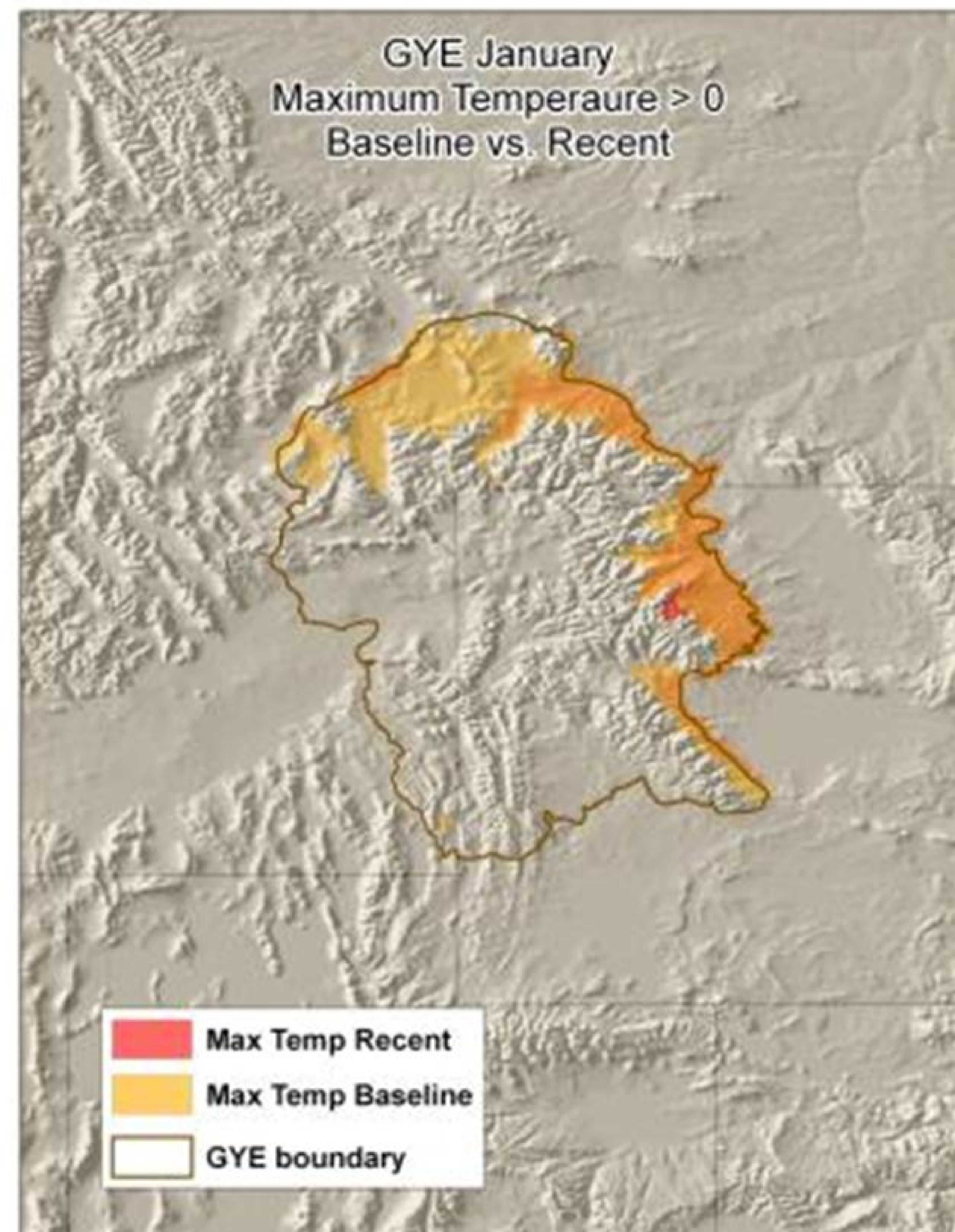
Modeling climate change impacts to wildlife and landscapes and the implications for conservation planning

Healy Hamilton, Ph.D.
Stephanie Auer
Miguel Fernandez
Otto Alvarez
Mariana Padron
Center for Applied Biodiversity Informatics

CALIFORNIA ACADEMY OF SCIENCES



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SCIENCES

CABI integrates biodiversity data with spatial information, such as climate and topography, to understand changing patterns of biodiversity

How can we use climate model outputs to project the future potential distributions for species of management concern?

Where are the areas of the most stable projected future climate for conservation targets? Where are areas of future 'climate turnover' to novel climatic conditions?

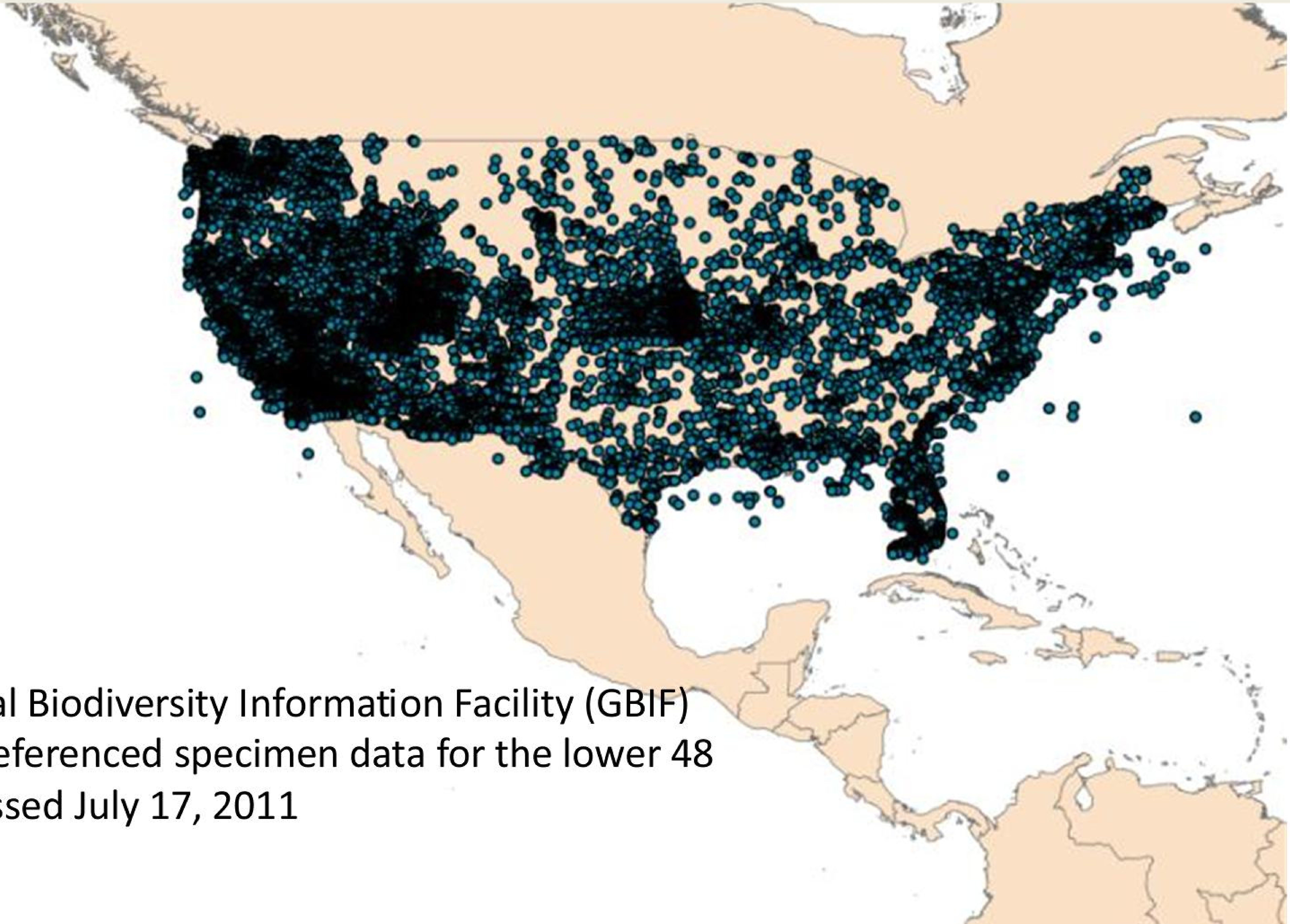
What is the relationship between 'baseline' climate, recent climate trends, and climate model future projections?

How are populations distributed in 'climate space'? Which populations are the most vulnerable to climate change, and which may be best adapted to future climates?

HOW CAN THIS INFORMATION BE USED TO IMPLEMENT CLIMATE CHANGE ADAPATION STRATEGIES TODAY?

Examples from *range shift modeling* and *climate space trend analysis*

Natural history specimen collections offer a spatial biodiversity dataset that reference “baseline” conditions from which to measure change



Global Biodiversity Information Facility (GBIF)
Georeferenced specimen data for the lower 48
Accessed July 17, 2011

Data and Tools for Predicting Ecological Impacts of Climate Change

1) Biogeographic data sampling species distributions
2) Distribution (Niche) modeling algorithms
3) Current *climate surfaces* characterizing environmental space
4) Many climate model outputs
5) Climate model outputs under alternative emissions scenarios
6) Methods to downscale coarse resolution global output to produce higher resolution *future climate surfaces*

Spatial Climate Datasets - Observations

Worldclim (Hijmans et al 2005)

Spatial Resolution:

20, 10, 5 and 1 km2

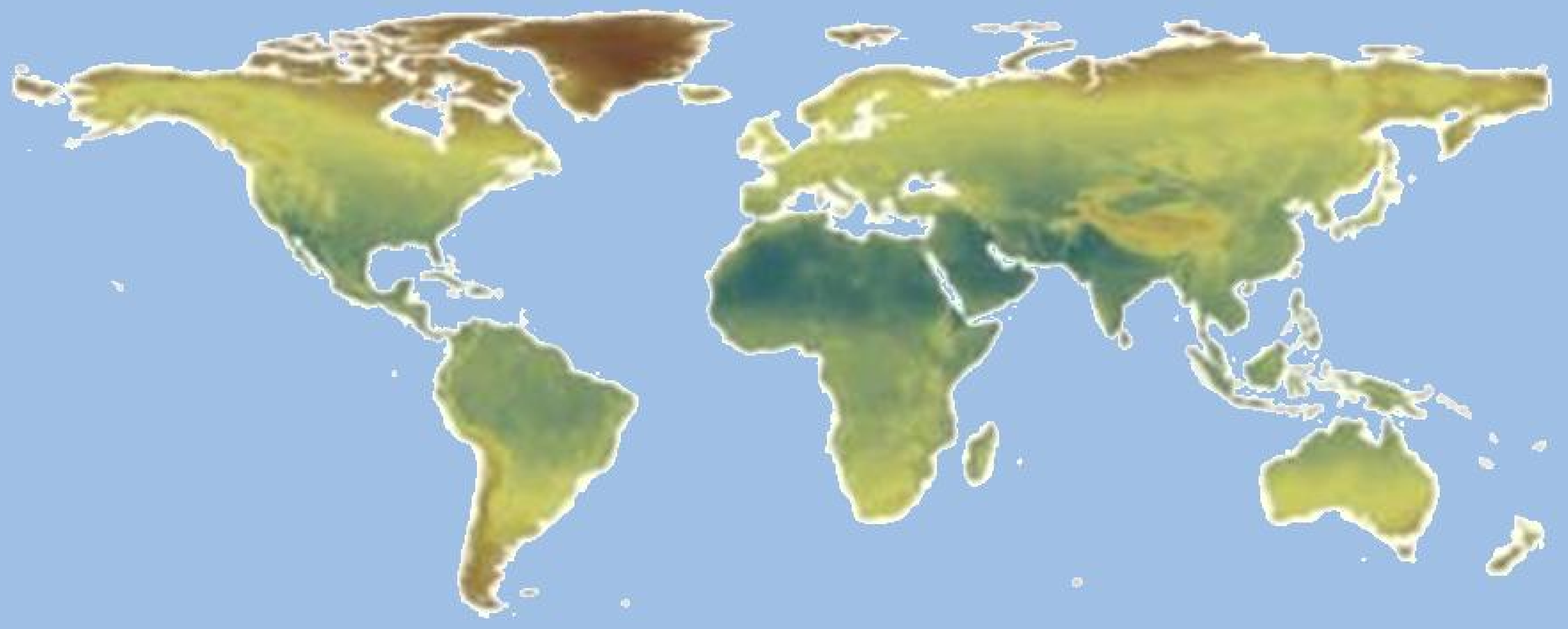
Monthly Env layers:

tmax, tmin, tave, pp

Temporal resolution:

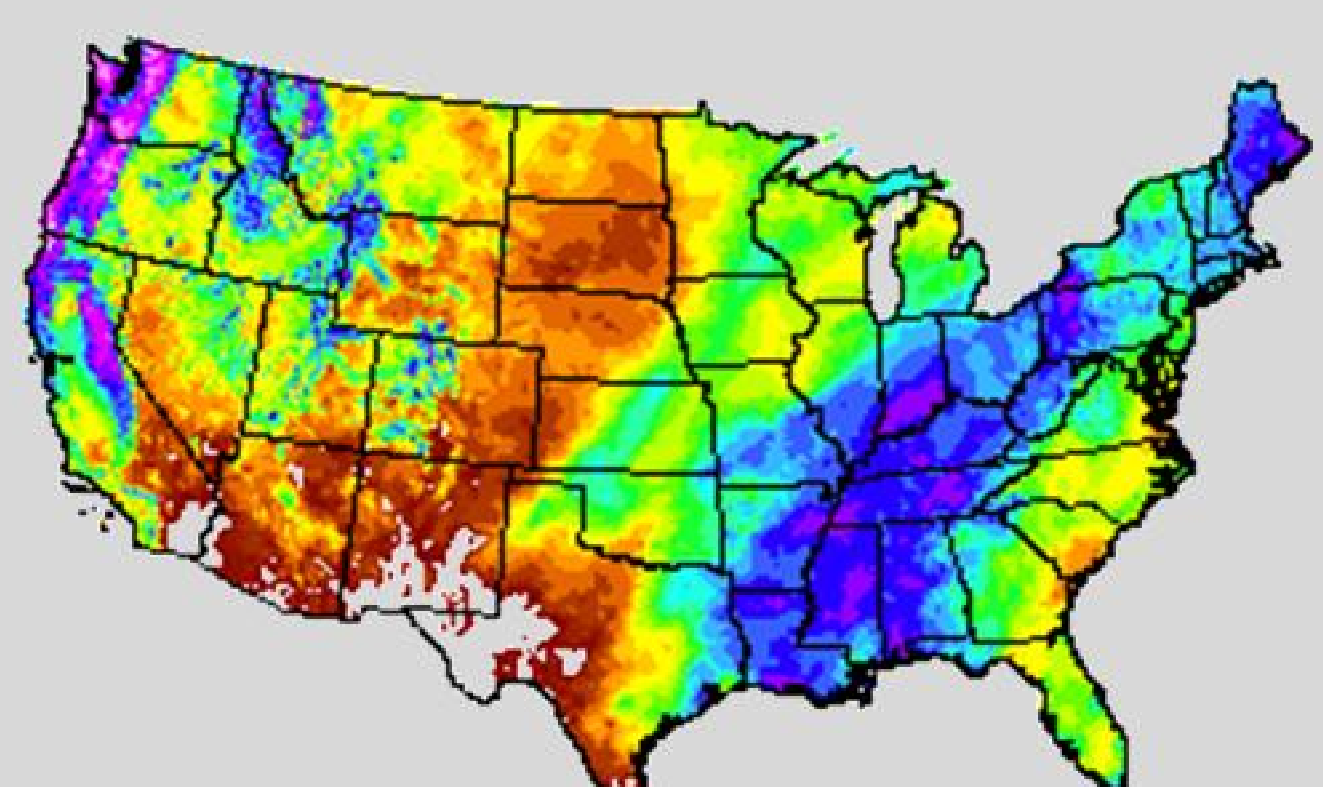
1950-2000 average

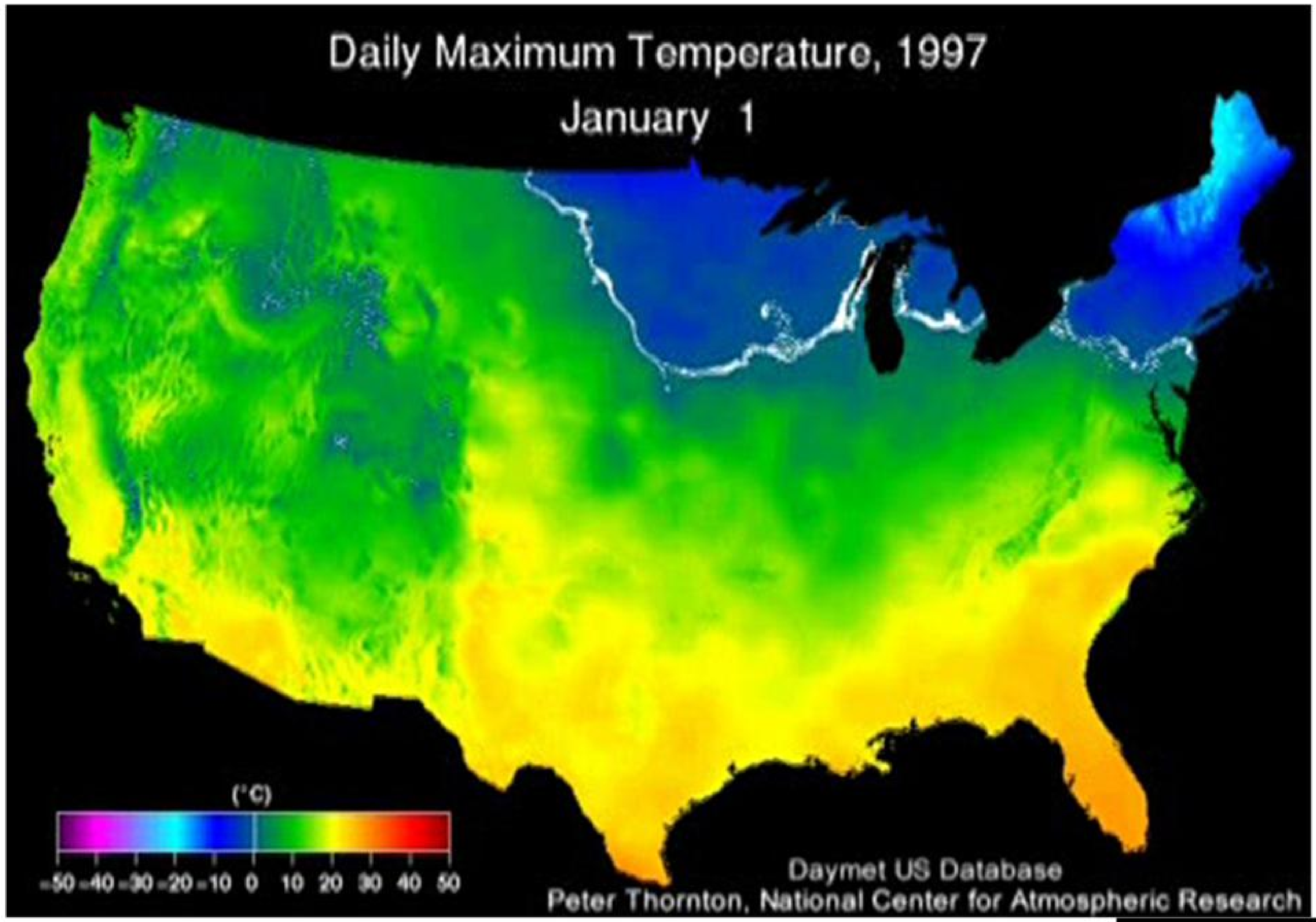
www.worldclim.org



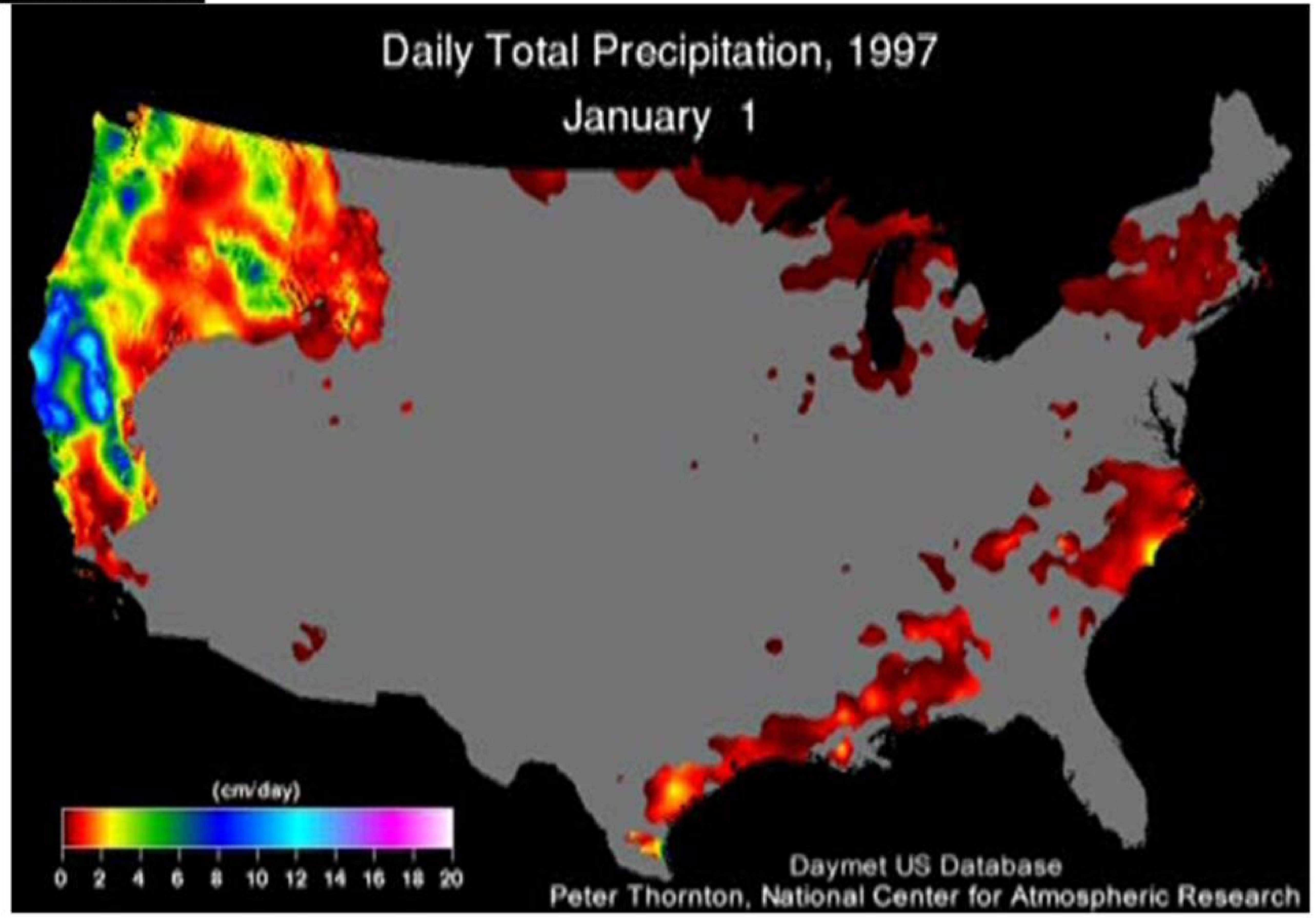
Spatial Climate Datasets - Observations

- Current climate
- Method: Parameter-elevation Regressions on Independent Slopes Model (Daly et al 2002)
- Yearly: 1895-Present
- Variables: Precipitation, Max Temp, Min Temp, Dewpoint, PPT % anomaly
- Spatial resolution: **4 km^2**, 2km^2 & 800 m

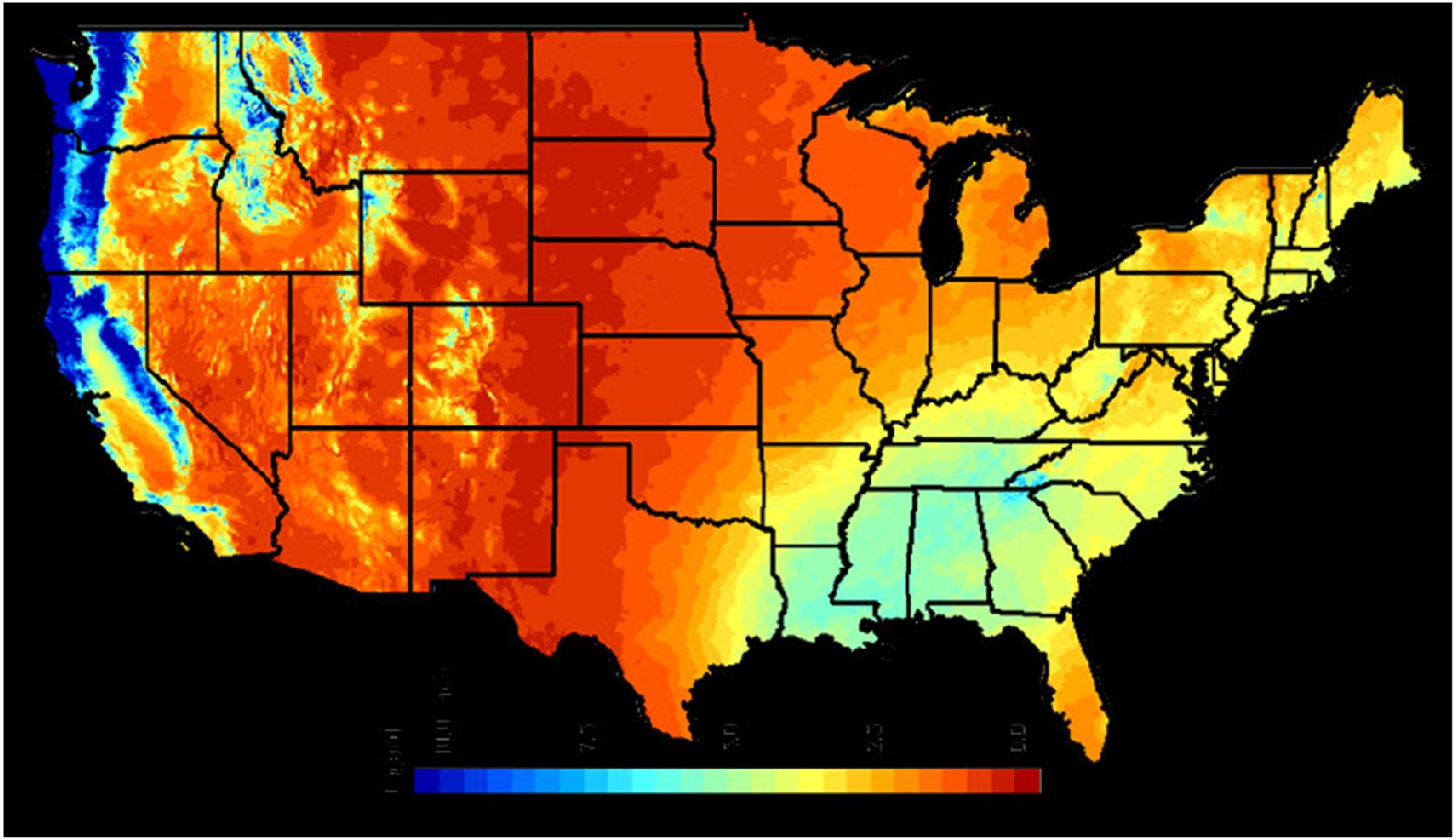




Historical and current *climate surfaces* are increasing in temporal and spatial resolution



