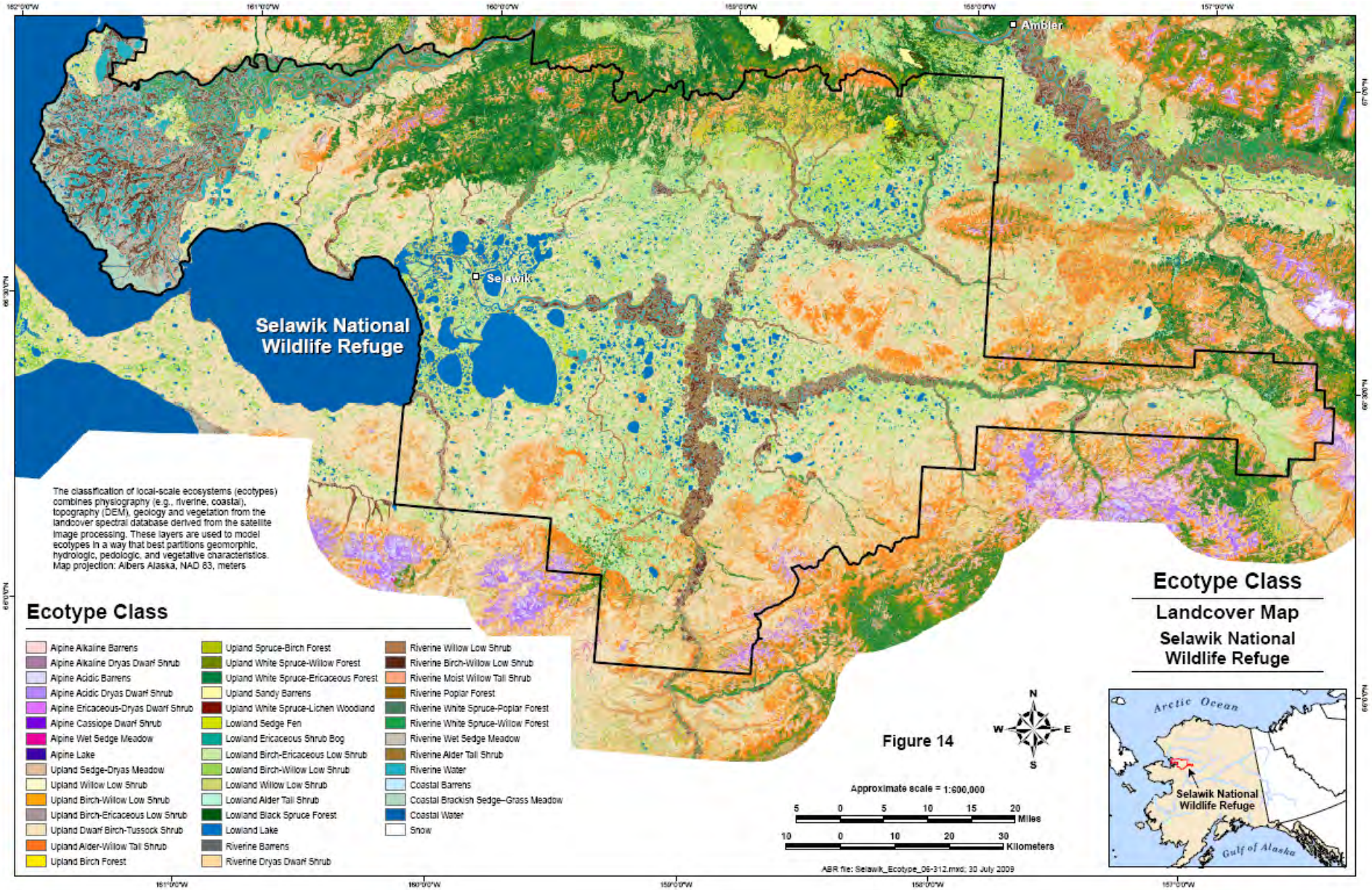



Temperature, °C
2.0
0.0
-2.0
-4.0
-6.0
-8.0
Mean Annual Air Temperature
Lithology
Depth, m
0
-10
-20
-30
-40
-50
-60
-1.5
-1.0
-0.5
0.0
Silt
Silt
Gravel
Bedrock
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000