Global climate models can be downscaled to current climate surfaces (such as PRISM) to generate future spatial climate data for ecological impacts analysis



Courtesy Phil Duffy, Climate Central

OPEN ACCESS Freely available online PLoS one

Climate Change and the Future of California's Endemic Flora

Scott R. Loarie[1]*, Benjamin E. Carter[2,4,5], Katharine Hayhoe[3], Sean McMahon[1], Richard Moe[4], Knight[2], David D. Ackerly[4,5]

Extinction risk from climate change

Chris D. Thomas[1], Alison Cameron[1], Rhys E. Green[2], Michel Bakkenes[3], Linda J. Beaumont[4], Yvonne C. Collingham[5], Barend F. N. Erasmus[6], Marinez Ferreira de Siqueira[7], Alan Grainger[8], Lee Hannah[9], Lesley Hughes[4], Brian Huntley[5], Albert S. van Jaarsveld[10], Guy F. Midgley[11], Lera Miles[8]*, Miguel A. Ortega-Huerta[12], A. Townsend Peterson[13], Oliver L. Phillips[8] & Stephen E. Williams[14]

Global Change Biology (2006) 12, 2272–2281, doi: 10.1111/j.1365-2486.2006.01256.x

The ability of climate envelope models to predict the effect of climate change on species distributions

ROBERT J. HIJMANS*[1] and CATHERINE H. GRAHAM†
*Museum of Vertebrate Zoology, University of California, 3101 Valley Life Sciences Building, Berkeley, CA 94720, USA,
†Department of Ecology and Evolution, Stony Brook University, 636 Life Science Building, Stony Brook, NY 11794, USA

Future projections for Mexican faunas under global climate change scenarios

A. Townsend Peterson*, Miguel A. Ortega-Huerta†, Jeremy Bartley
Víctor Sánchez-Cordero§, Jorge Soberón||, Robert H. Buddemeier
vid R. B. Stockwell¶

Potential Changes in Suitable Habitat for 134 Tree Species in the Northeastern United States

Louis Iverson, Anantha Prasad, and Stephen Matthews

Global Change Biology (2007) 13, 1368–1385, doi: 10.1111/j.1365-2486.2007.01357.x

Where will species go? Incorporating new advances in climate modelling into projections of species distributions

LINDA J. BEAUMONT*, A. J. PITMAN†, MICH

Ecology, 90(3), 2009, pp. 588–597

Global Change Biology (2005) 11, 1504–1513, doi: 10.1111/j.1365-2486.2005.001000.x

Validation of species–climate impact models under climate change

MIGUEL B. ARAÚJO*†, RICHARD G. PEARSON*‡, WILFRIED THUILLER§ and MARKUS ERHARD¶

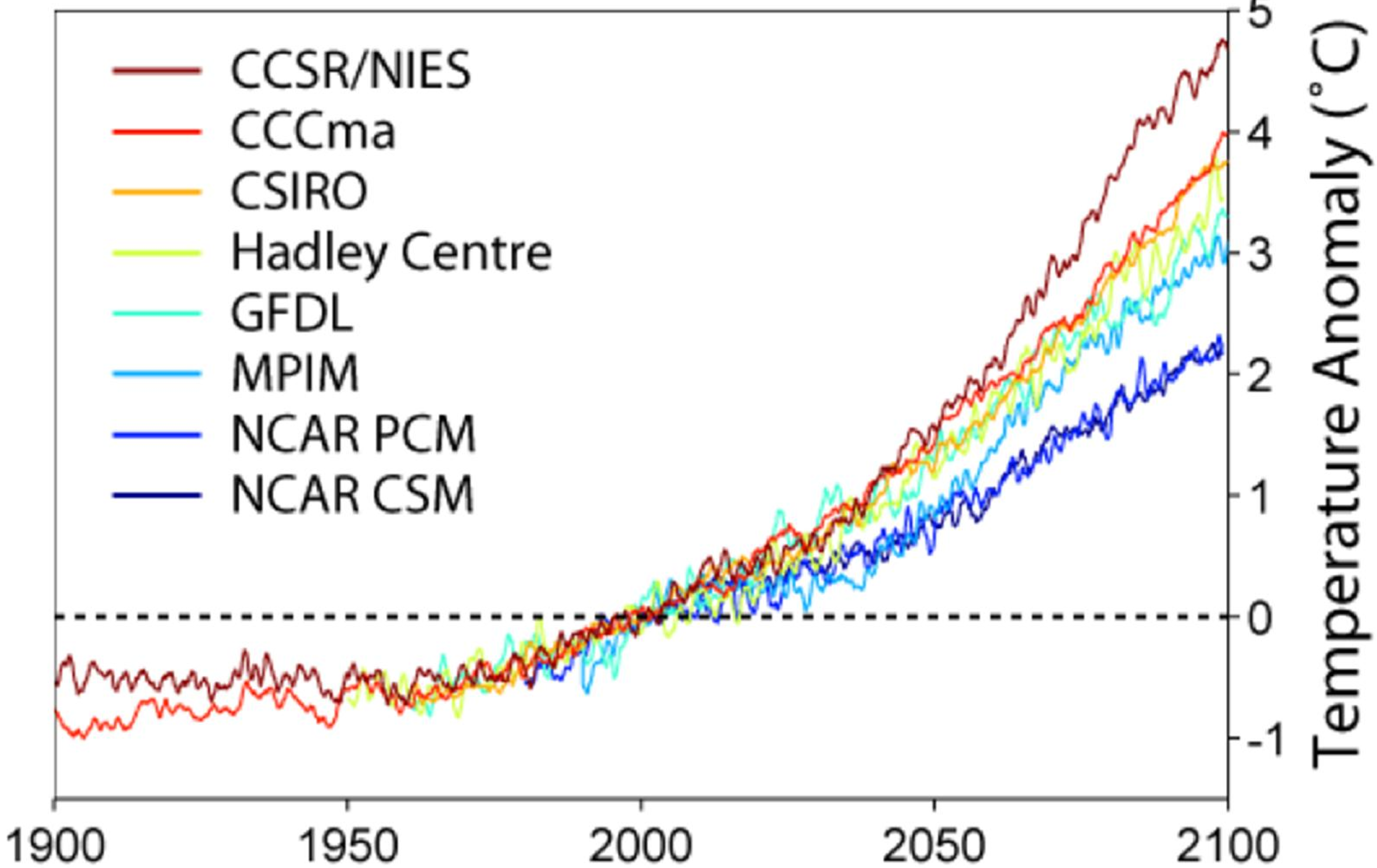
Projected climate-induced faunal change in the Western Hemisphere

JOSHUA J. LAWLER,[1,7] SARAH L. SHAFER,[2] DENIS WHITE,[3] PETER KAREIVA,[4] EDWIN P. MAURER,[5] ANDREW R. BLAUSTEIN,[1] AND PATRICK J. BARTLEIN[6]

Sources of uncertainty in predicting ecological impacts of climate change

1) Biogeographic data sampling species distributions
2) Distribution modeling algorithms
3) Current ‘climate surfaces’ characterizing environmental space
4) Variation in climate model output
5) Downscaling coarse resolution global output to generate higher resolution *future climate surfaces*
6) Uncertainty in extent of future greenhouse gas emissions

Global Warming Projections



Quantification of modelling uncertainties in a large ensemble of climate change simulations

James M. Murphy[1], David M. H. Sexton[1], David N. Barnett[1], Gareth S. Jones[1], Mark J. Webb[1], Matthew Collins[1] & David A. Stainforth[2]

[1] *Hadley Centre for Climate Prediction and Research, Met Office, FitzRoy Road, Exeter EX1 3PB, UK*
[2] *Department of Physics, University of Oxford, Parks Road, Oxford OX1 3PU, UK*

Comprehensive global climate models[1] are the only tools that account for the complex set of processes which will determine future climate change at both a global and regional level. Planners are typically faced with a wide range of predicted changes from different models of unknown relative quality[2,3], owing to large but unquantified uncertainties in the modelling

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

Phil. Trans. R. Soc. A (2007) **365**, 1957–1970
doi:10.1098/rsta.2007.2068
Published online 14 June 2007

Ensembles and probabilities: a new era in the prediction of climate change

By Mat Collins*

Met Office, Hadley Centre, FitzRoy Road, Exeter EX1 3PB, UK

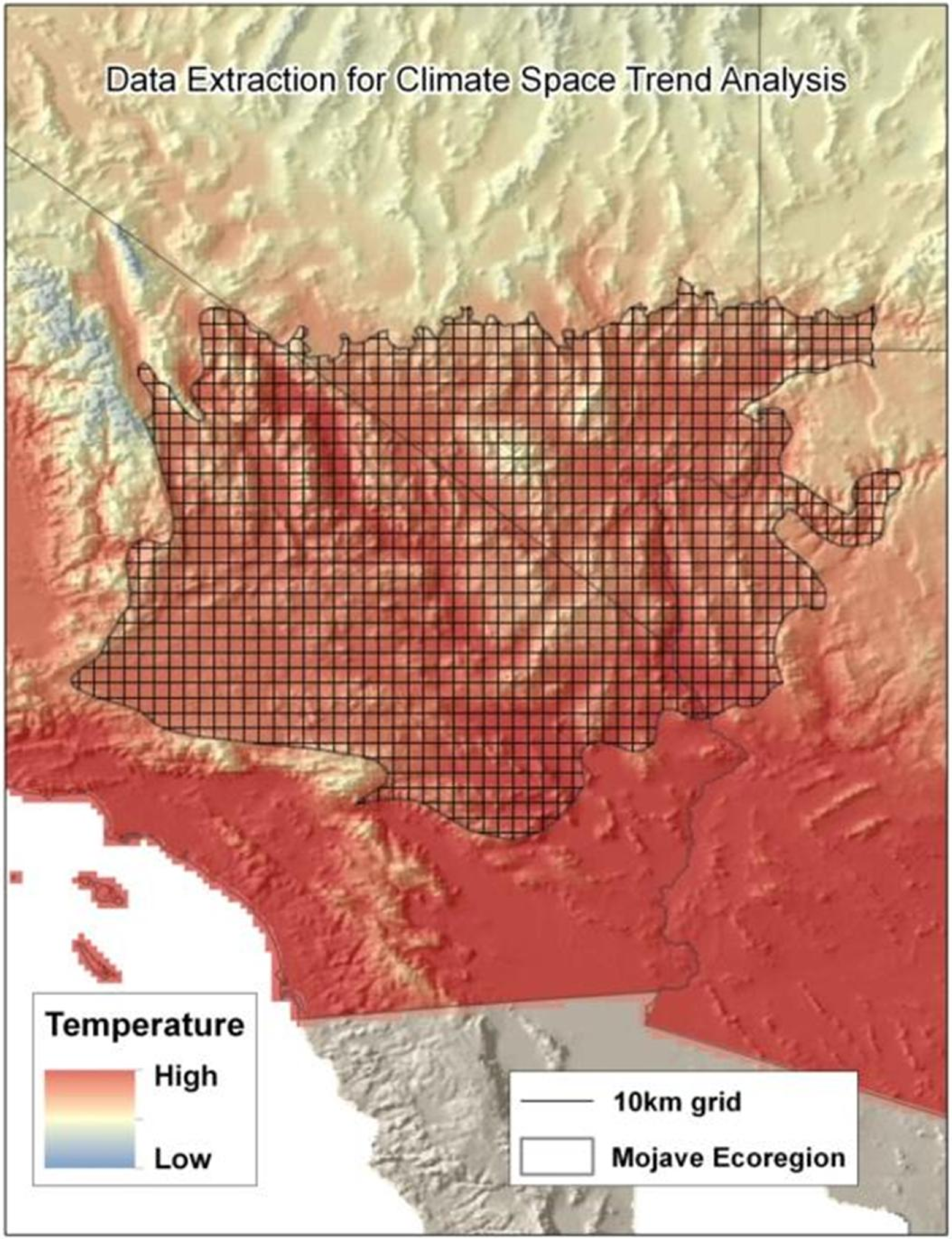
Phil. Trans. R. Soc. A (2007) **365**, 2053–2075
doi:10.1098/rsta.2007.2076
Published online 14 June 2007

Review

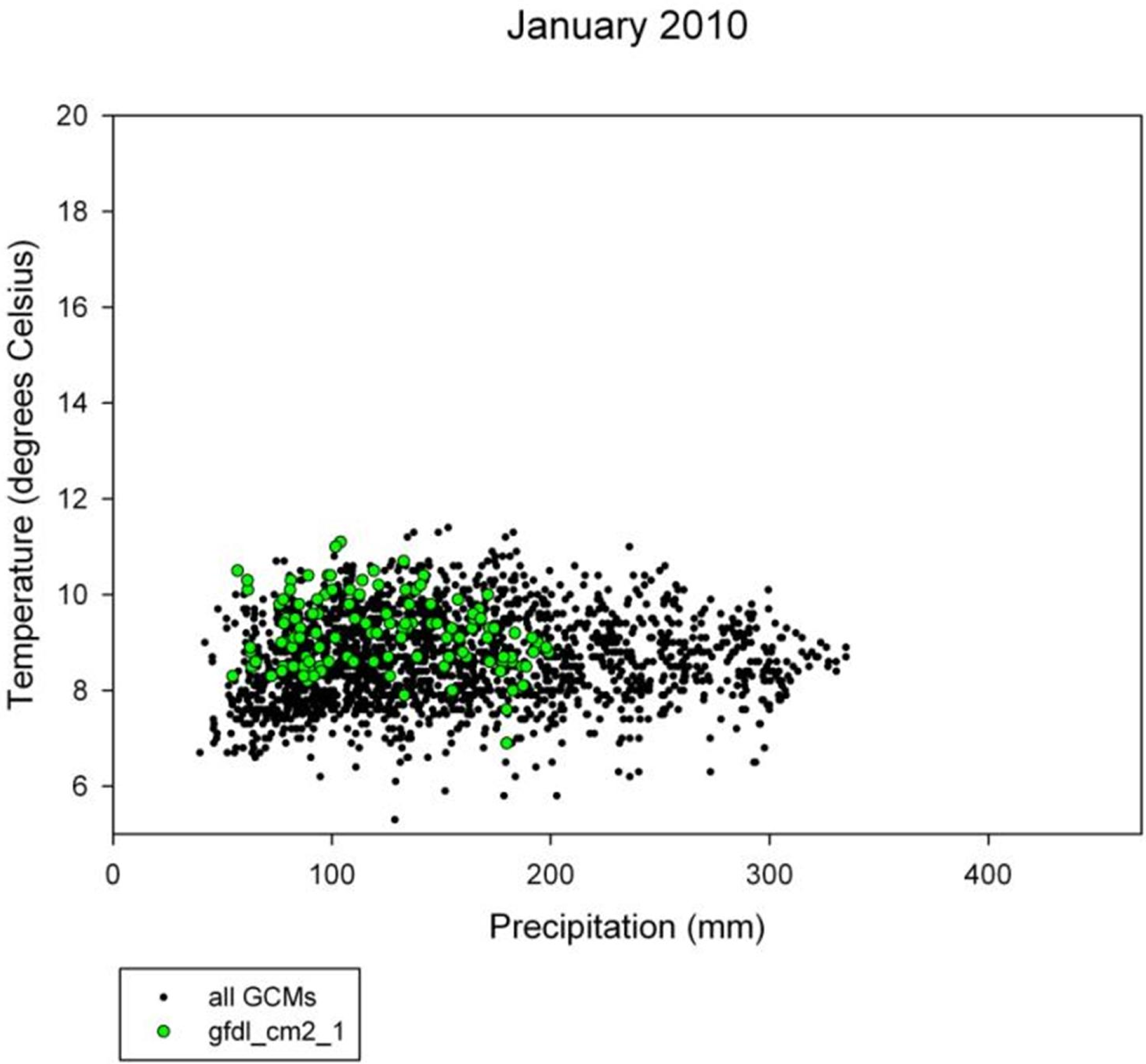
The use of the multi-model ensemble in probabilistic climate projections

By Claudia Tebaldi[1,*] and Reto Knutti[2]

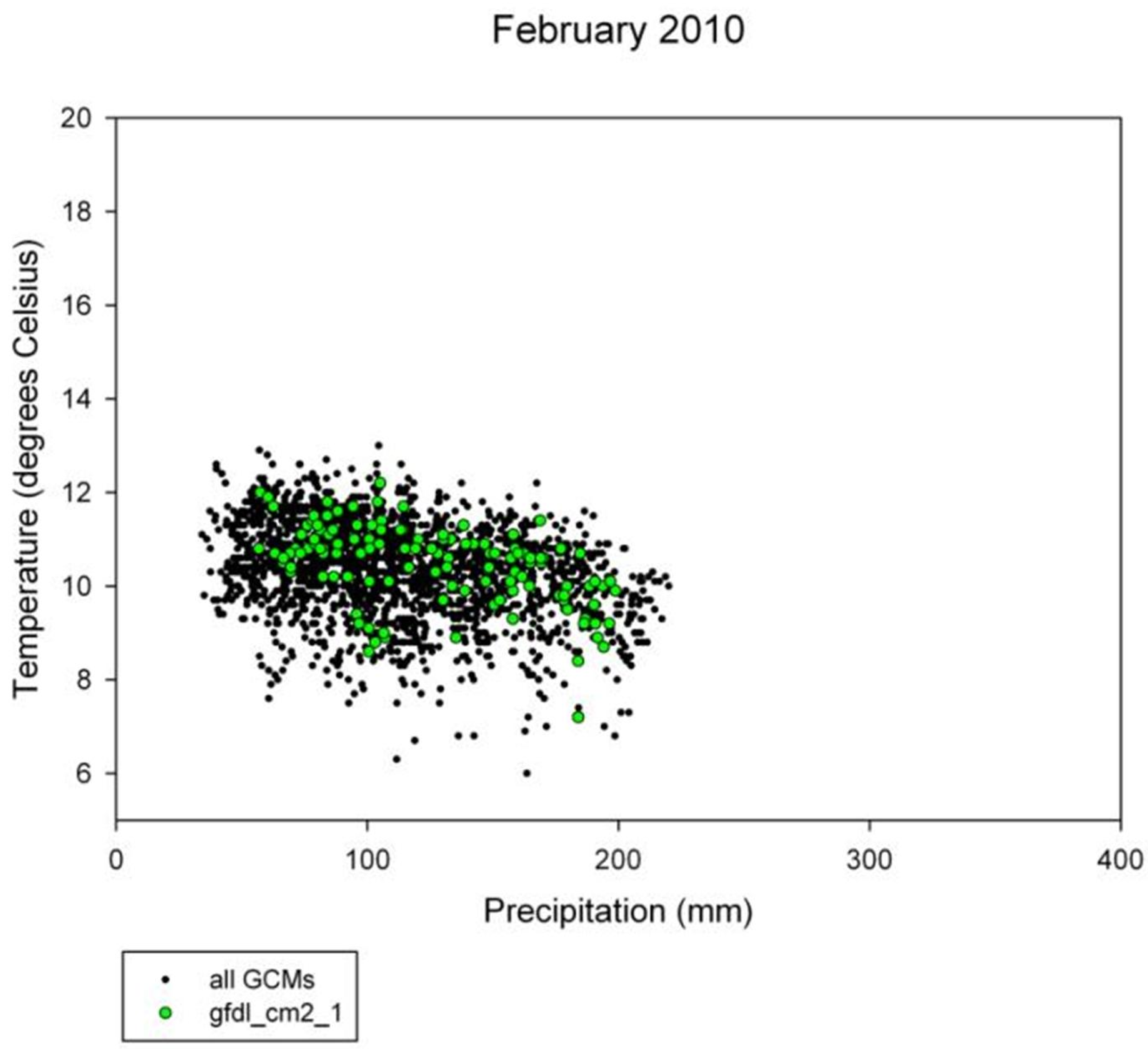
[1] *Institute for the Study of Society and Environment, National Center for Atmospheric Research, PO Box 3000, Boulder, CO 80304, USA*
[2] *Institute for Atmospheric and Climate Science, Swiss Federal Institute of Technology, Universitätstrasse 16 (CHN N 12.1), 8092 Zürich, Switzerland*

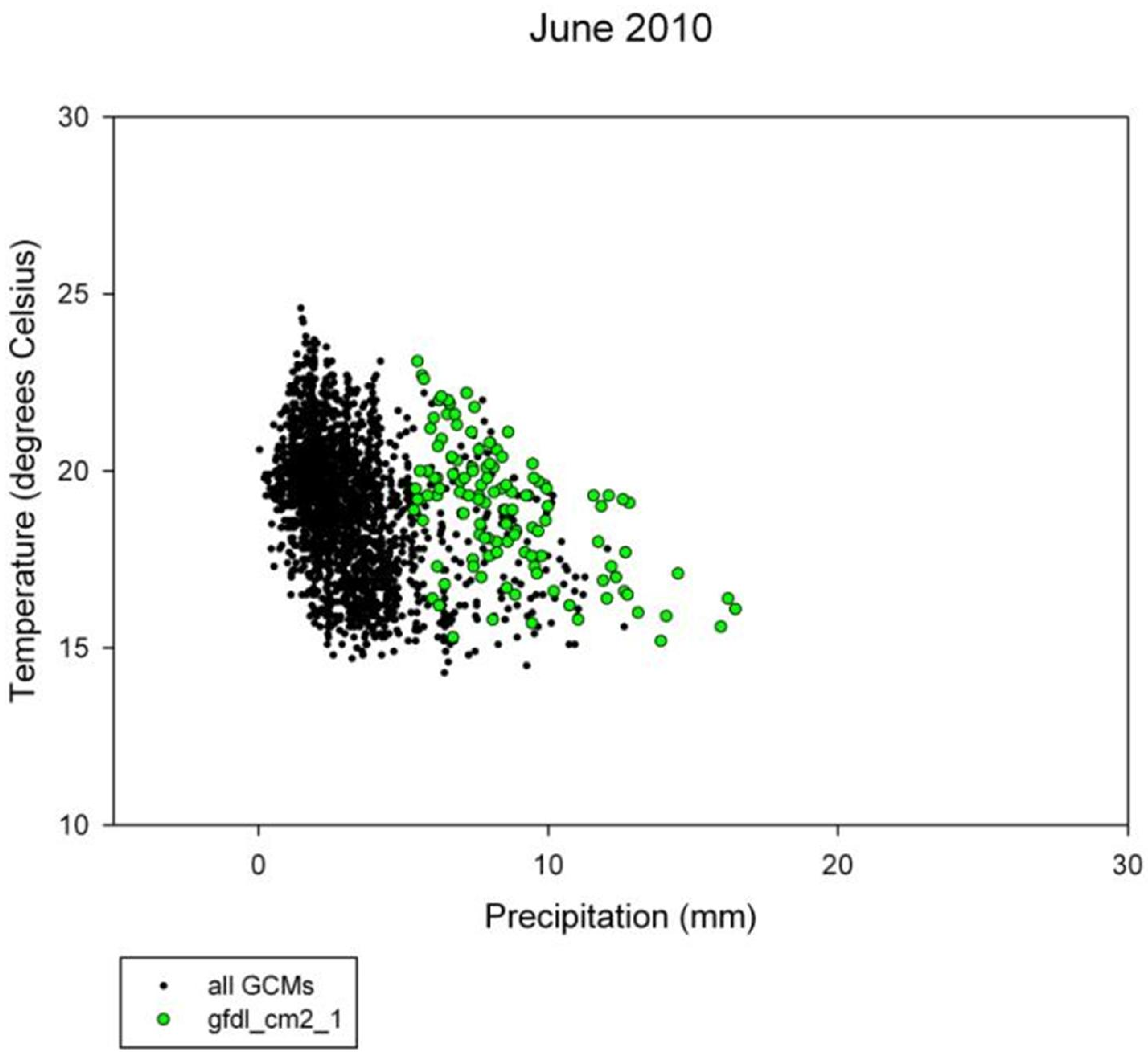


Data Extraction for Climate Space Trend Analysis
Temperature
High
Low
10km grid
Mojave Ecoregion

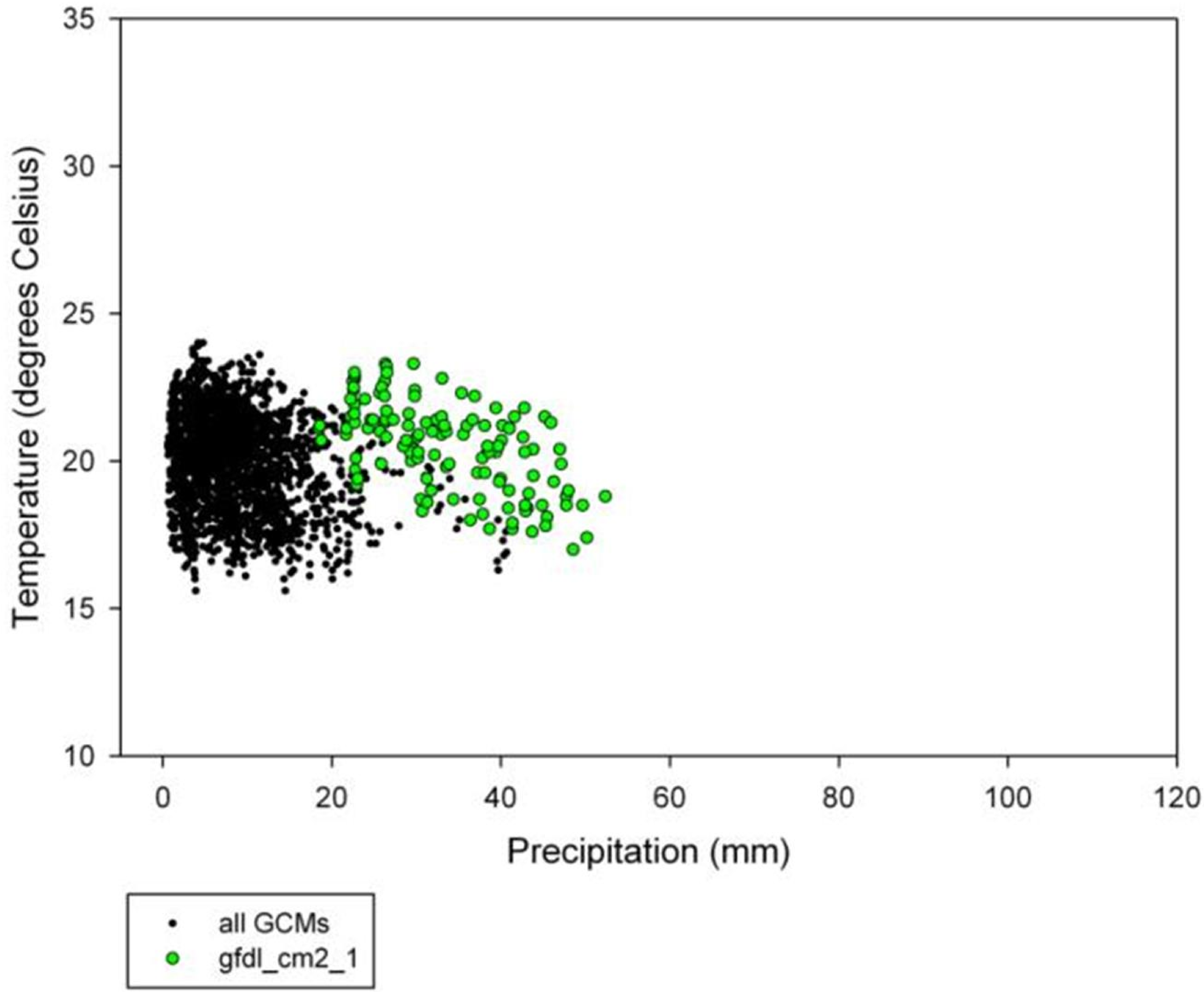


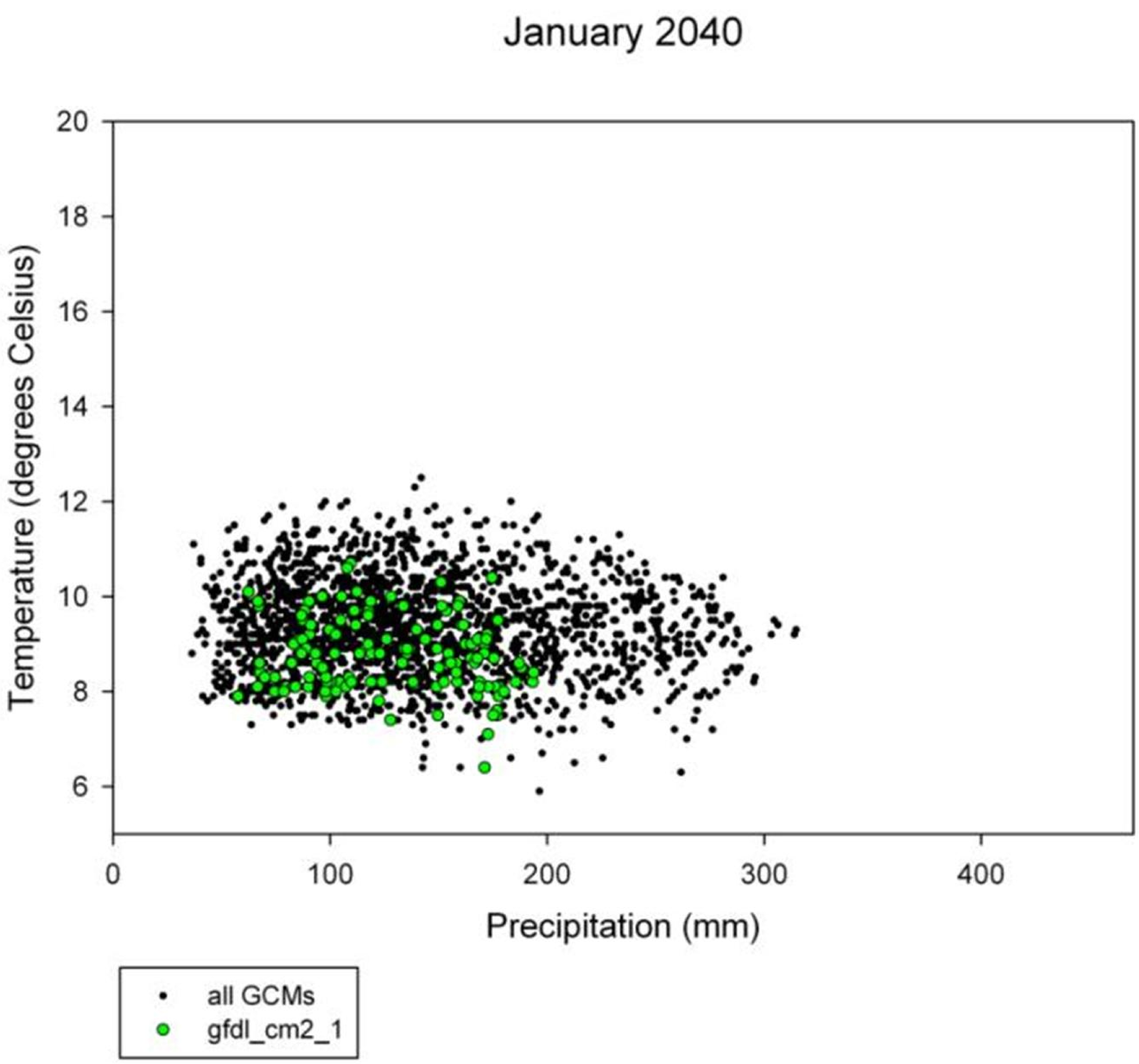
January 2010
Temperature (degrees Celsius)
20
18
16
14
12
10
8
6
0
100
200
300
400
Precipitation (mm)
all GCMs
gfdl_cm2_1

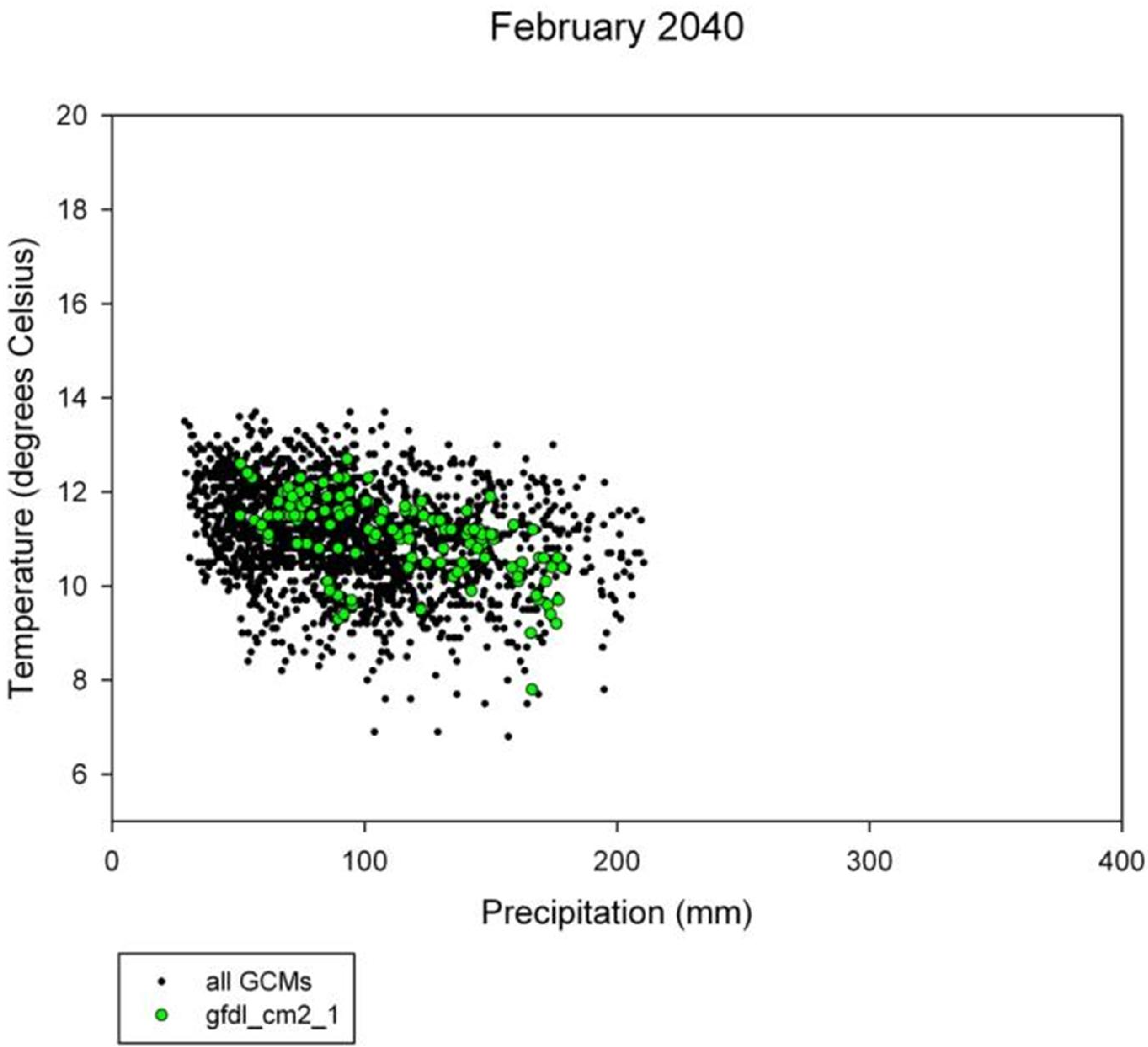

February 2010
Temperature (degrees Celsius)
20
18
16
14
12
10
8
6
0
100
200
300
400
Precipitation (mm)
all GCMs
gfdl_cm2_1


June 2010
Temperature (degrees Celsius)
30
25
20
15
10
0
10
20
30
Precipitation (mm)
all GCMs
gfdl_cm2_1

September 2010

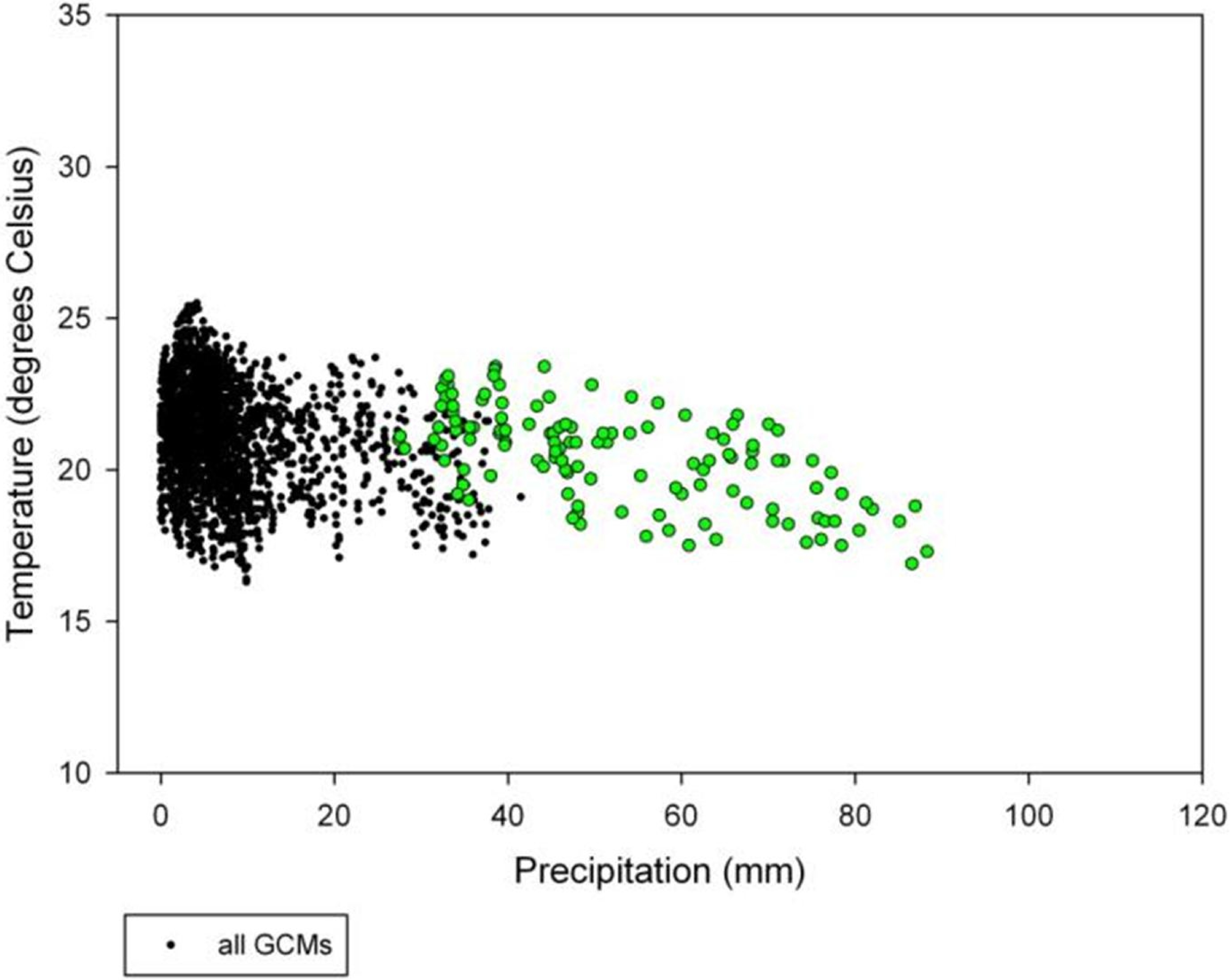



January 2040
Temperature (degrees Celsius)
20
18
16
14
12
10
8
6
0
100
200
300
400
Precipitation (mm)
all GCMs
gfdl_cm2_1

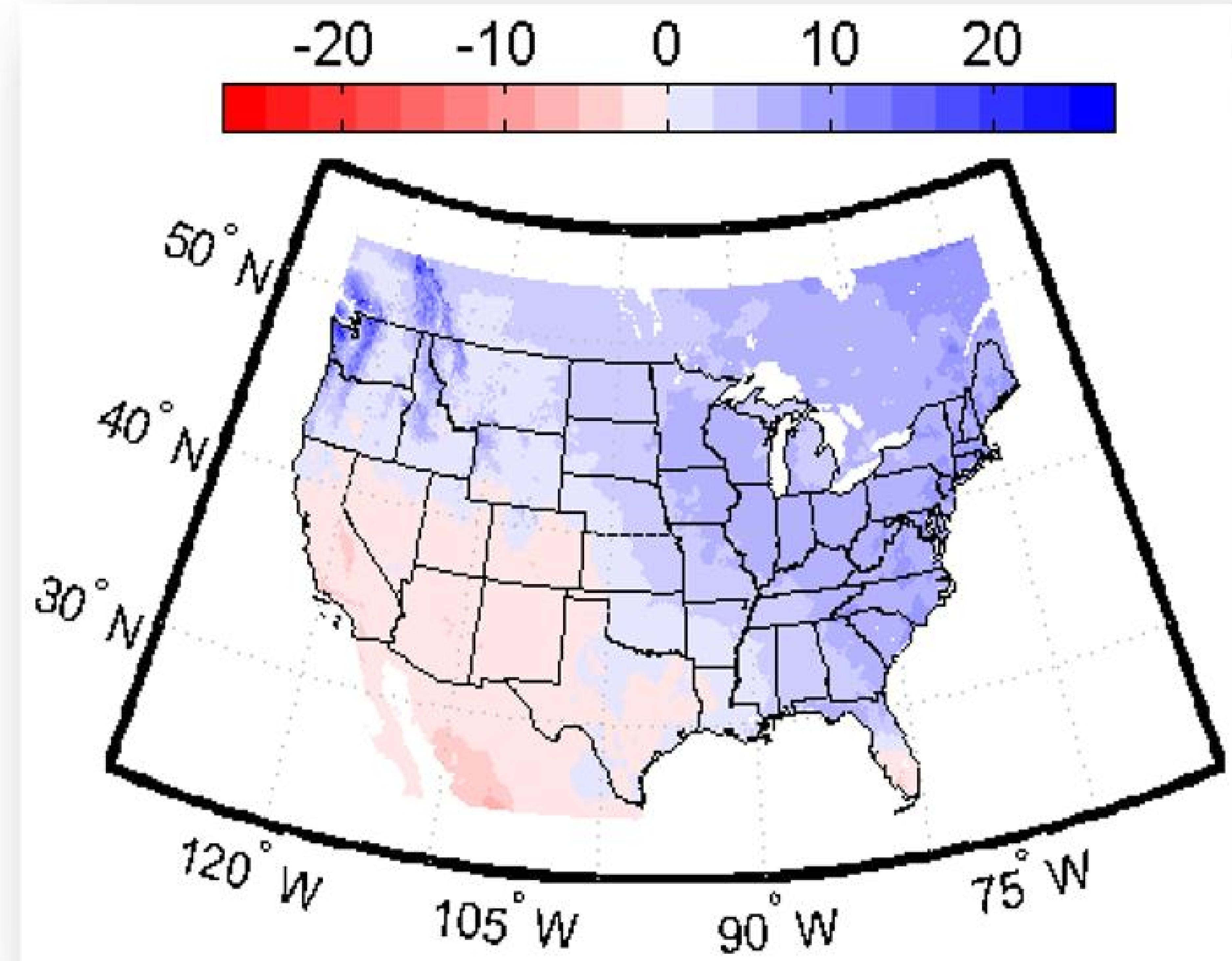


February 2040
Temperature (degrees Celsius)
20
18
16
14
12
10
8
6
0
100
200
300
400
Precipitation (mm)
all GCMs
gfdl_cm2_1

September 2040

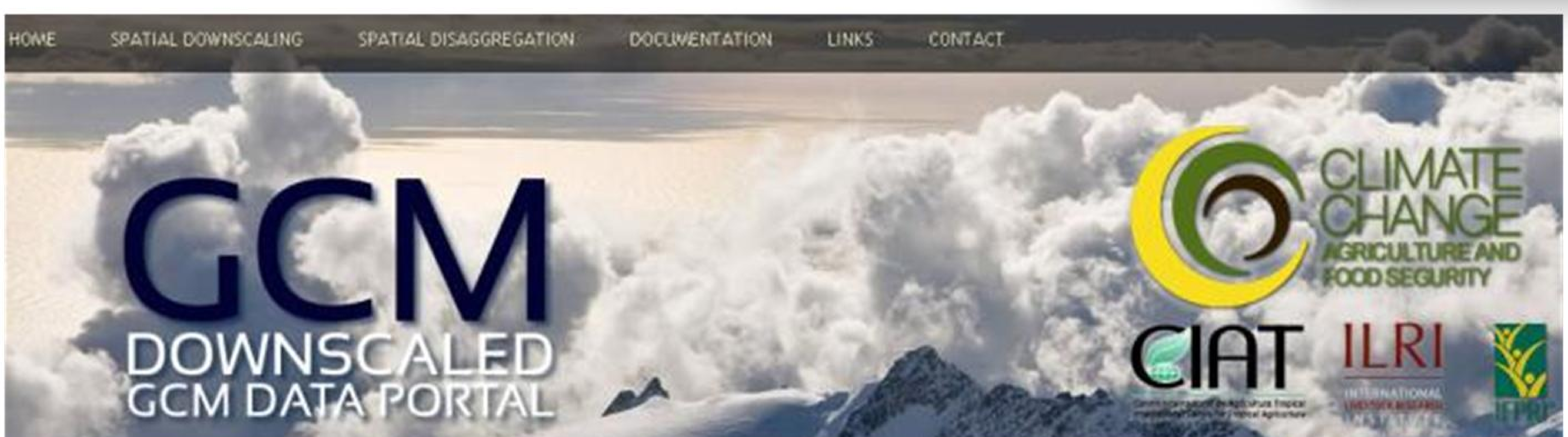


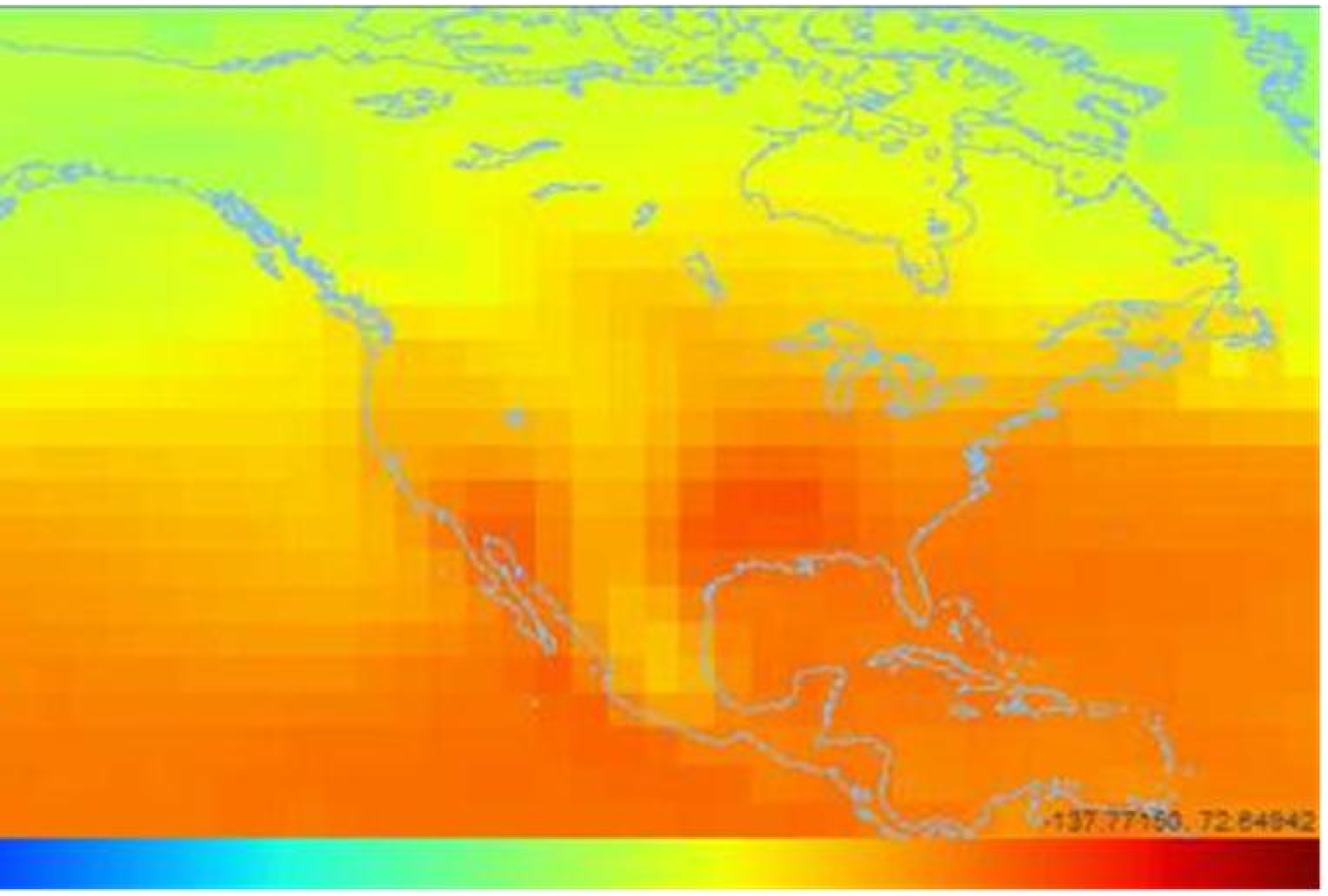
Library of Downscaled Climate Projections