Council #3 Woodland Site
Air Temperature
Temperature, °C
Snow Depth
Depth, m
Surface Temperature
Measured
Modeled
0.15 m Depth
0.43 m Depth
0.66 m Depth
07/01/99
01/01/00
07/01/00
01/01/01
07/01/01
01/01/02
07/01/02
01/01/03
07/01/03
10/01/03


Mean Annual Air Temperature
Temperature, °C
2.0
0.0
-2.0
-4.0
-6.0
-8.0
Snow Depth
Snow Depth, m
2.0
1.0
0.0
Lithology
Ground Temperature Field
Depth, m
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
Temperature Scale, °C
-5
-4
-3
-2
-1
0
1
2
3
4
5


Temperature, °C
2.0
0.0
-2.0
-4.0
-6.0
-8.0
Mean Annual Air Temperature
Snow Depth, m
2.0
1.0
0.0
Snow Depth
Depth, m
-1.0
-2.0
-3.0
-4.0
Ground Temperature Field
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
Lithology
Peat
Silt
Temperature Scale, °C
-4
-3
-2
-1
0
1
2
3
4


Ambler
Selawik
Selawik National Wildlife Refuge
The classification of local-scale ecosystems (ecotypes) combines physiography (e.g., riverine, coastal), topography (DEM), geology and vegetation from the landcover spectral database derived from the satellite image processing. These layers are used to model ecotypes in a way that best partitions geomorphic, hydrologic, pedologic, and vegetative characteristics.
Map projection: Albers Alaska, NAD 83, meters
Ecotype Class
Alpine Alkaline Barrens
Alpine Alkaline Dryas Dwarf Shrub
Alpine Acidic Barrens
Alpine Acidic Dryas Dwarf Shrub
Alpine Ericaceous-Dryas Dwarf Shrub
Alpine Cassiope Dwarf Shrub
Alpine Wet Sedge Meadow
Alpine Lake
Upland Sedge-Dryas Meadow
Upland Willow Low Shrub
Upland Birch-Willow Low Shrub
Upland Birch-Ericaceous Low Shrub
Upland Dwarf Birch-Tussock Shrub
Upland Alder-Willow Tall Shrub
Upland Birch Forest
Upland Spruce-Birch Forest
Upland White Spruce-Willow Forest
Upland White Spruce-Ericaceous Forest
Upland Sandy Barrens
Upland White Spruce-Lichen Woodland
Lowland Sedge Fen
Lowland Ericaceous Shrub Bog
Lowland Birch-Ericaceous Low Shrub
Lowland Birch-Willow Low Shrub
Lowland Willow Low Shrub
Lowland Alder Tall Shrub
Lowland Black Spruce Forest
Lowland Lake
Riverine Barrens
Riverine Dryas Dwarf Shrub
Riverine Willow Low Shrub
Riverine Birch-Willow Low Shrub
Riverine Moist Willow Tall Shrub
Riverine Poplar Forest
Riverine White Spruce-Poplar Forest
Riverine White Spruce-Willow Forest
Riverine Wet Sedge Meadow
Riverine Alder Tall Shrub
Riverine Water
Coastal Barrens
Coastal Brackish Sedge–Grass Meadow
Coastal Water
Snow
Figure 14
N
W
E
S
Approximate scale = 1:600,000
5 0 5 10 15 20 Miles
10 0 10 20 30 Kilometers
ABR file: Selawik_Ecotype_09-312.mxd; 30 July 2009
Ecotype Class
Landcover Map
Selawik National Wildlife Refuge
Arctic Ocean
Selawik National Wildlife Refuge
Gulf of Alaska

Conclusions

- Despite our accumulating knowledge of changing permafrost conditions, future permafrost dynamics and its impacts remain poorly quantified, especially on regional and local scales

- Development of a new approach that will combine ground observations, modeling and remote sensing is essential for further progress

- Permafrost research is becoming increasingly interdisciplinary, involving geophysicists, hydrologists, terrestrial and aquatic ecologists, geochemists, geologists, engineers, modelers, and sociologists

- To make progress, disciplines must team together to understand the patterns, processes, and consequences of permafrost thaw to the Earth System


Thank you very much !
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