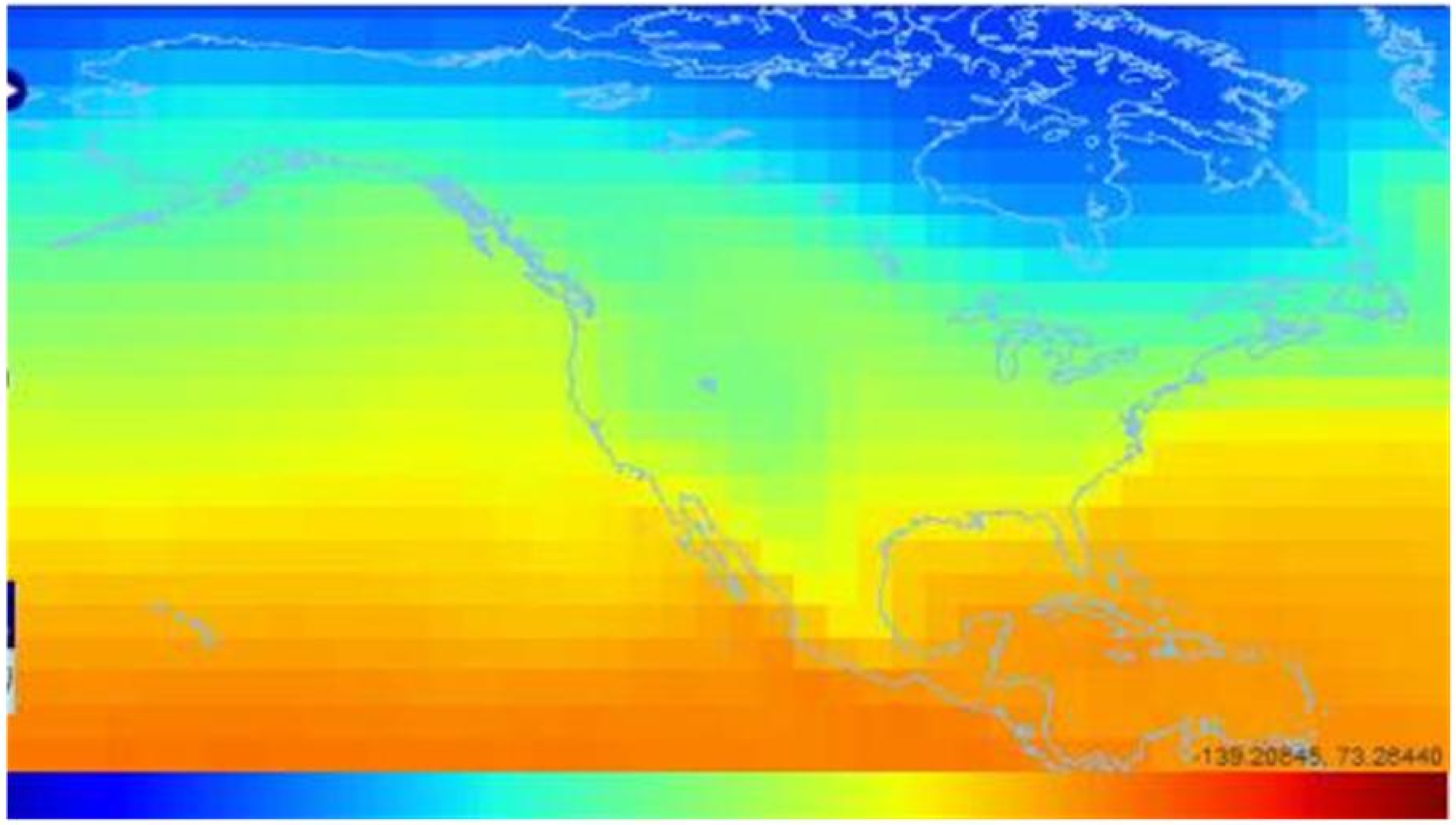
Santa Clara University

RECLAMATION

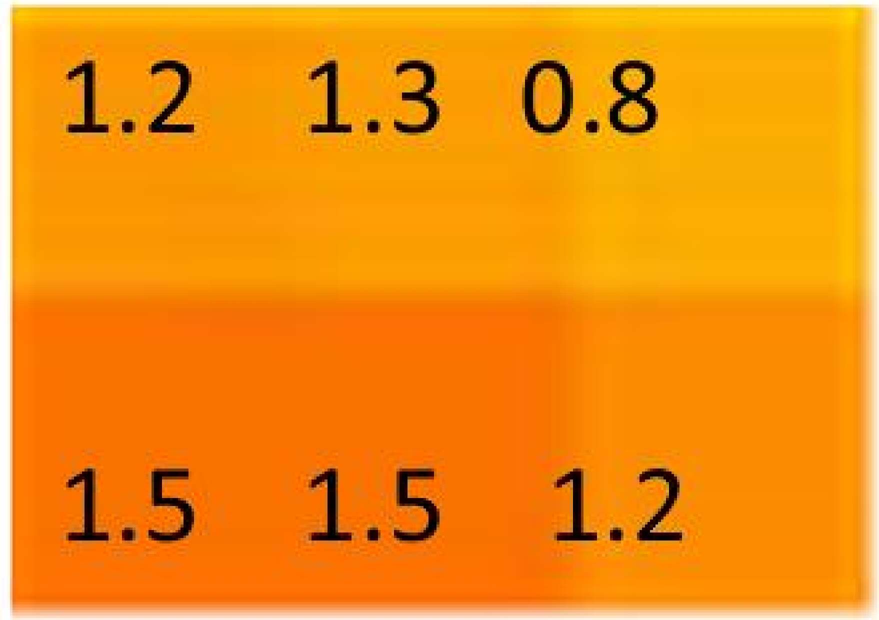




CCSM3 Tave July 2037 B1

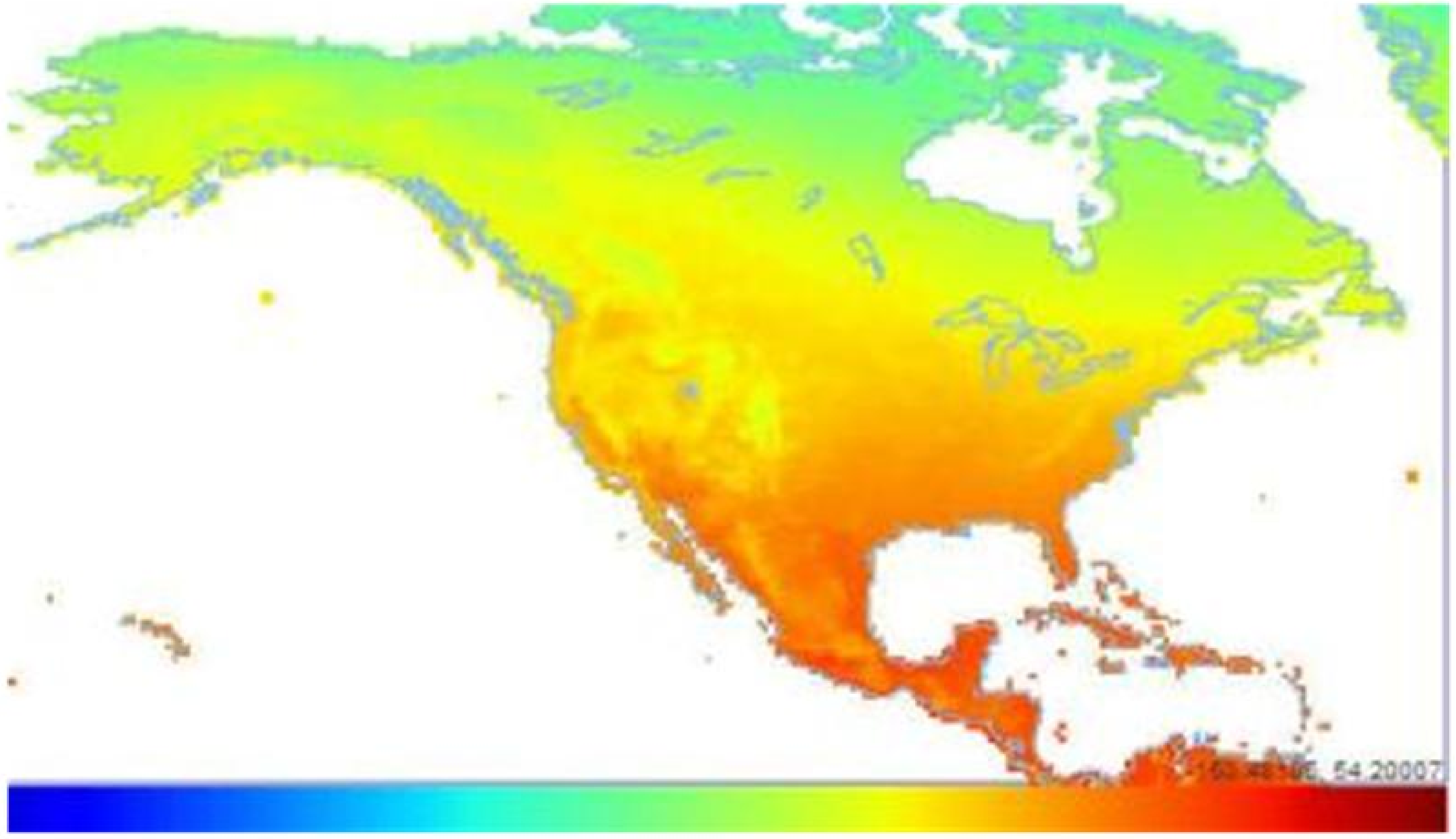


20th century re-analysis, Tave July observed



"Deltas"

Change factors



Interpolate deltas to 10km[2] spatial resolution a baseline climatology, i.e. Worldclim (Hijmans et al 2005)

World Climate Research Programme (WCRP)

WCRP CMIP3 Multi-Model Dataset Archive at PCMDI

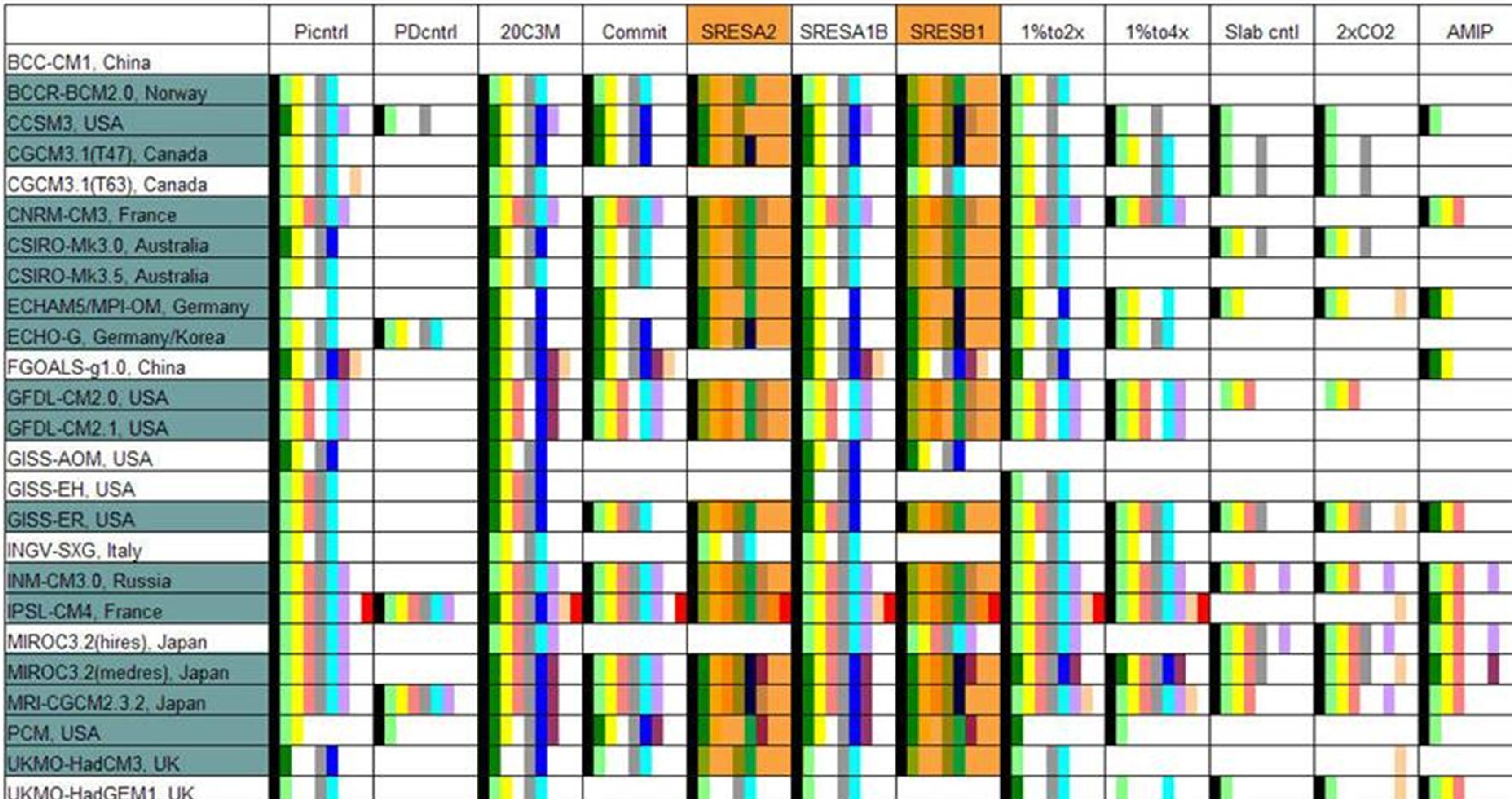
Data Availability Summary **(as of 27 February 2008)**

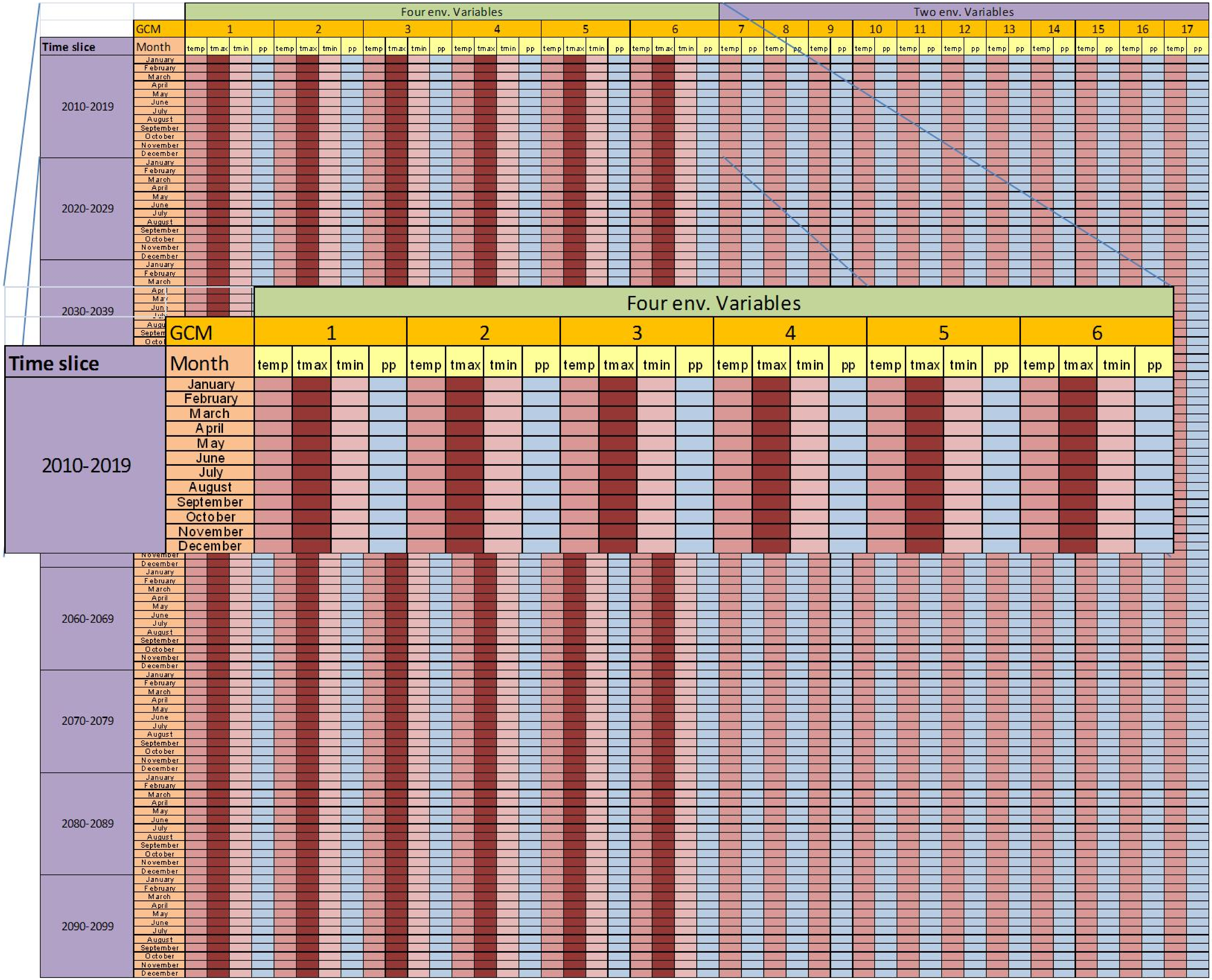
shaded area indicates that at least some but not necessarily all fields are available for data type indicated

17 GCMs for two emissions scenarios (A2 & B1)

Simple downscaling for monthly Tave, precip

6 GCMs for monthly Tmax & Tmin

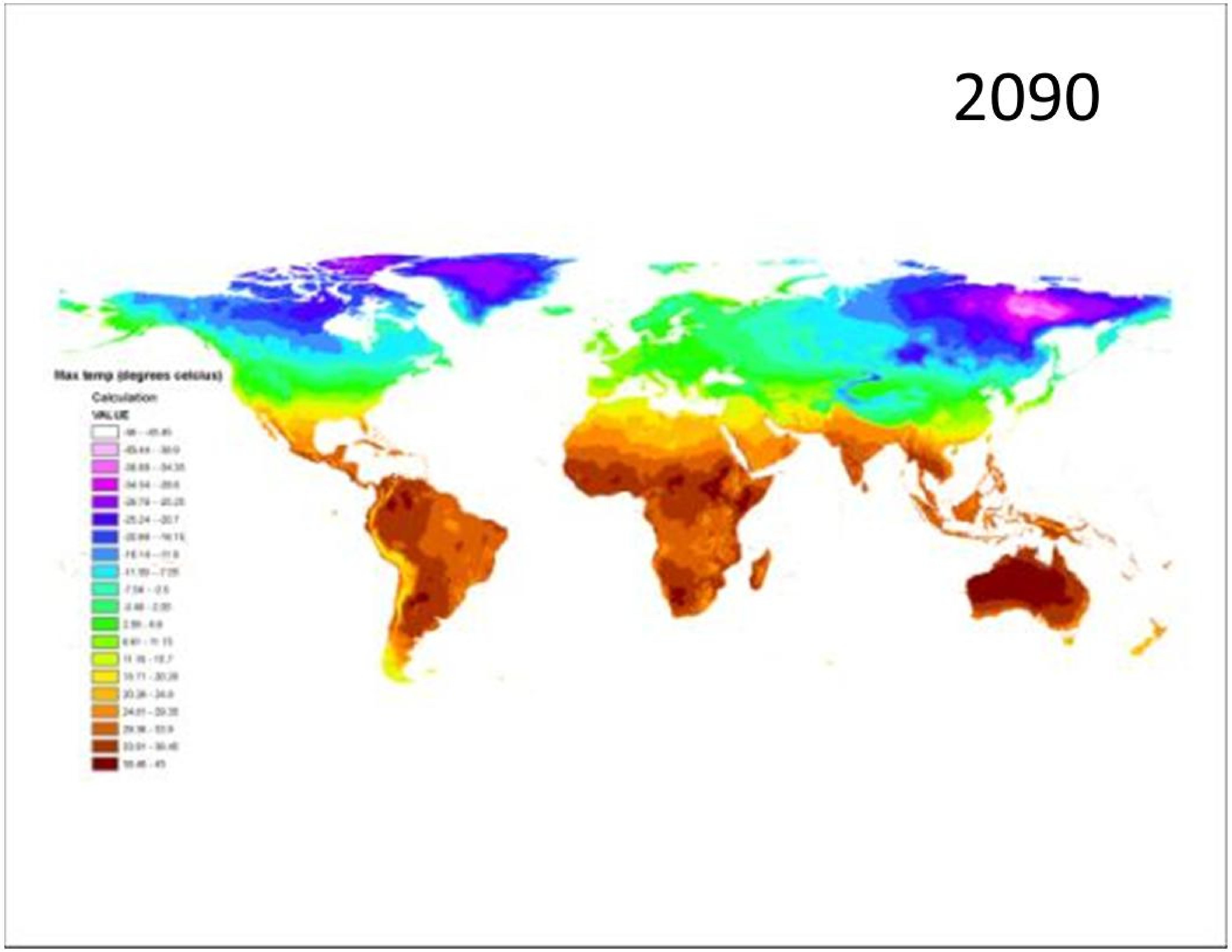


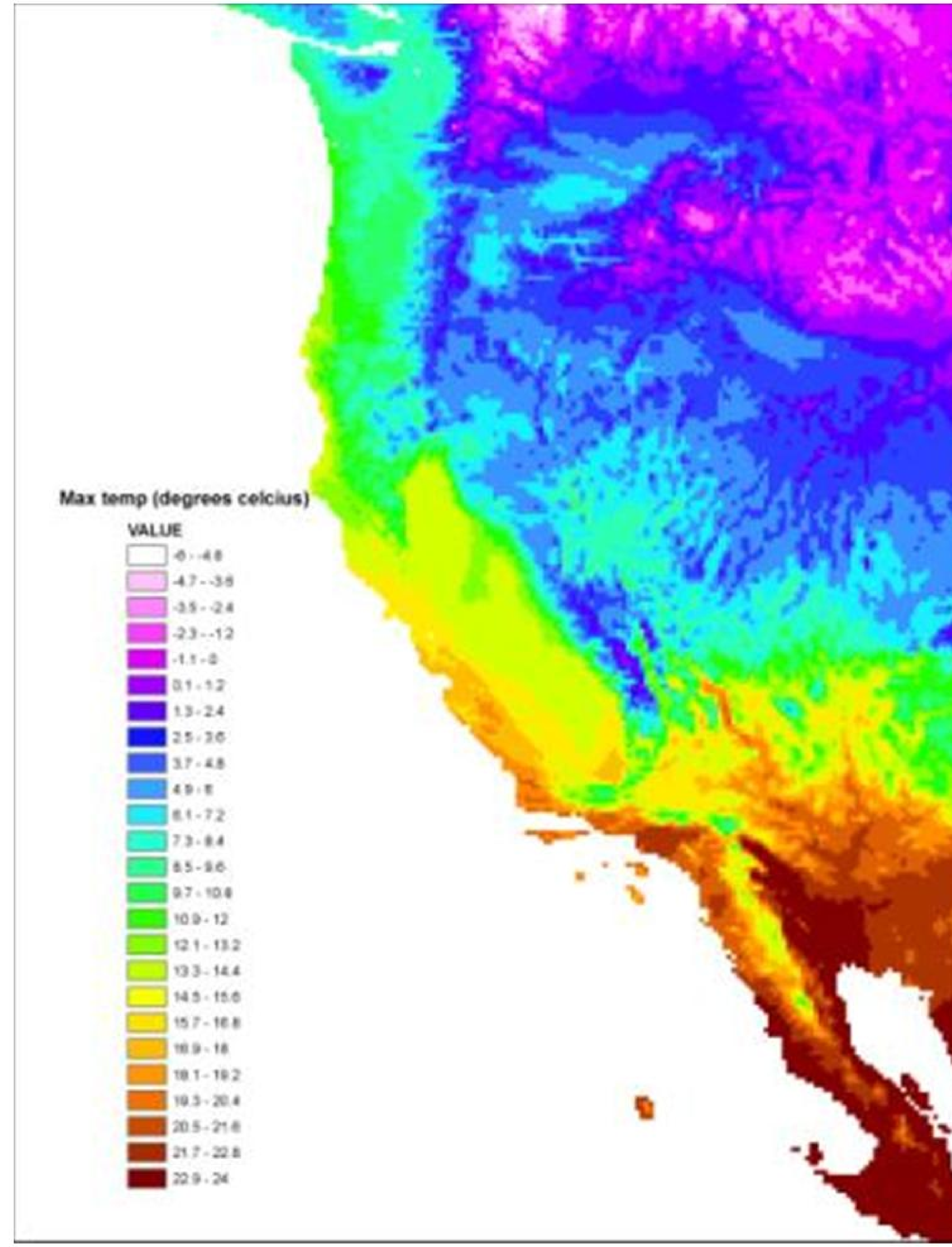


Four env. Variables
Two env. Variables
GCM
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Time slice
Month
temp
tmax
tmin
pp
January
February
March
April
May
June
July
August
September
October
November
December
2010-2019
2020-2029
2030-2039
2060-2069
2070-2079
2080-2089
2090-2099


EcoClim.org
Spatial climate data for ecological forecasting
HOME
DATA
TEAM
CONTACT INFO
Map
Satellite
Terrain
North America
Atlantic Ocean
Europe
Asia
Africa
South America
Indian Ocean
Australia
POWERED BY Google
2000 mi
5000 km
Terms of Use
DATA DOWNLOAD
Region: North America
Scenario: A2
GCM: bccr_bcm2_0
Year: 2010's
Variable: All Variable
Submit

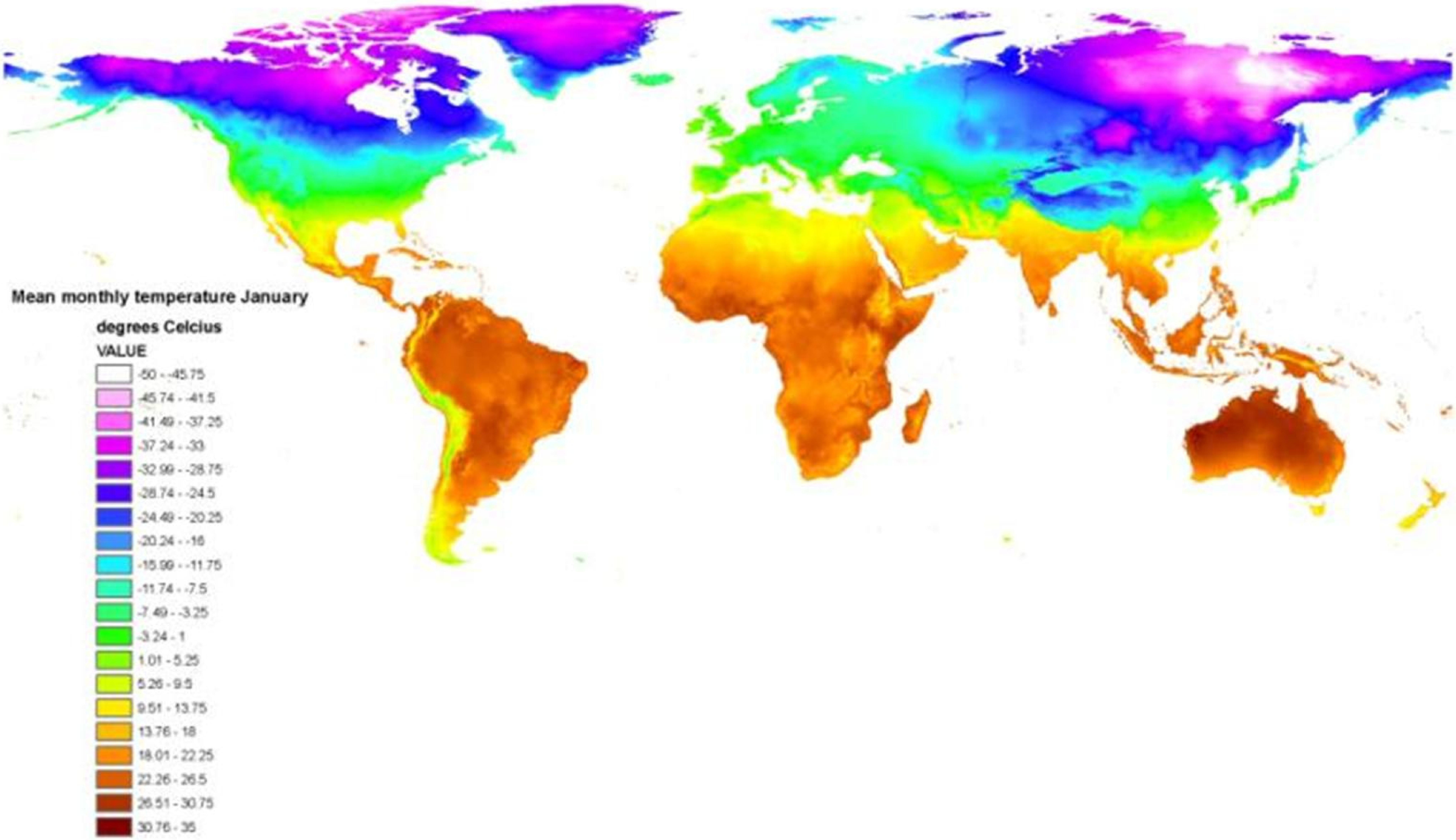
Decadal variation



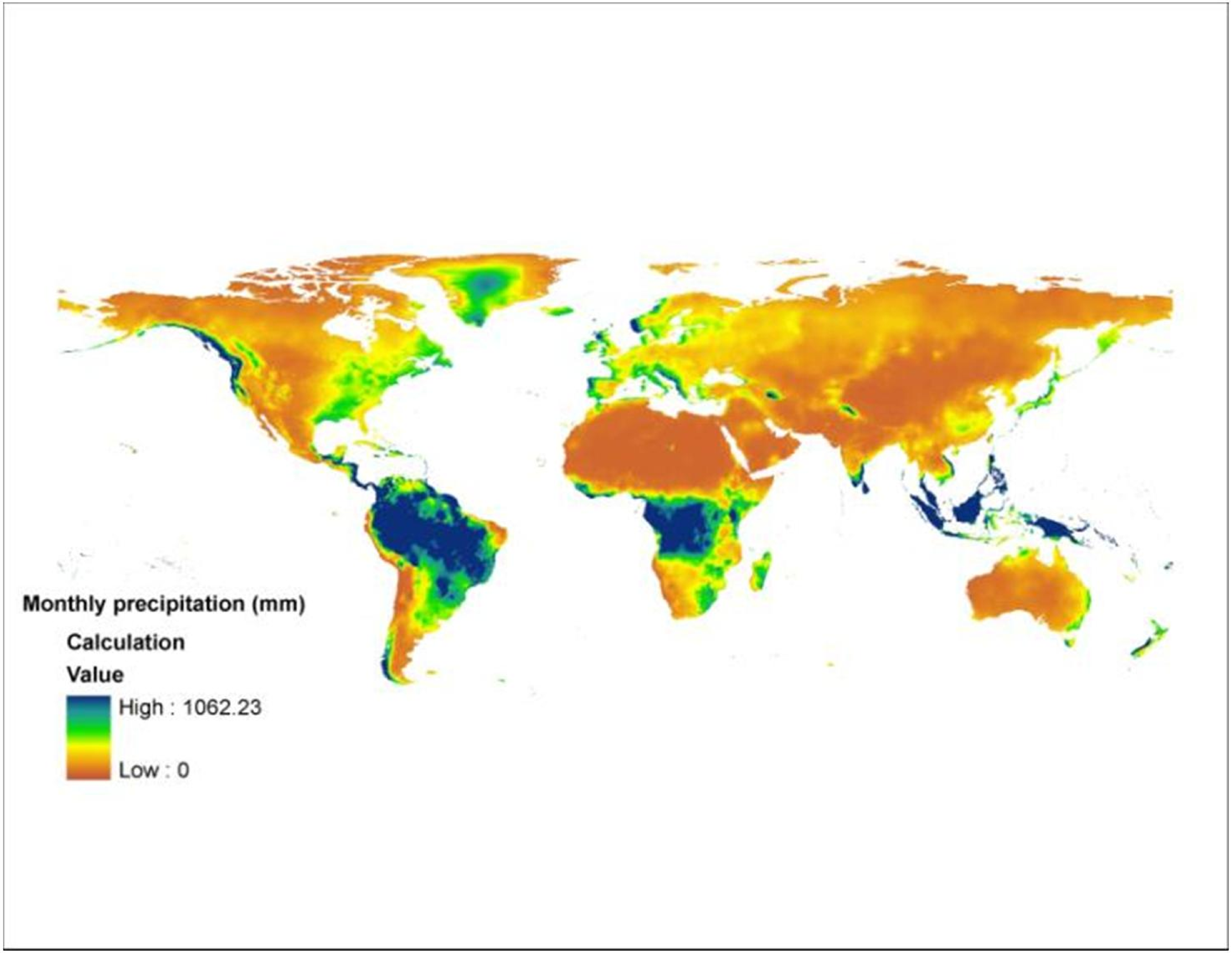


GCM variation

ukmo_hadcm3



Monthly variation

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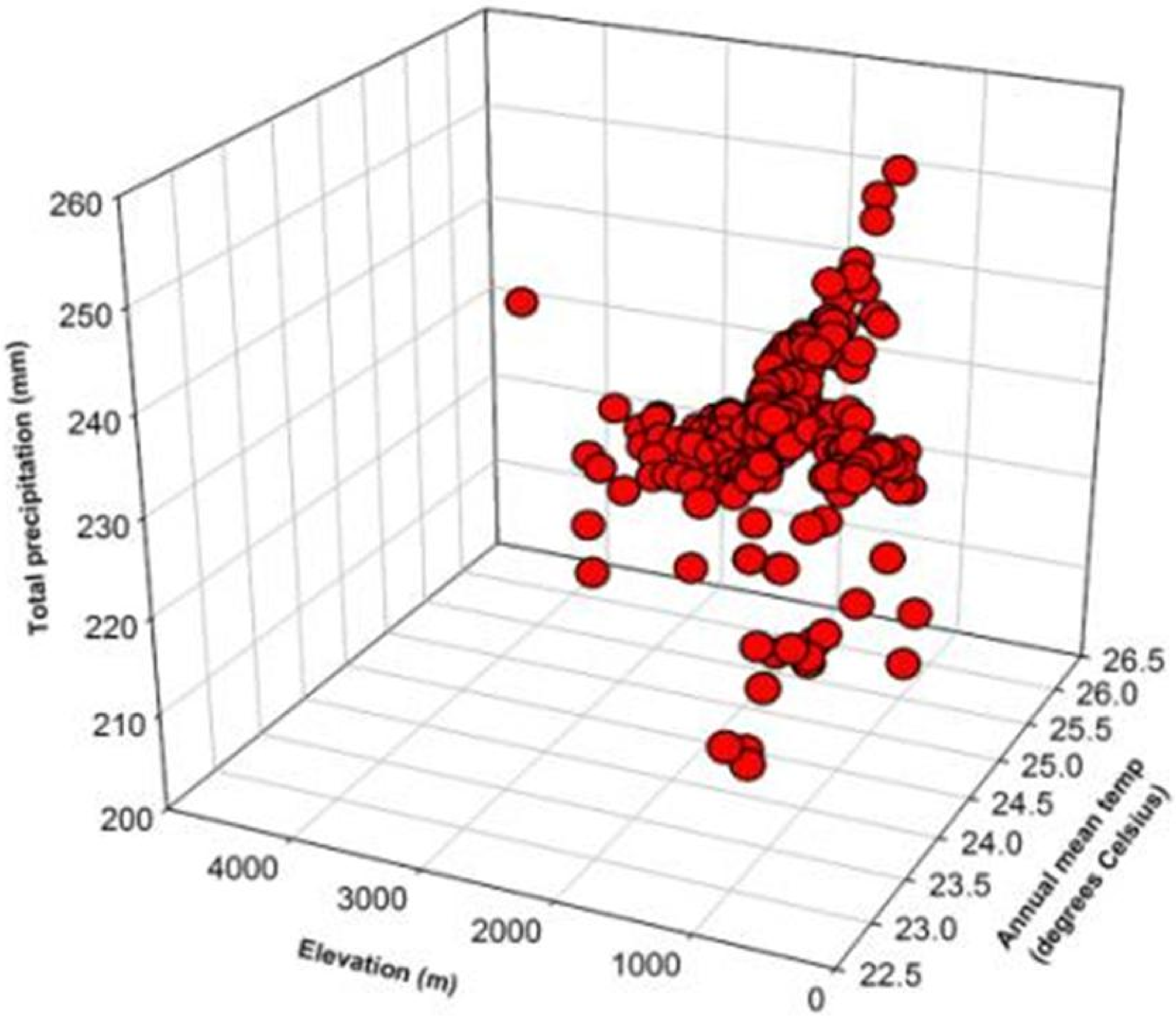
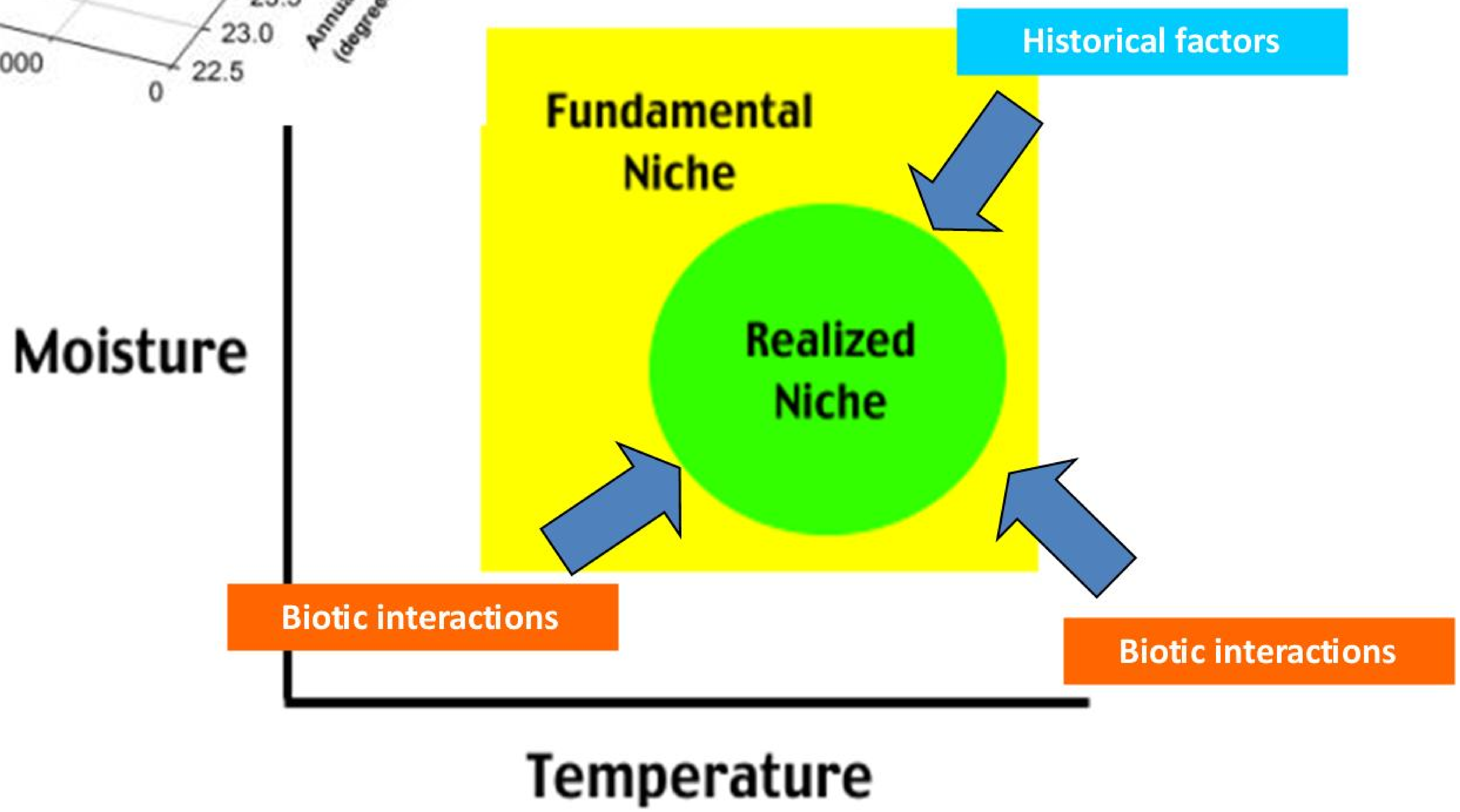
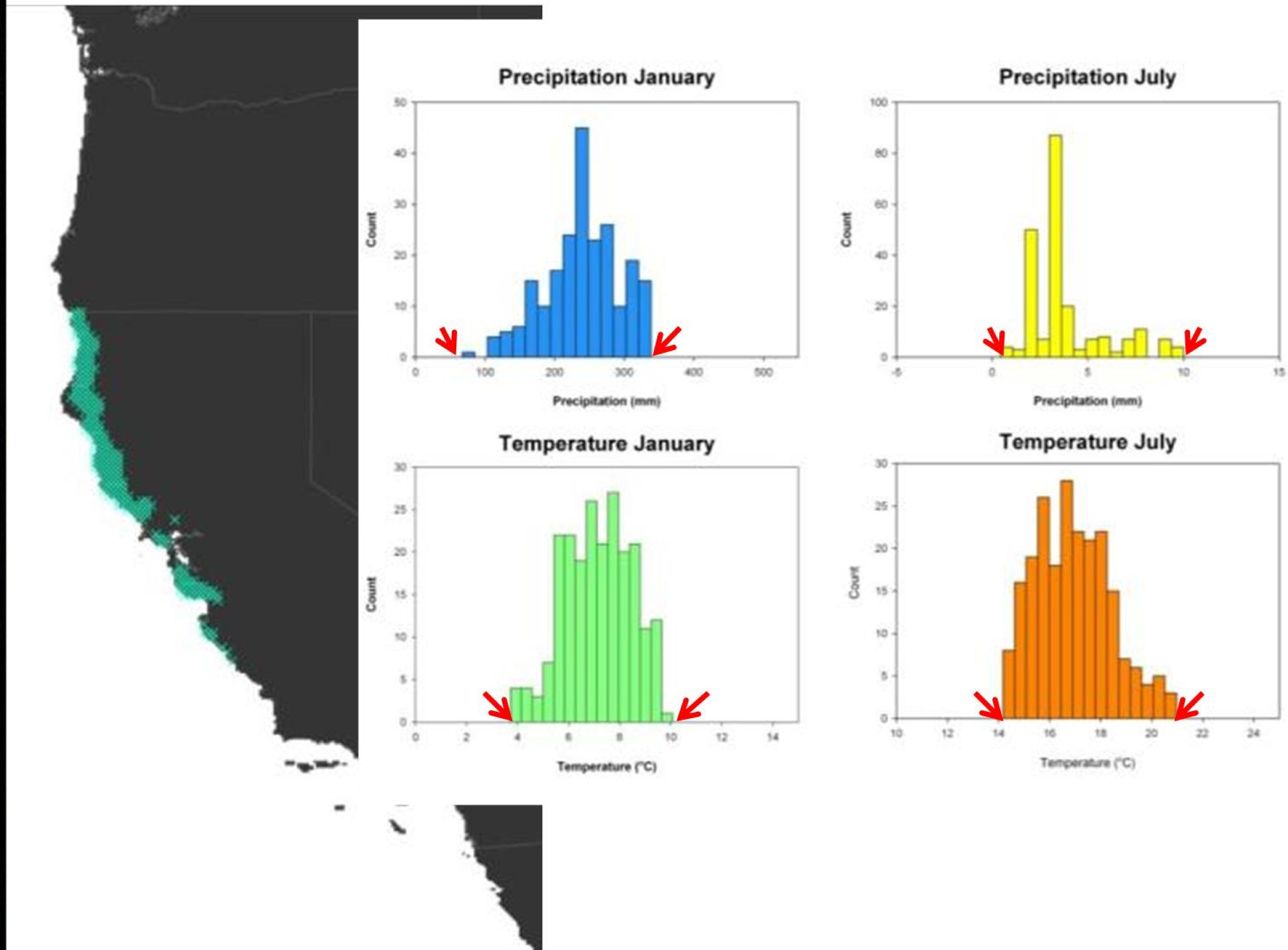


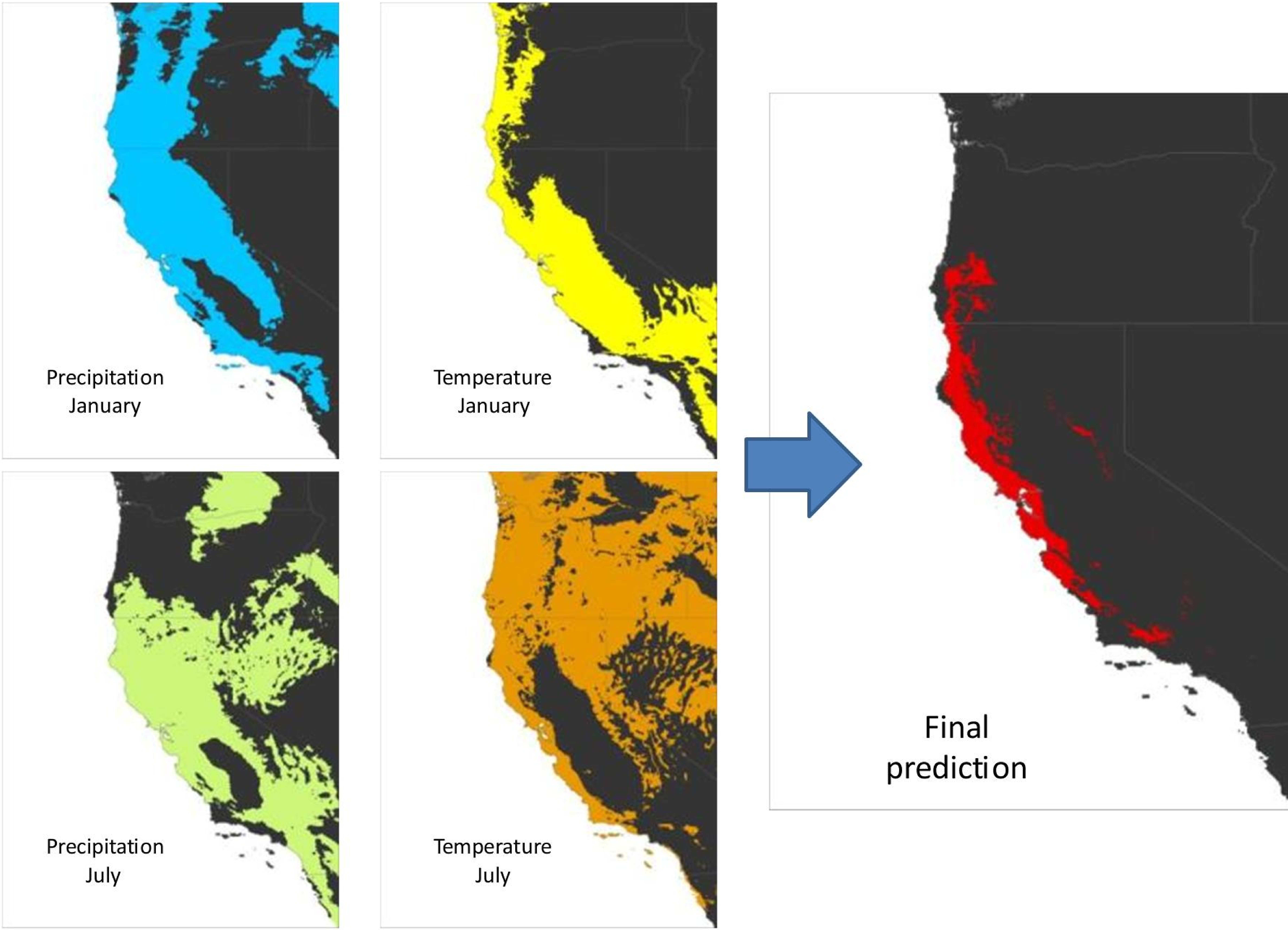
G. Evelyn Hutchinson 1903-1991



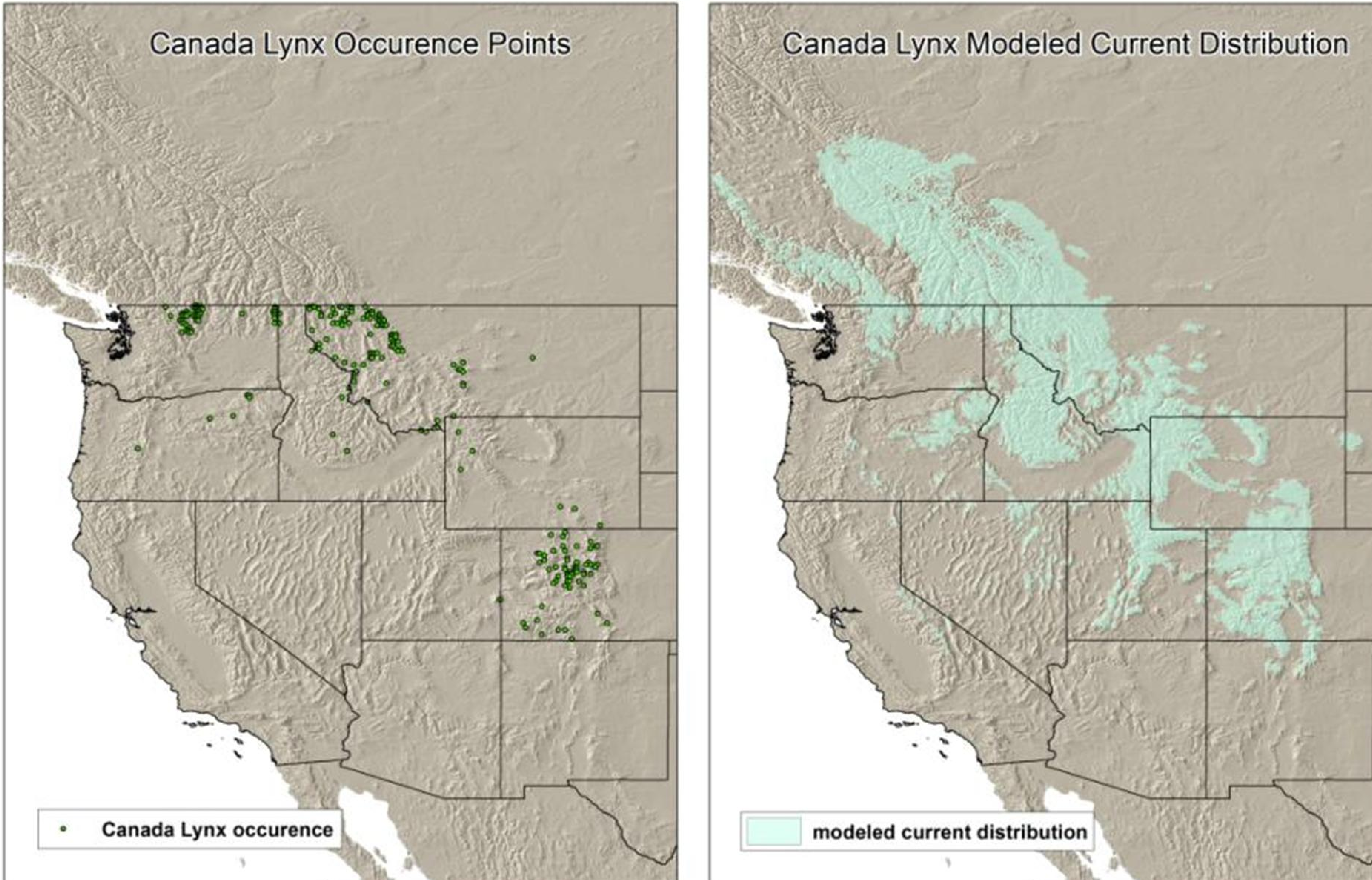
Climate and environmental data can be combined with observations to generate *species distribution models*



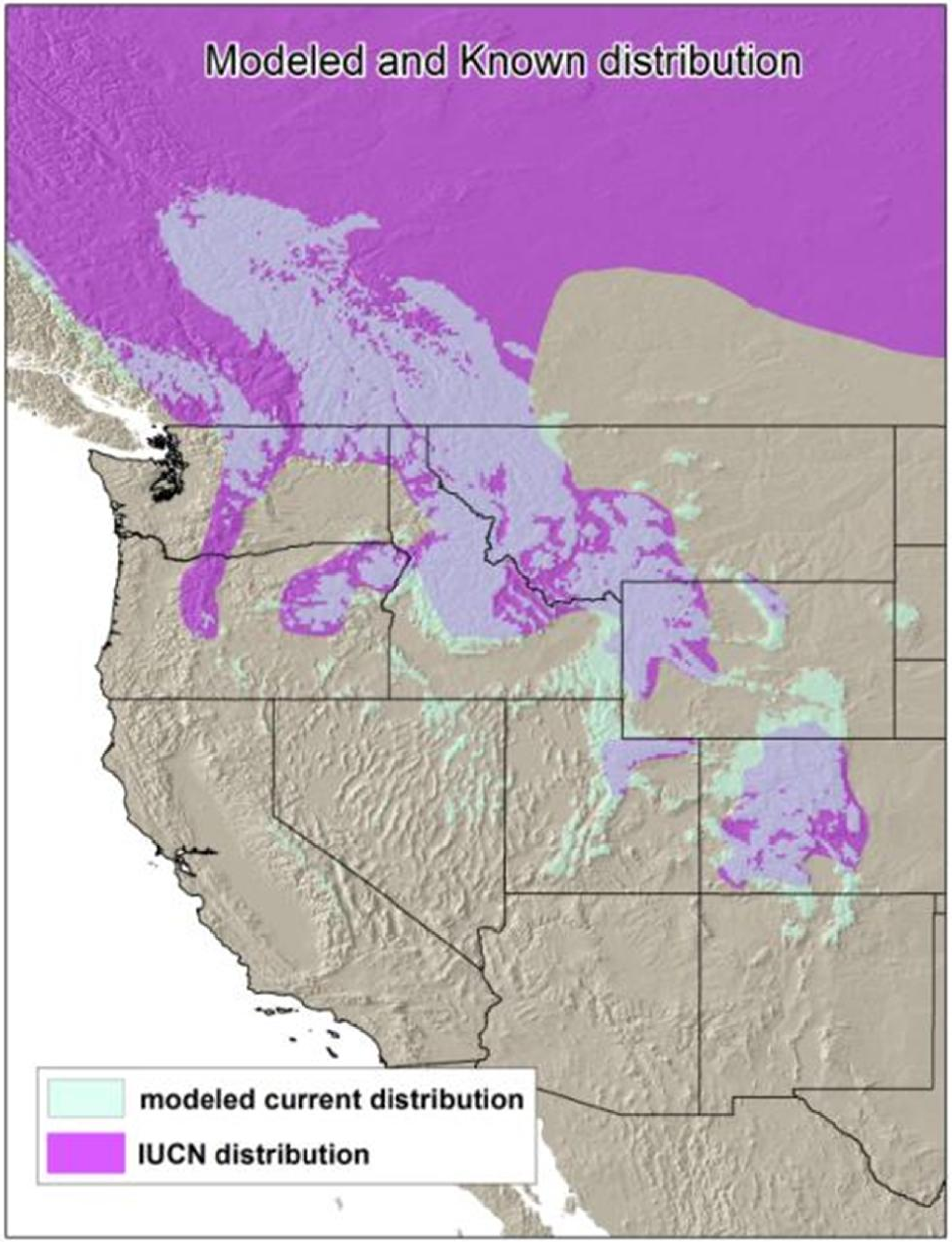
Coast redwood (*Sequoia sempervirens*) occurences


Precipitation
January
Temperature
January
Precipitation
July
Temperature
July
Final
prediction

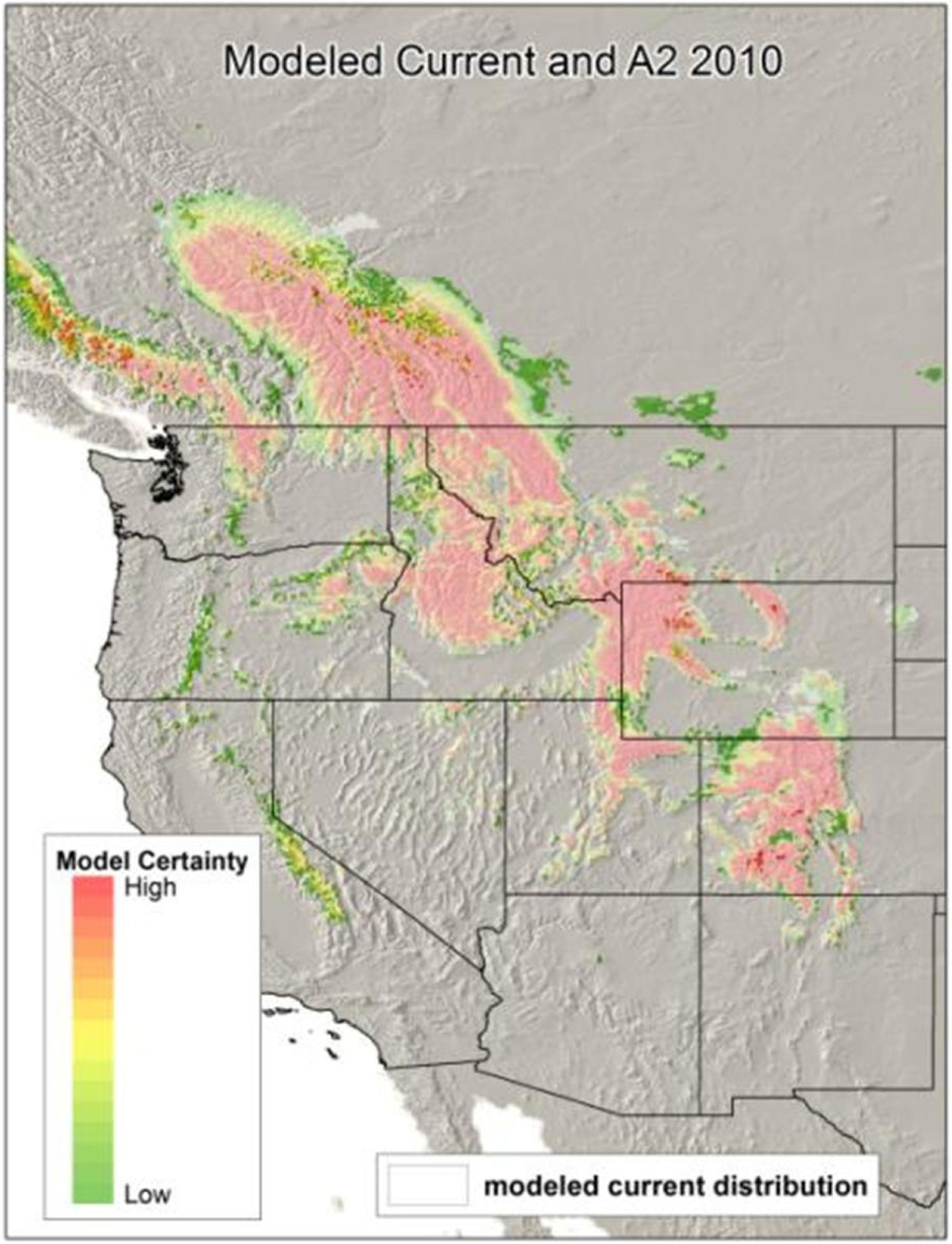
Canada Lynx Distribution

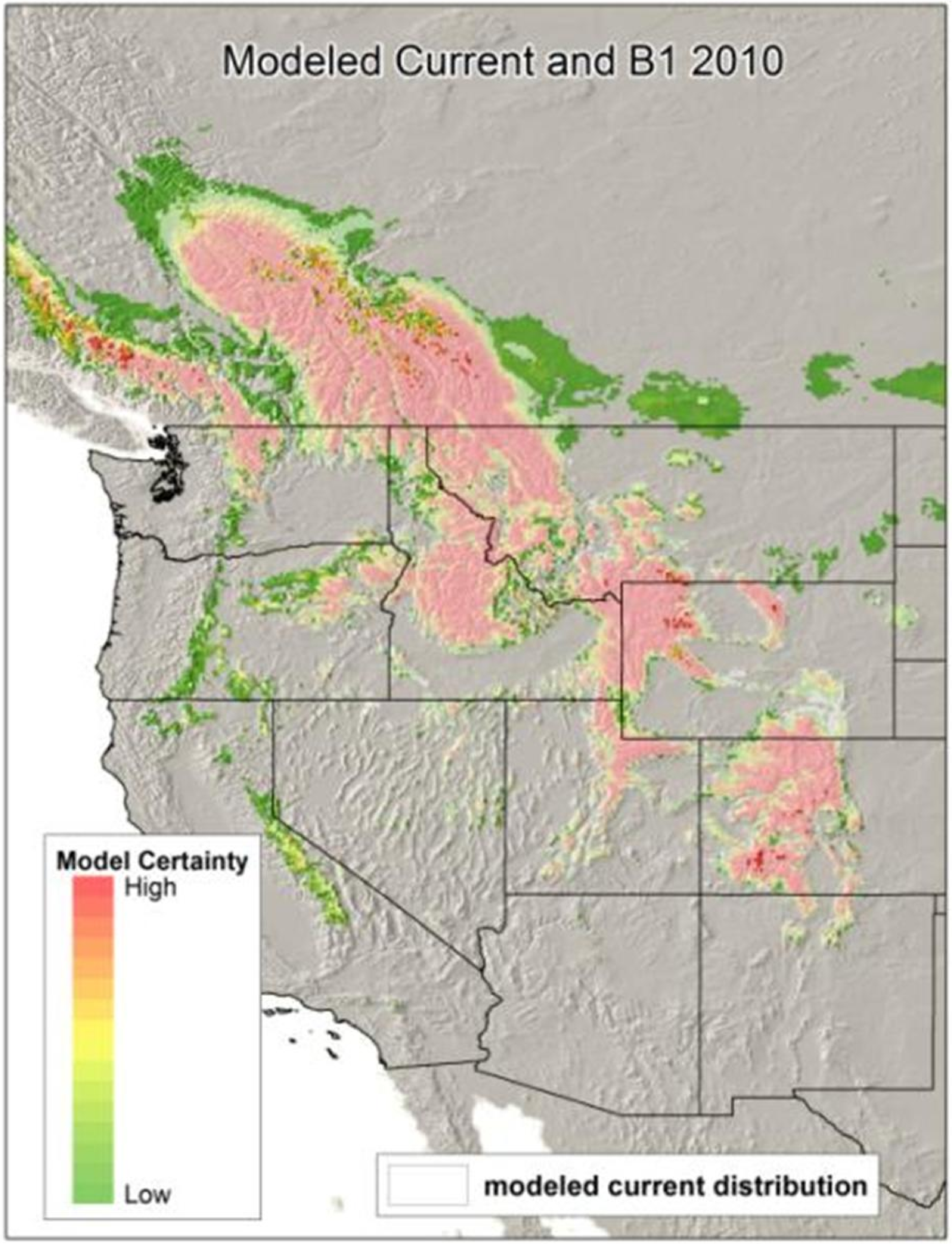


Canada Lynx Distribution

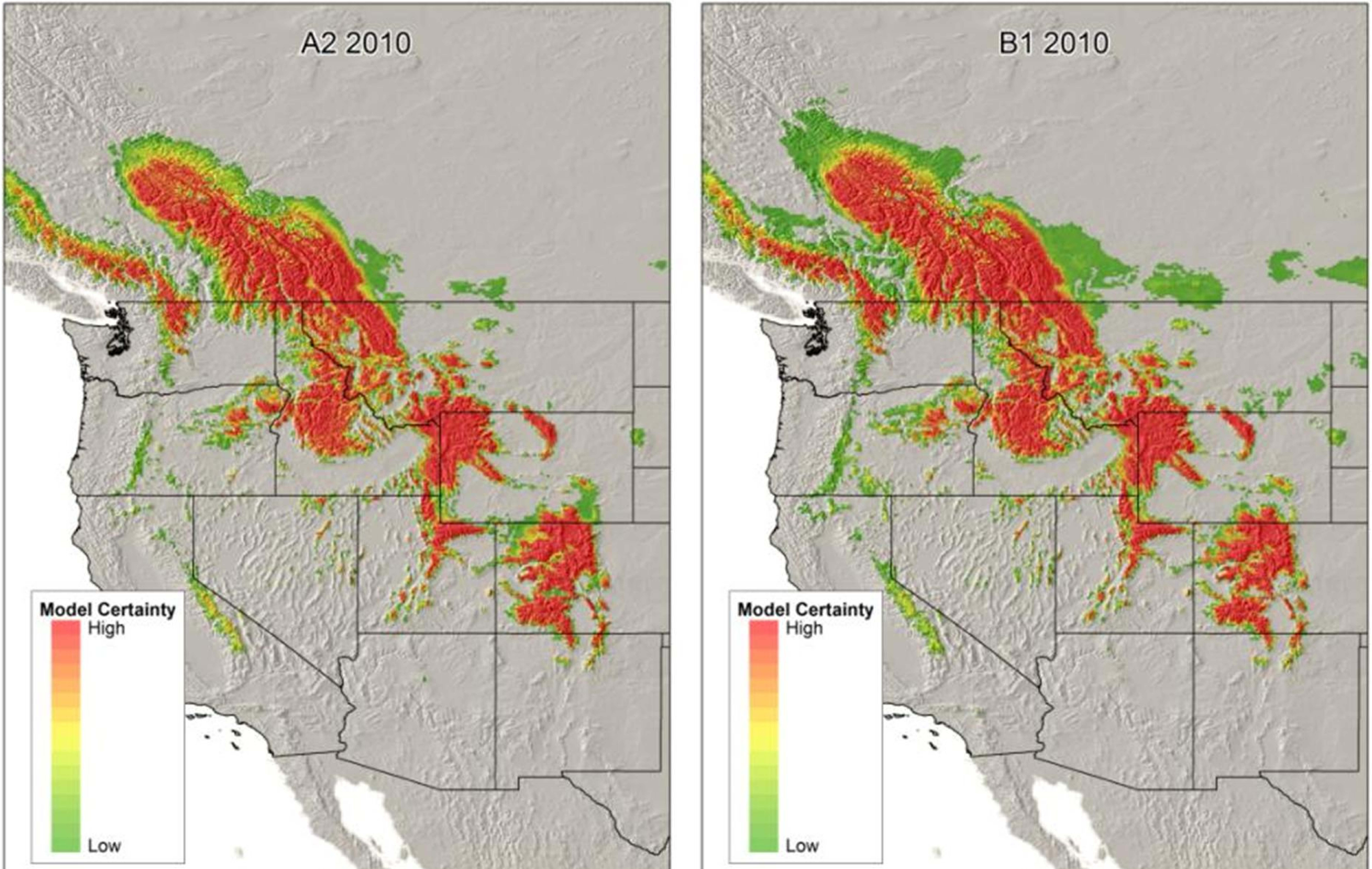


Canada Lynx Distribution

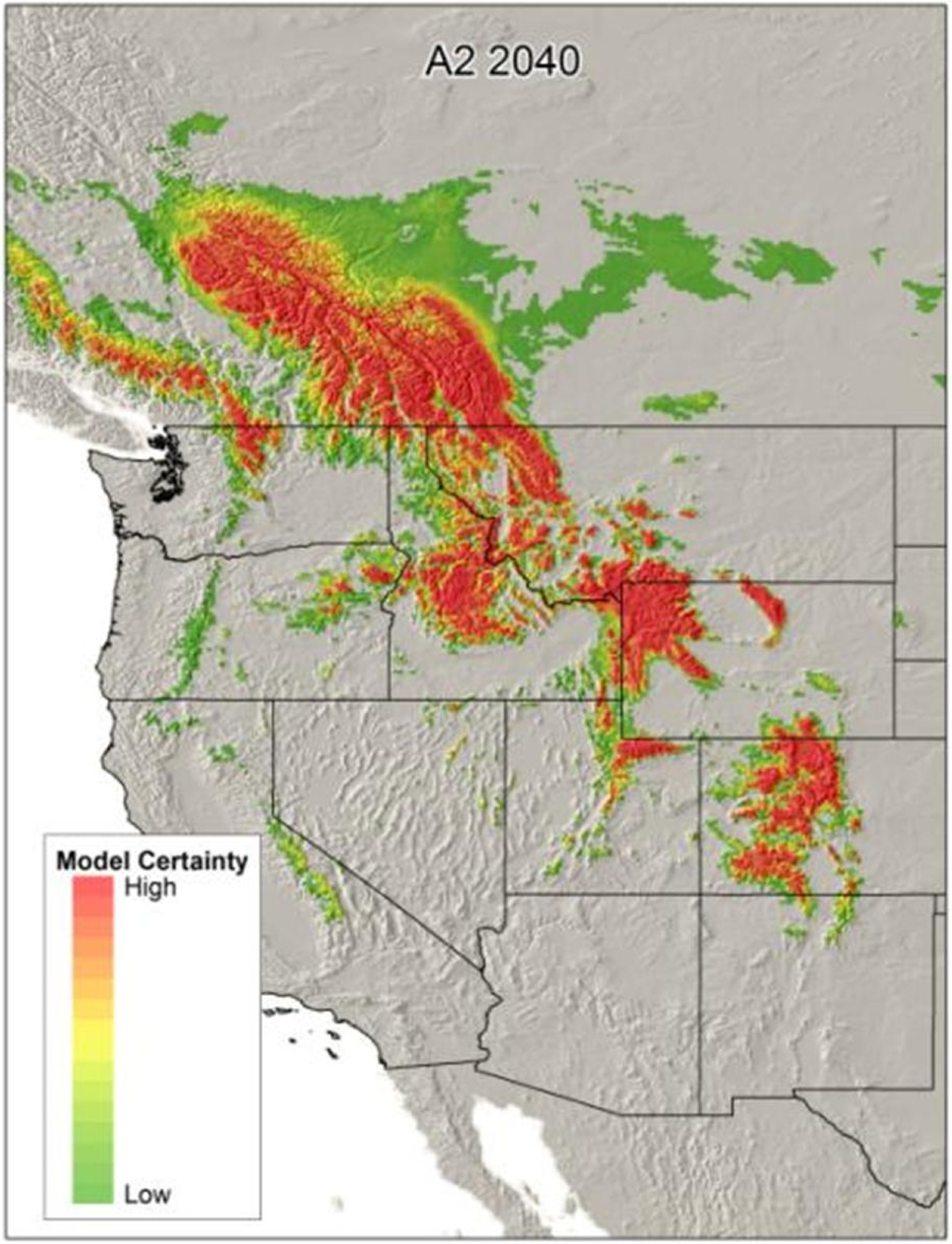


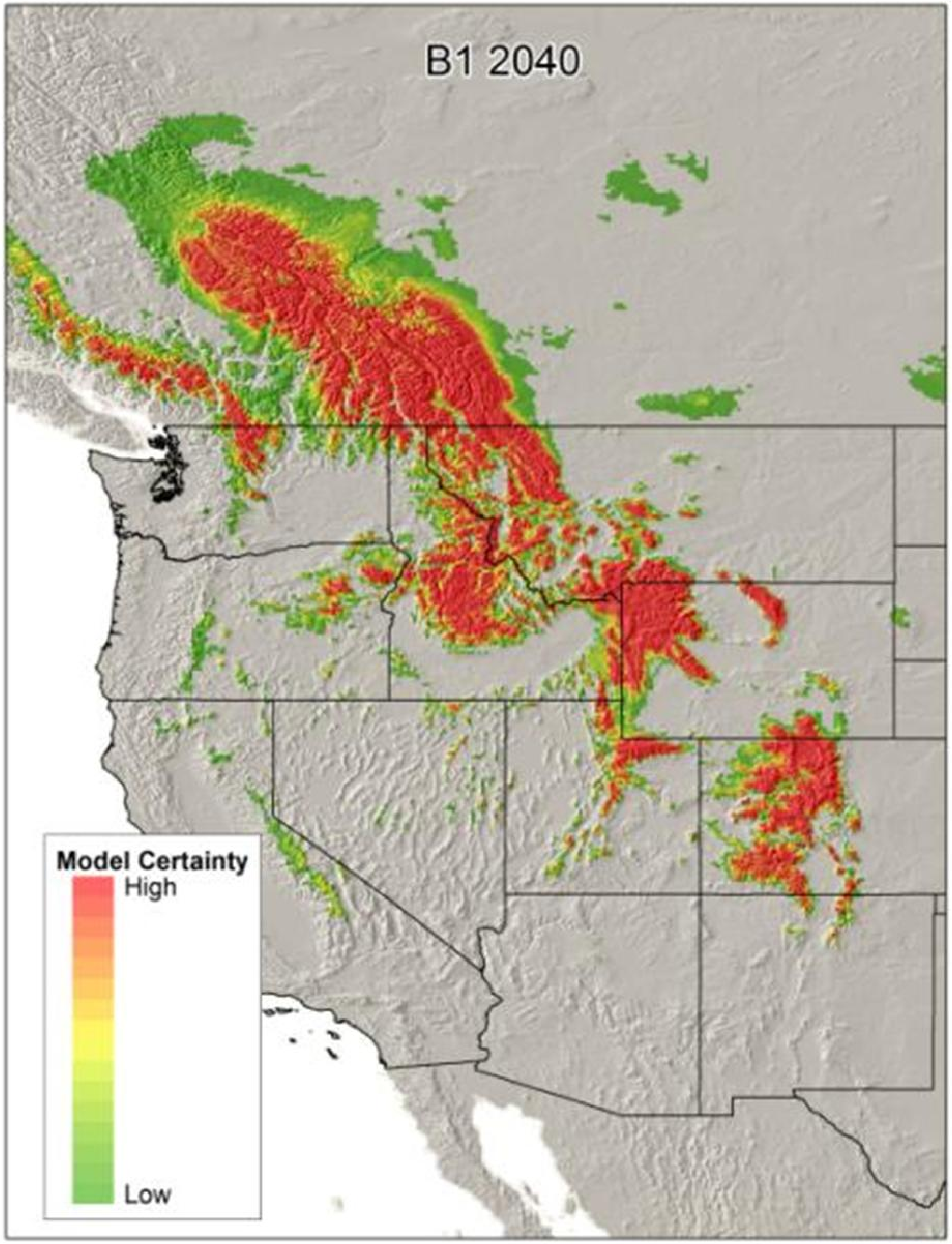


Canada Lynx Distribution

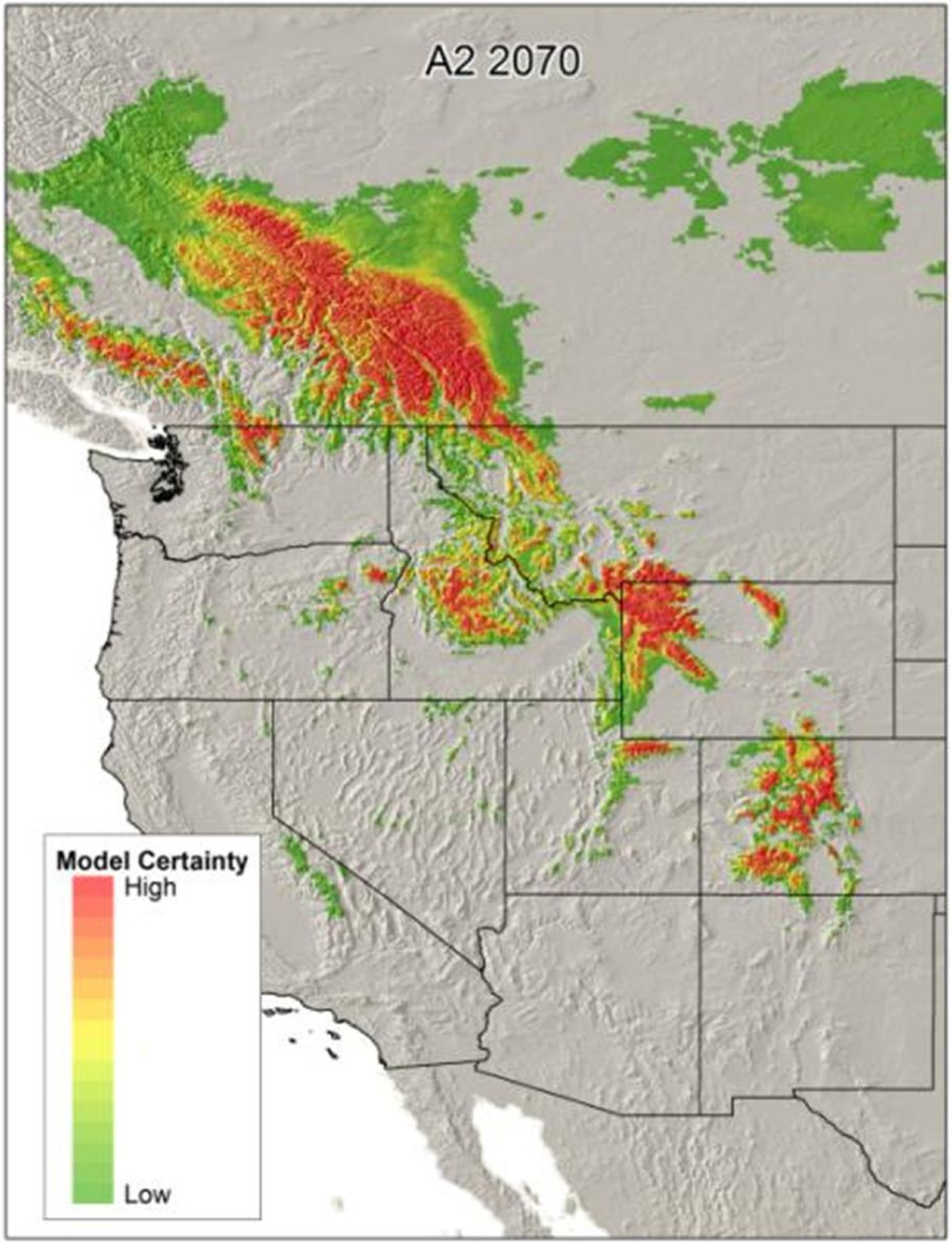


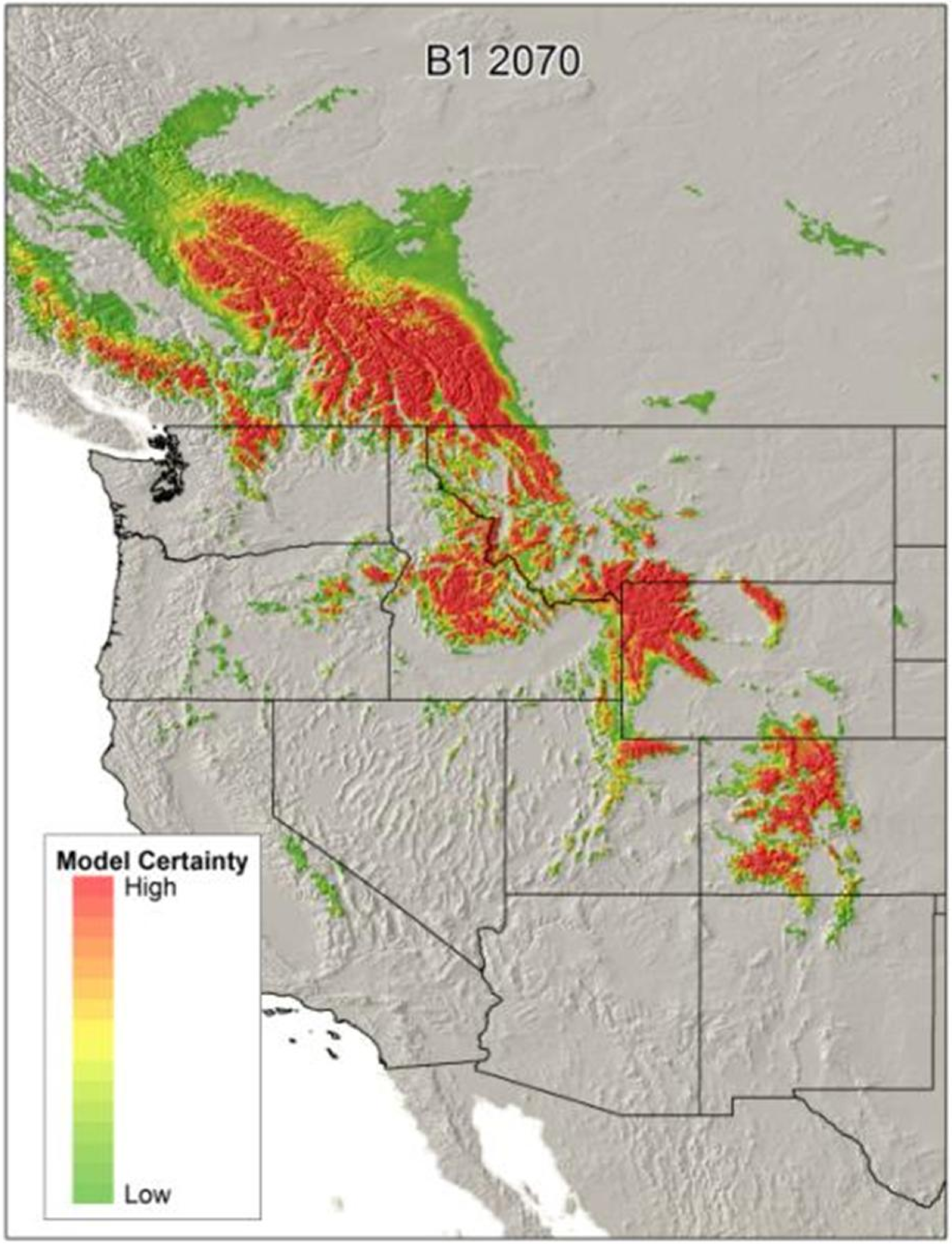
Canada Lynx Distribution



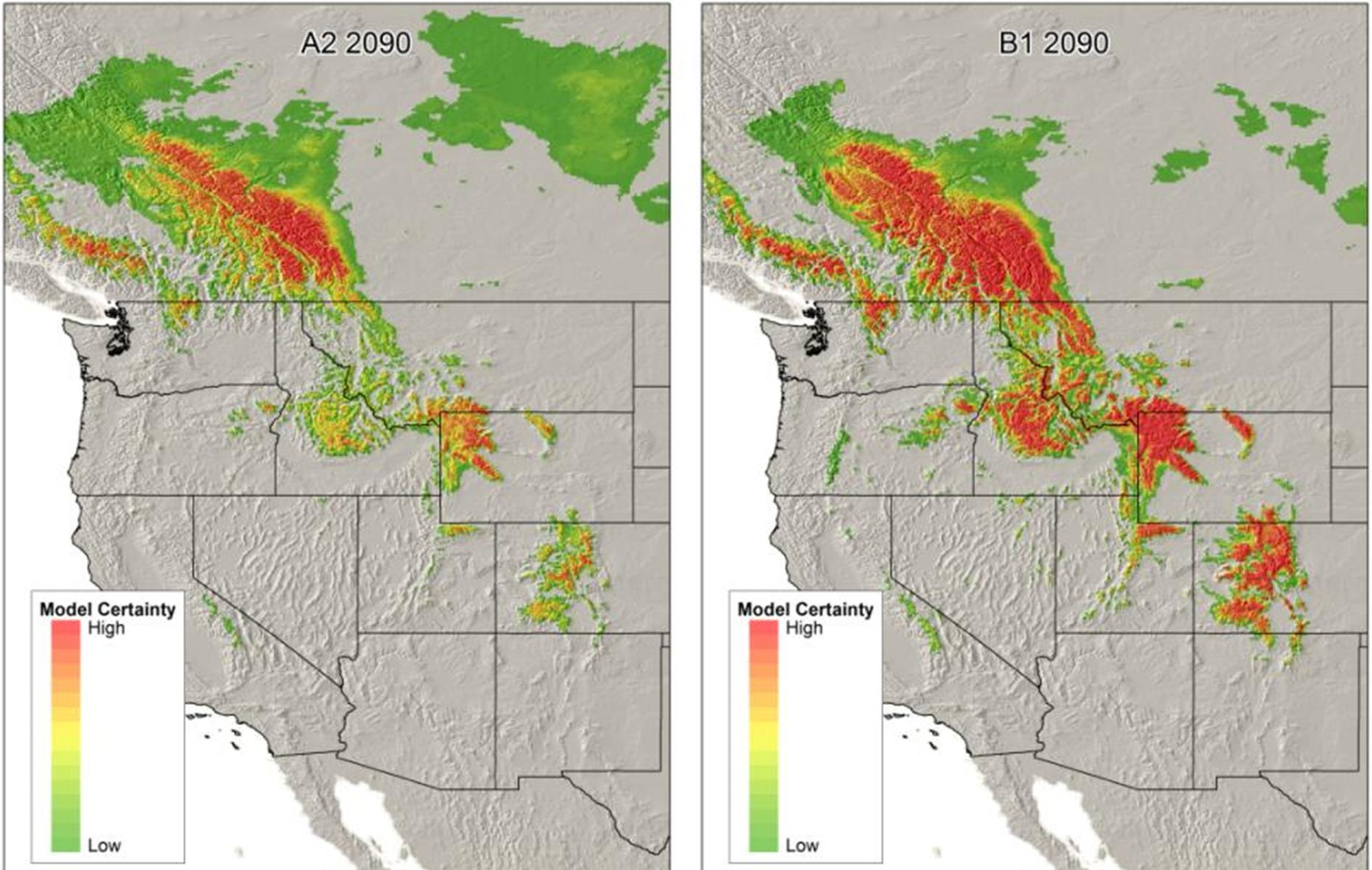


Canada Lynx Distribution



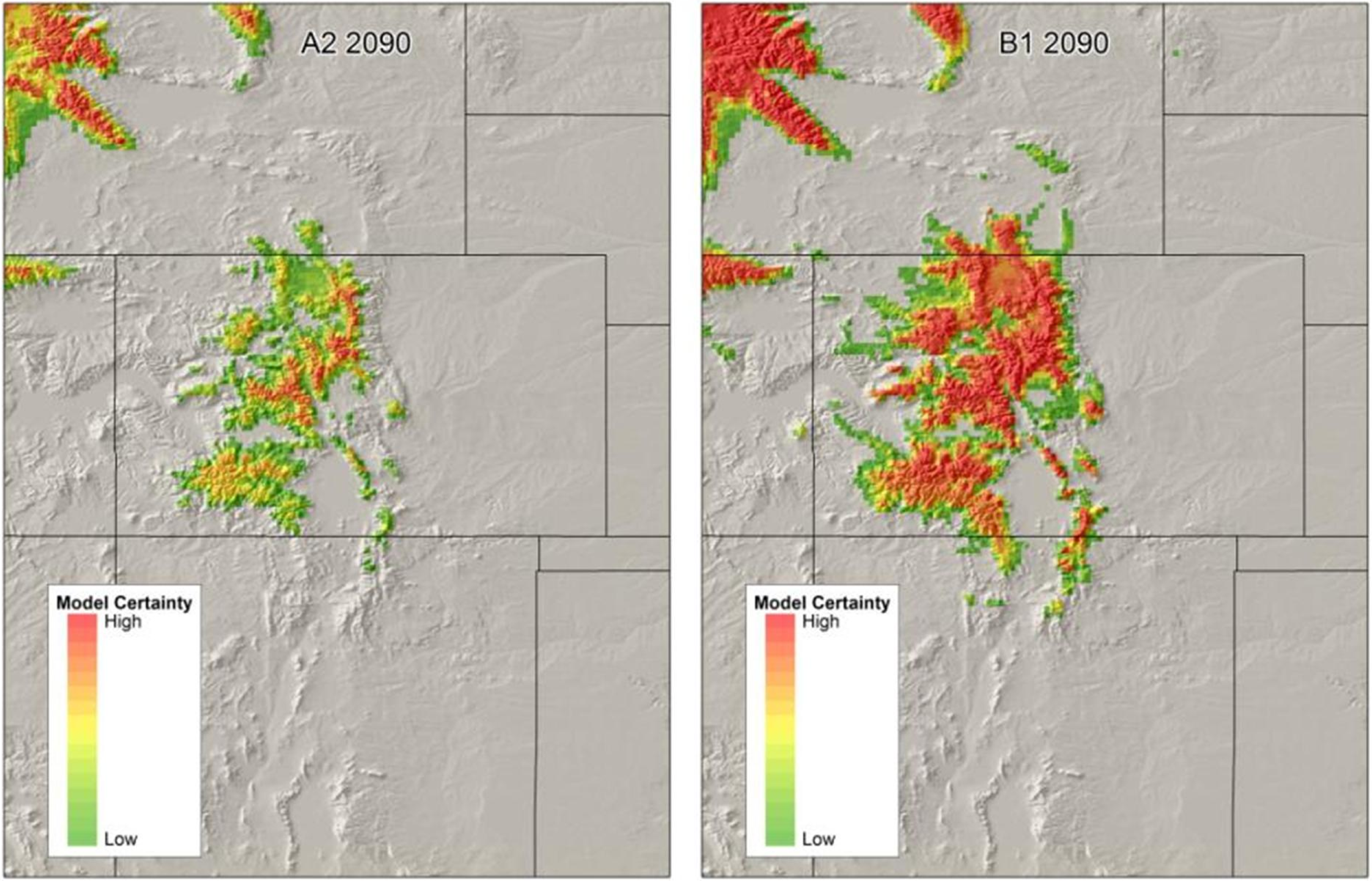


Canada Lynx Distribution

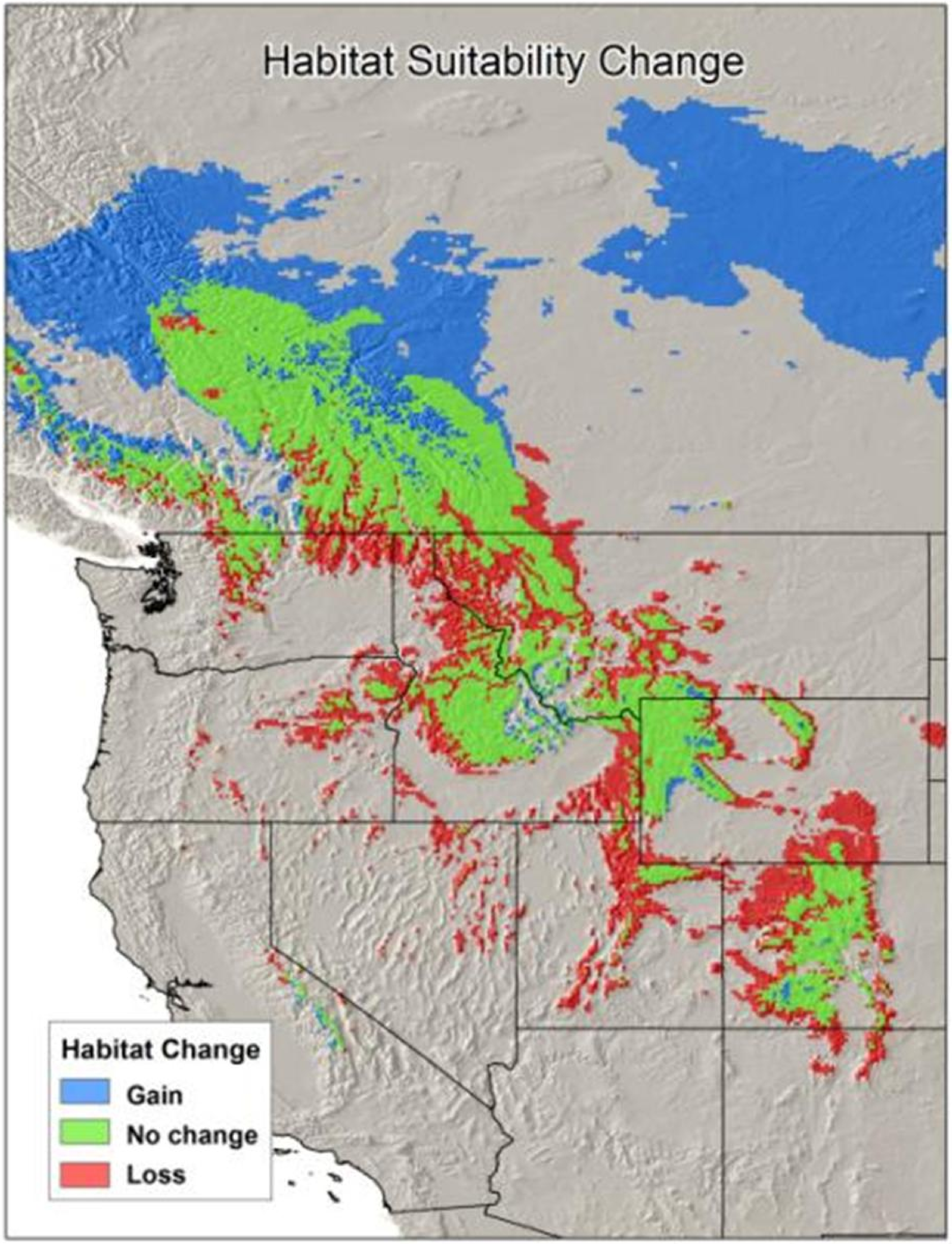


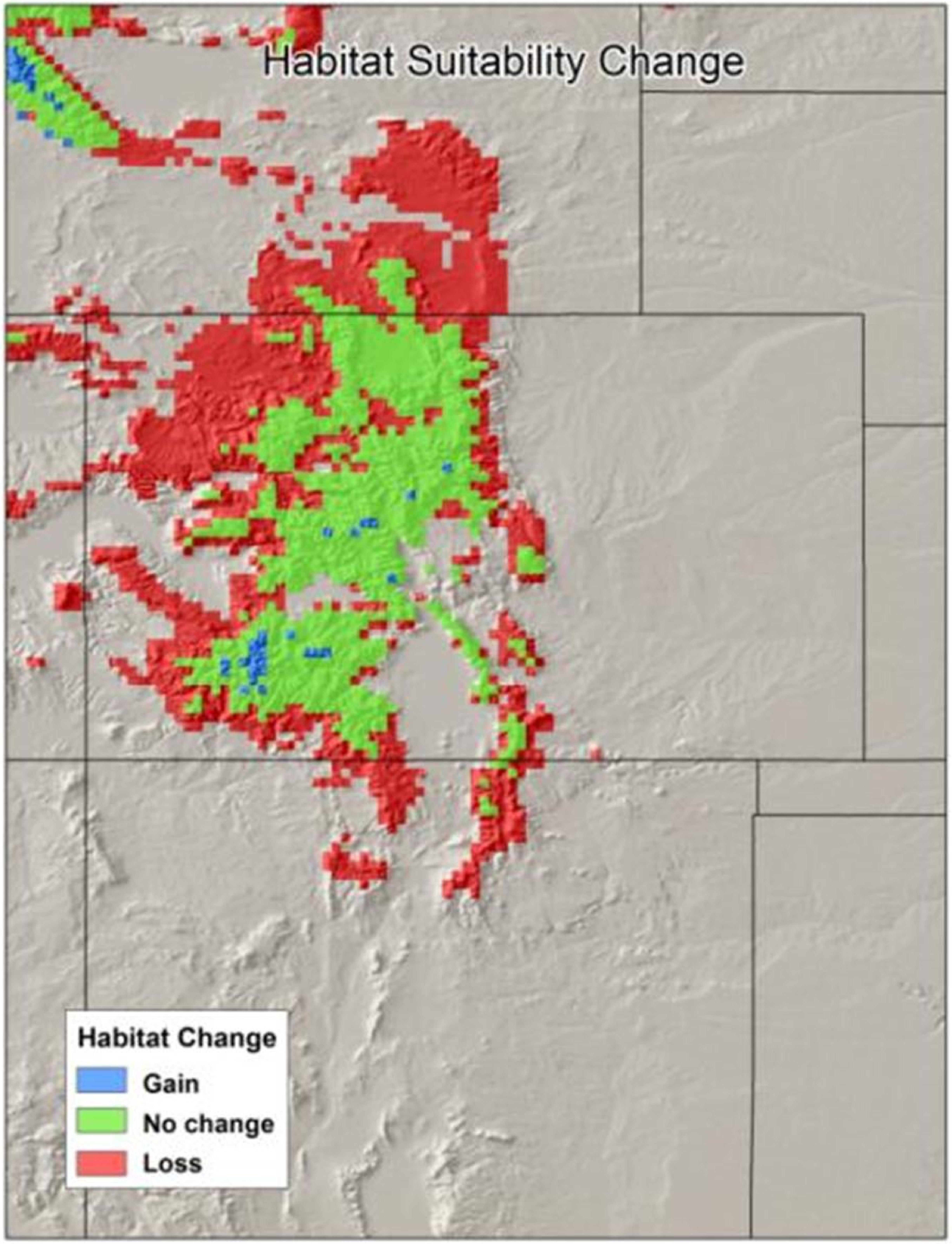
Projected impacts climate change impacts on Canada lynx: management implications

Canada Lynx Distribution

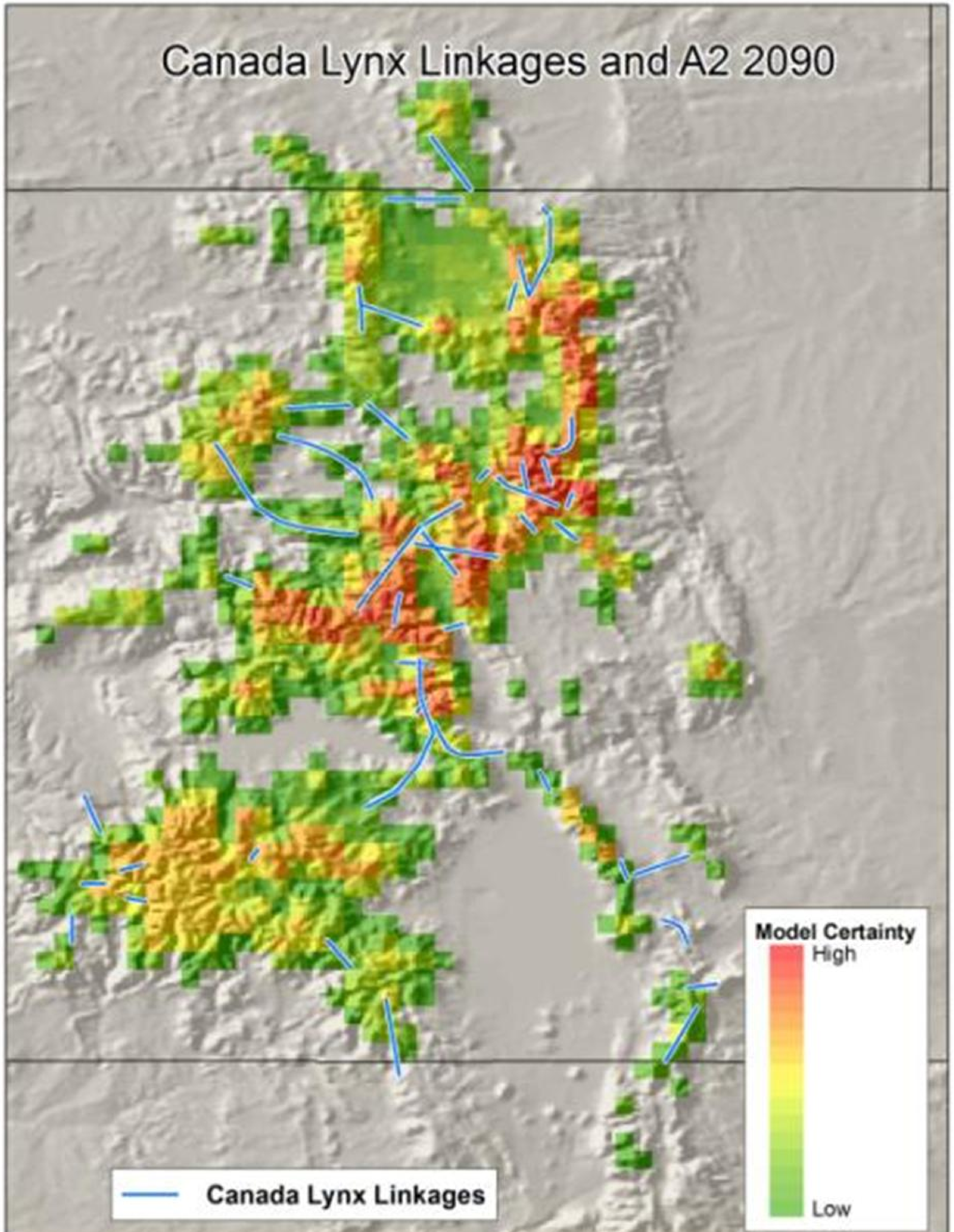


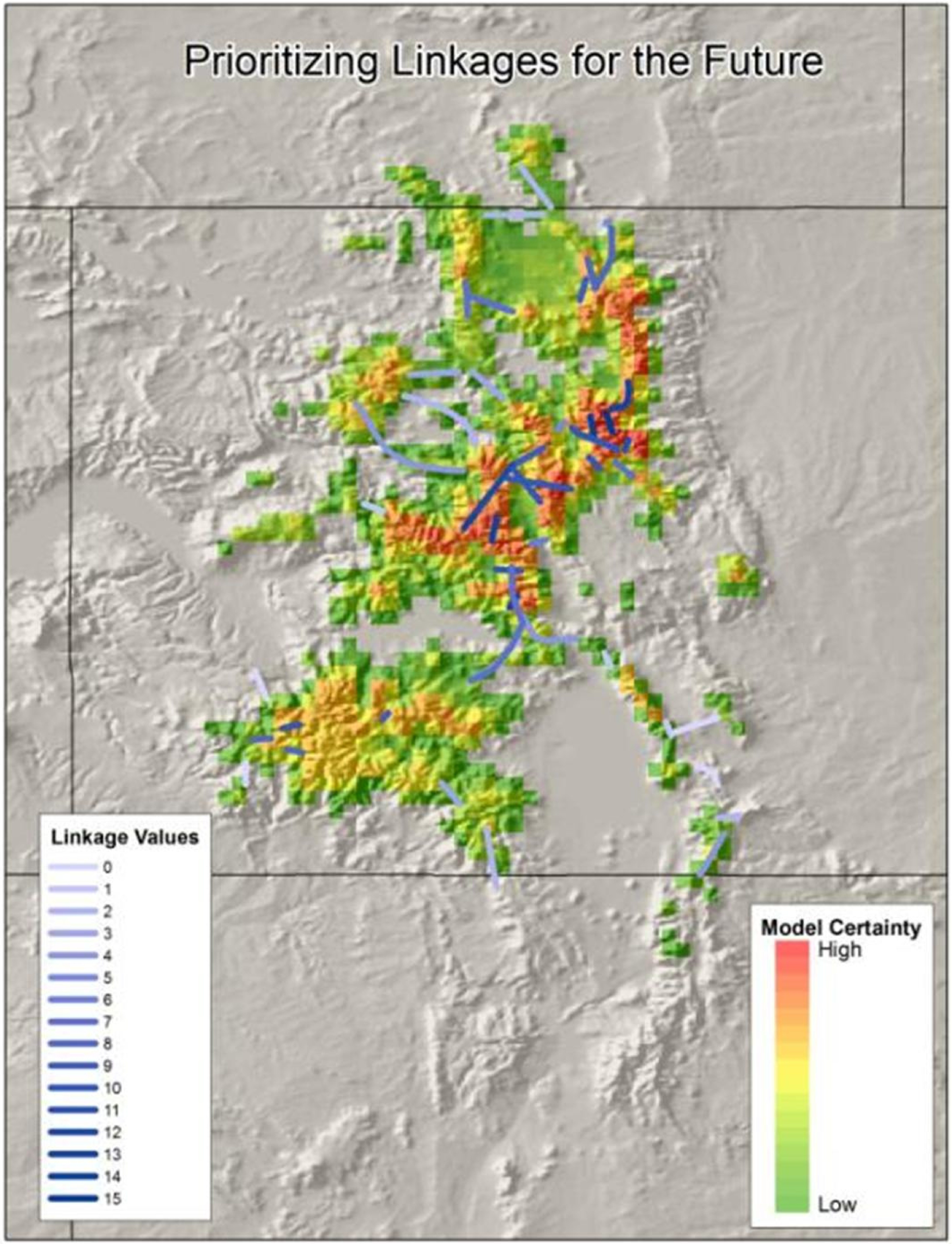
Which areas will remain suitable in the future?





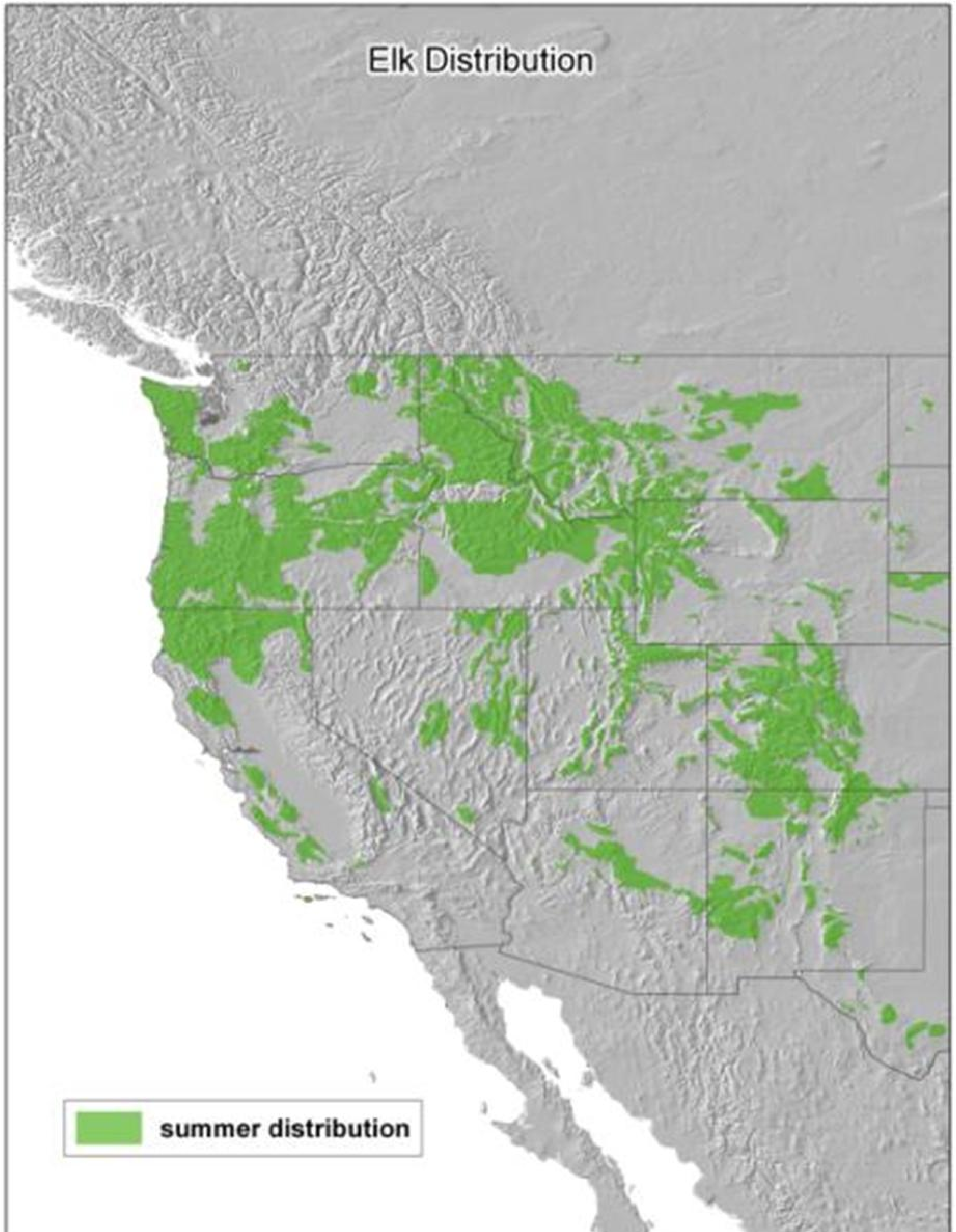
Which Linkages designed for current distribution of Canada Lynx will be useful under future climates?

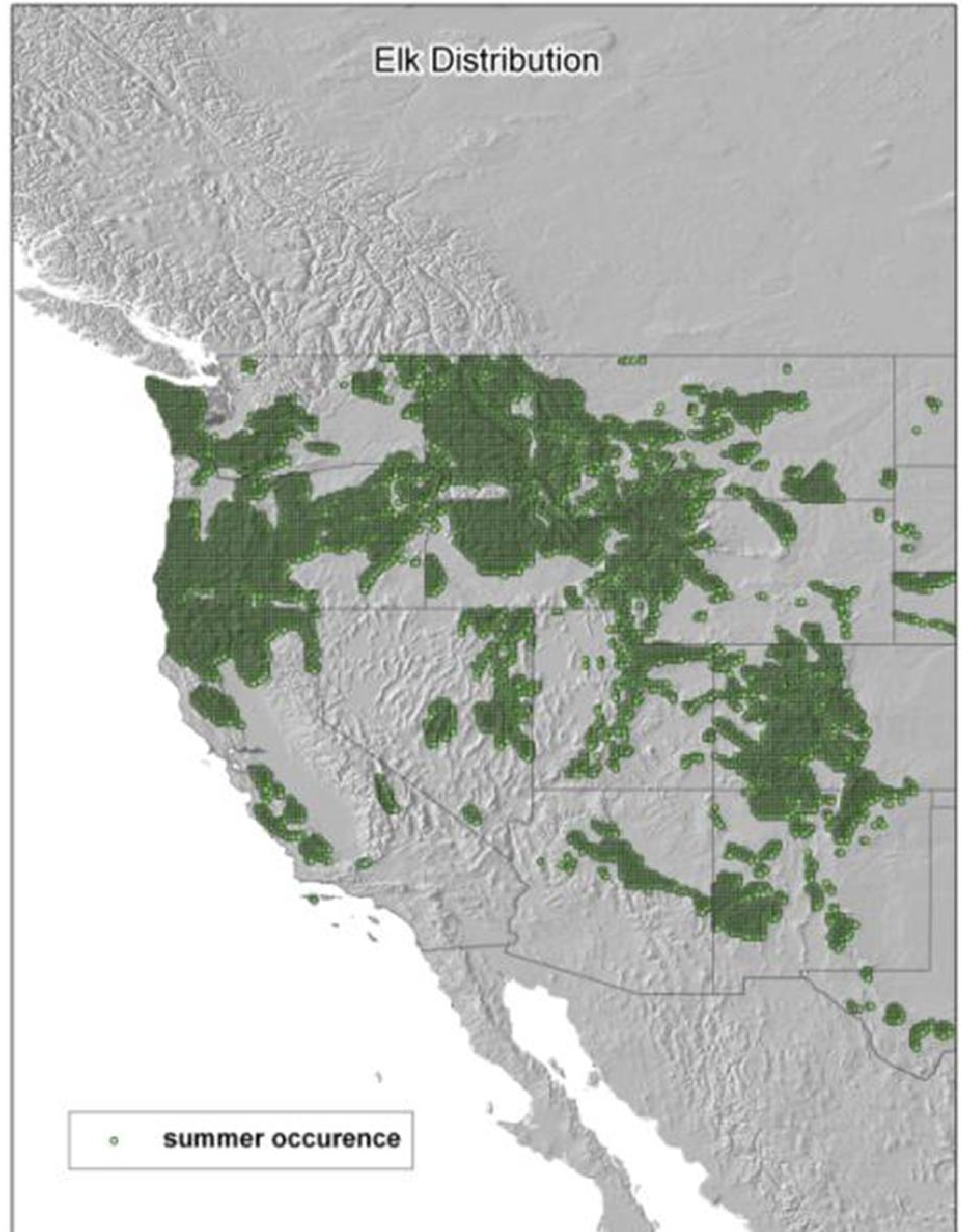




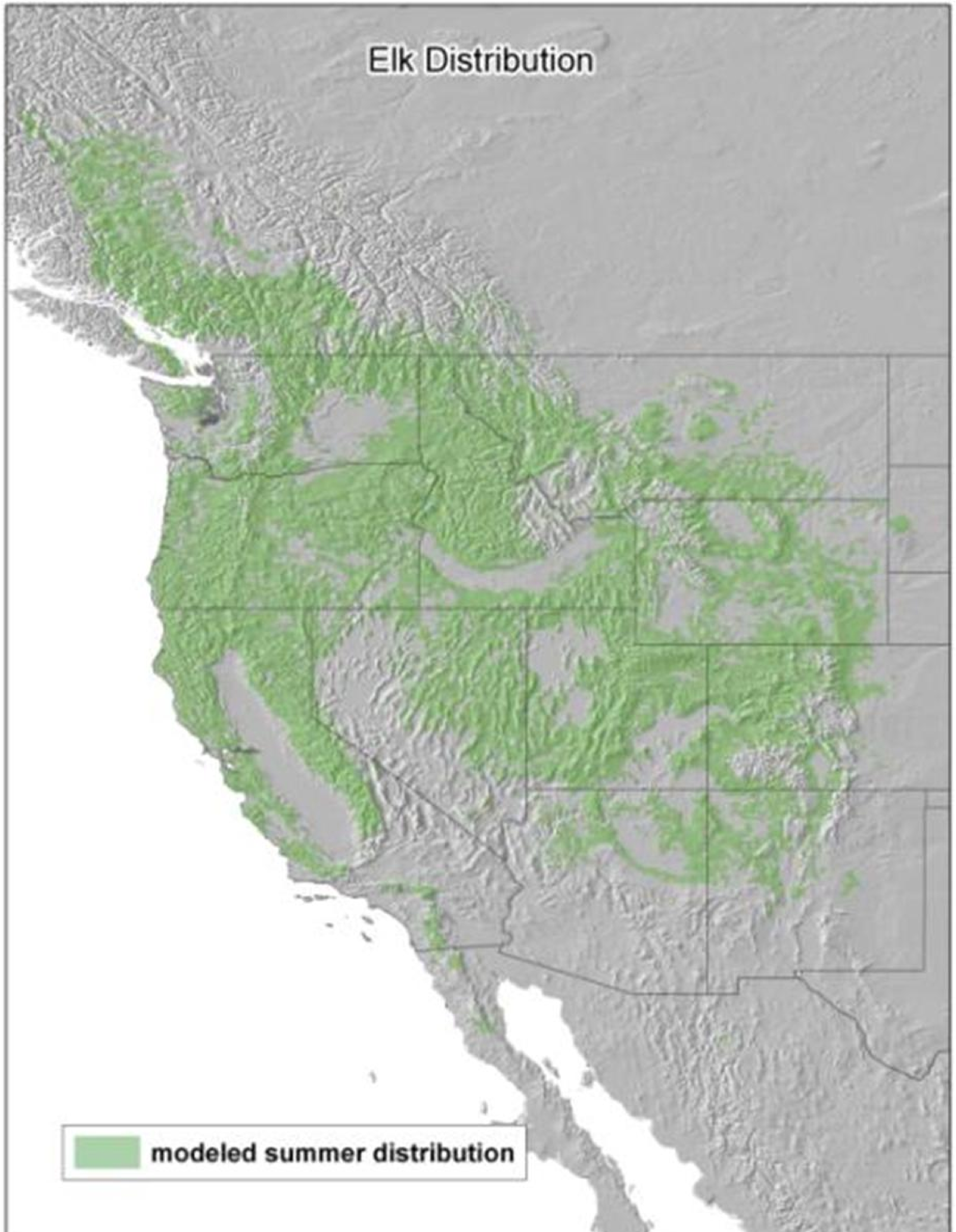
Prioritizing Linkages for the Future
Linkage Values
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Model Certainty
High
Low

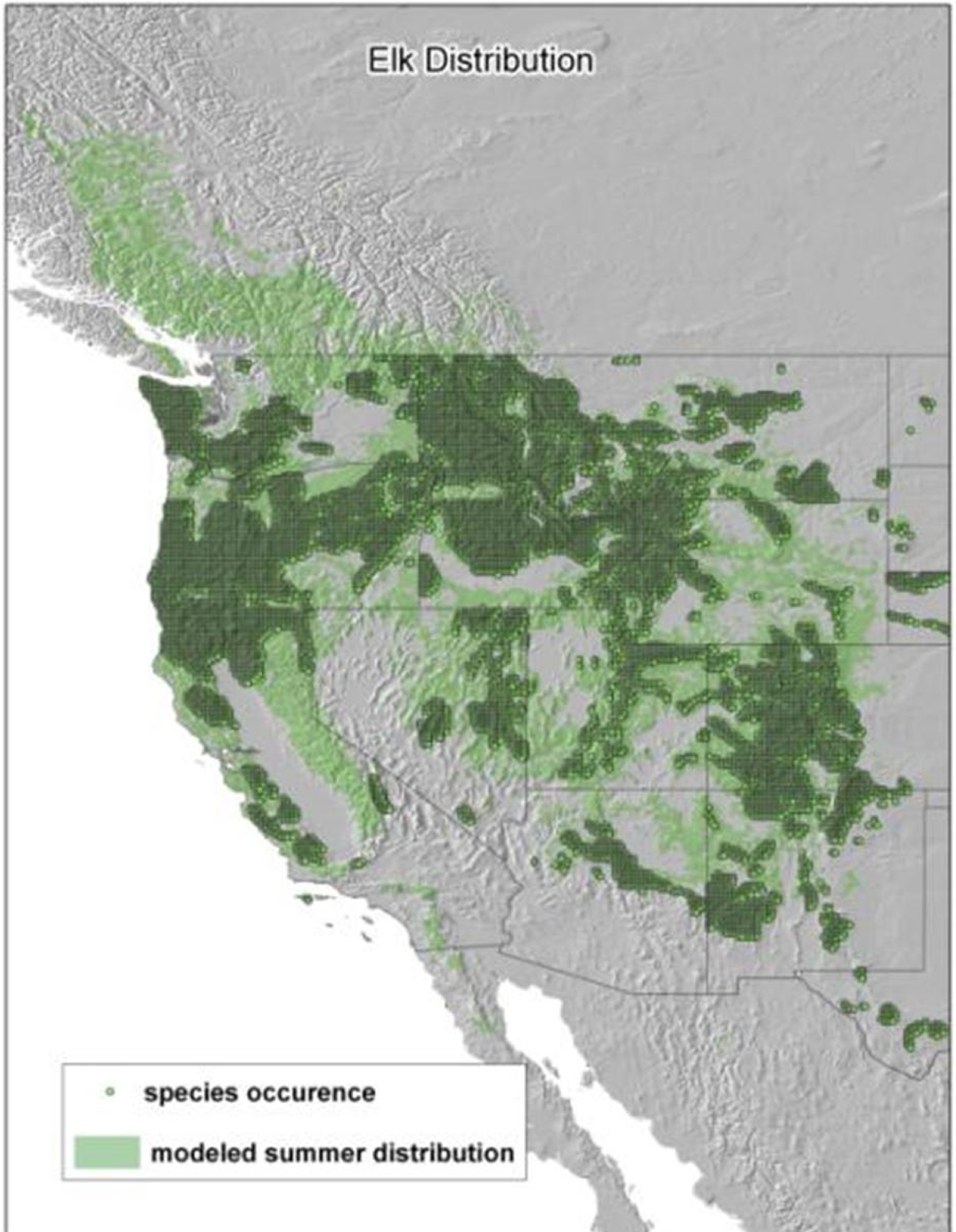
Elk


Elk Distribution
summer distribution

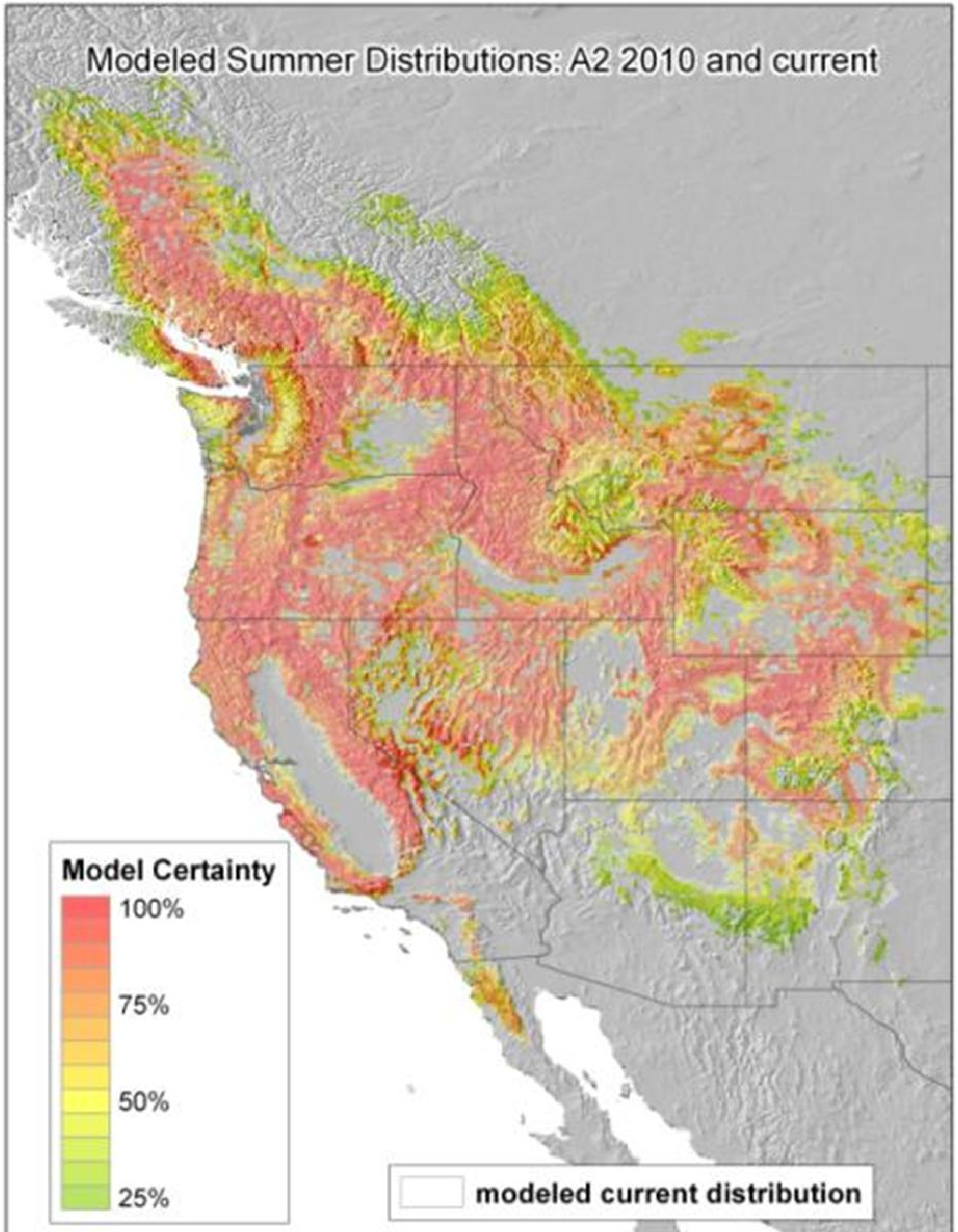

Elk Distribution
summer occurence

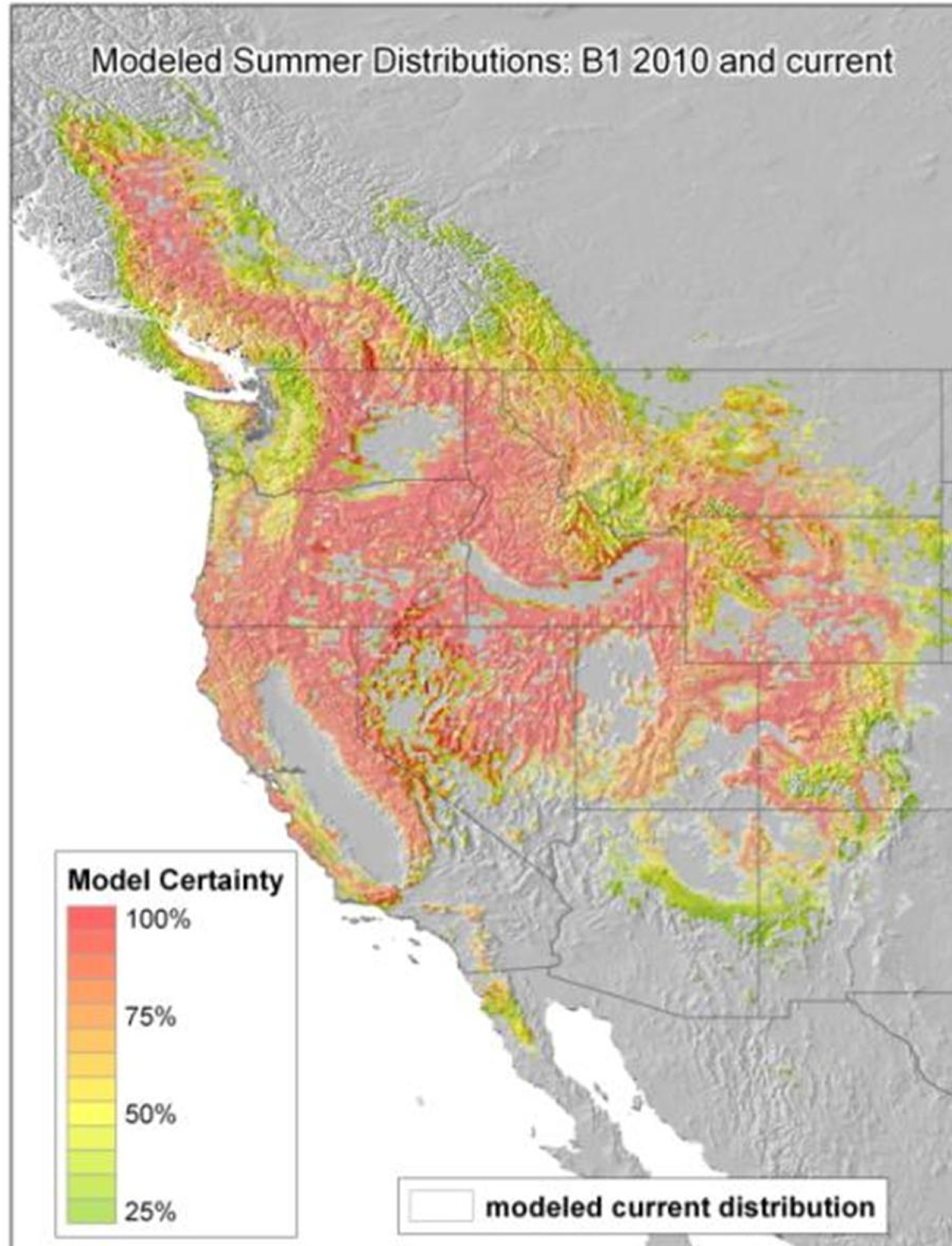
Elk


Elk Distribution
modeled summer distribution

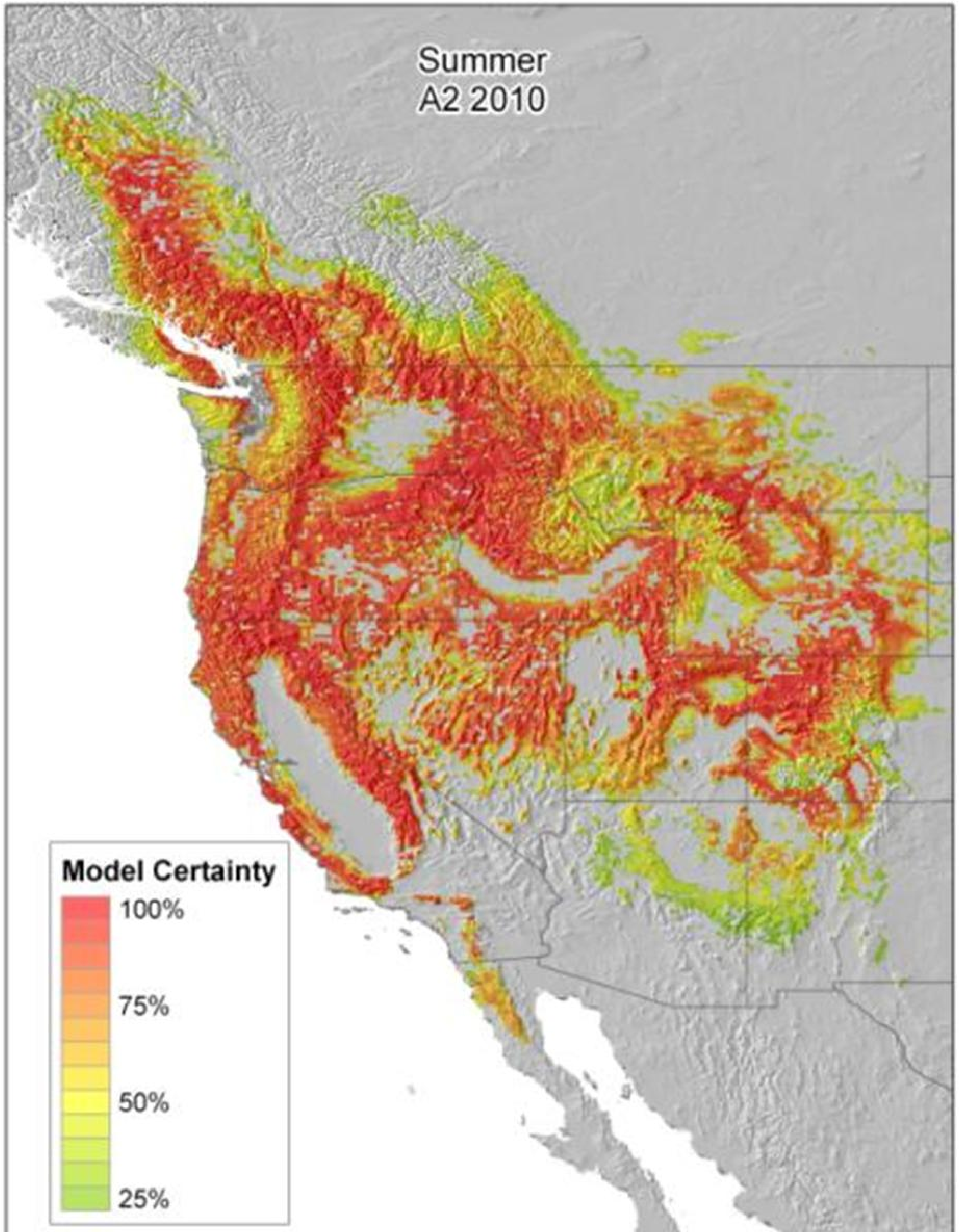

Elk Distribution
species occurence
modeled summer distribution

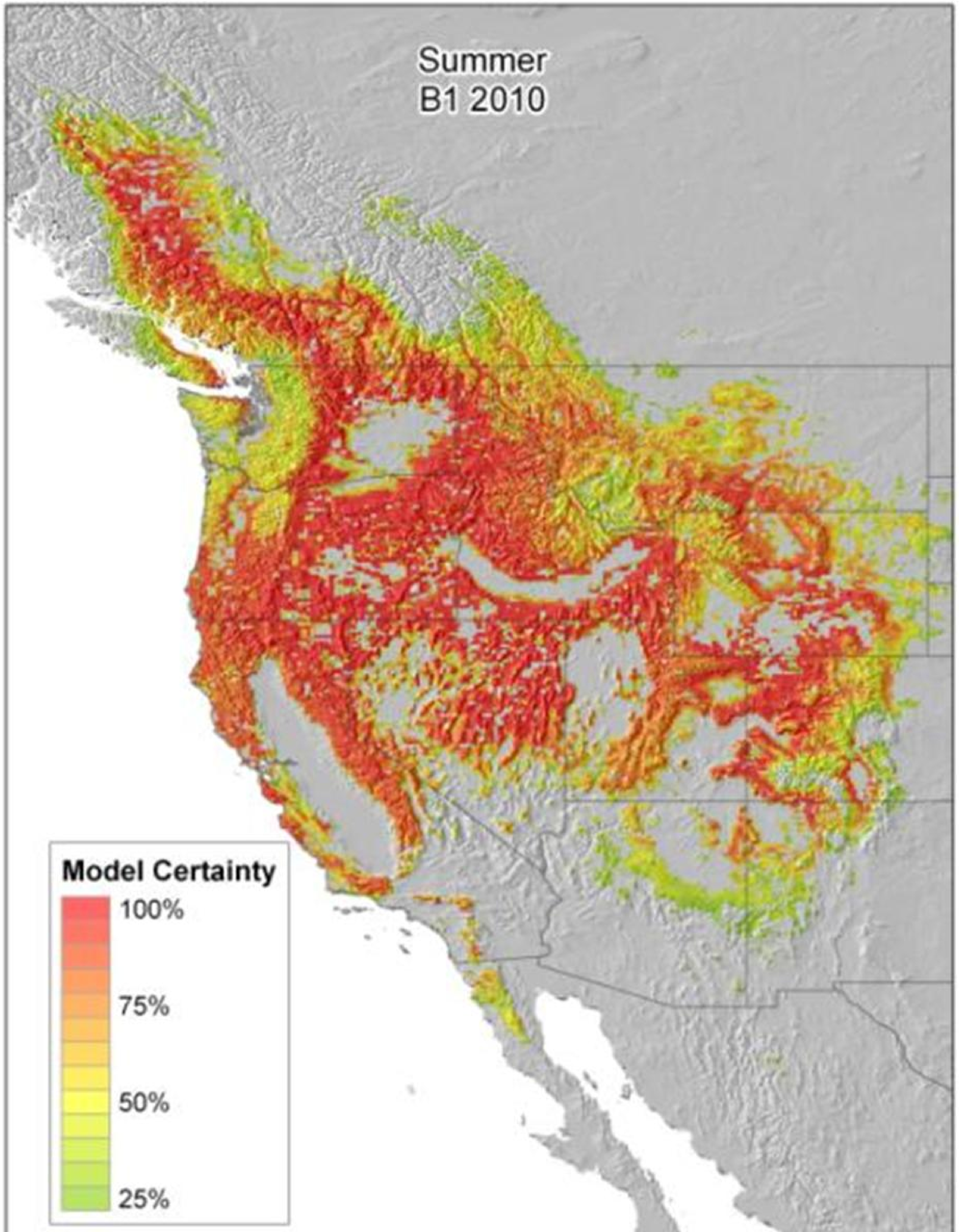
Elk


Modeled Summer Distributions: A2 2010 and current
Model Certainty
100%
75%
50%
25%
modeled current distribution

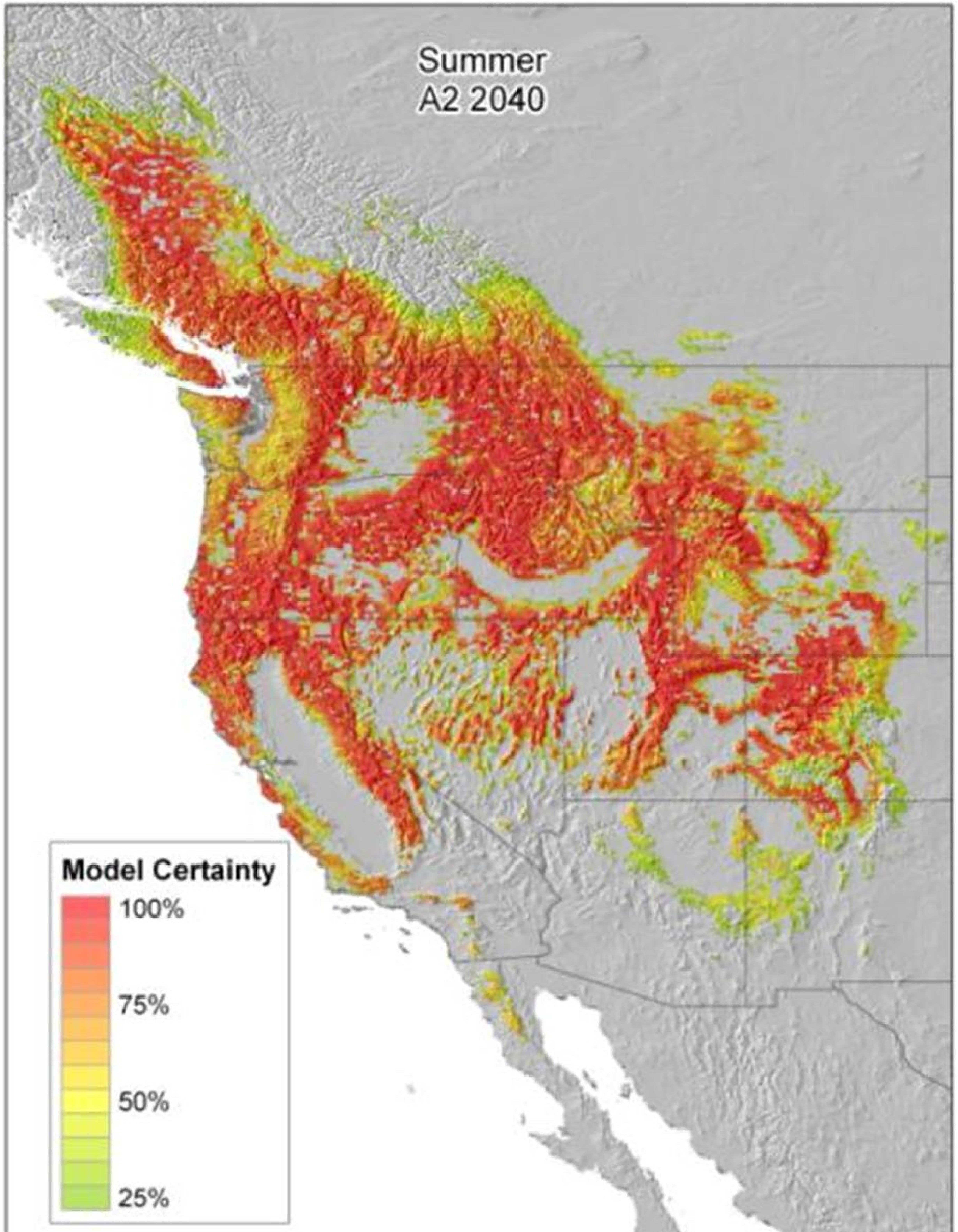

Modeled Summer Distributions: B1 2010 and current
Model Certainty
100%
75%
50%
25%
modeled current distribution

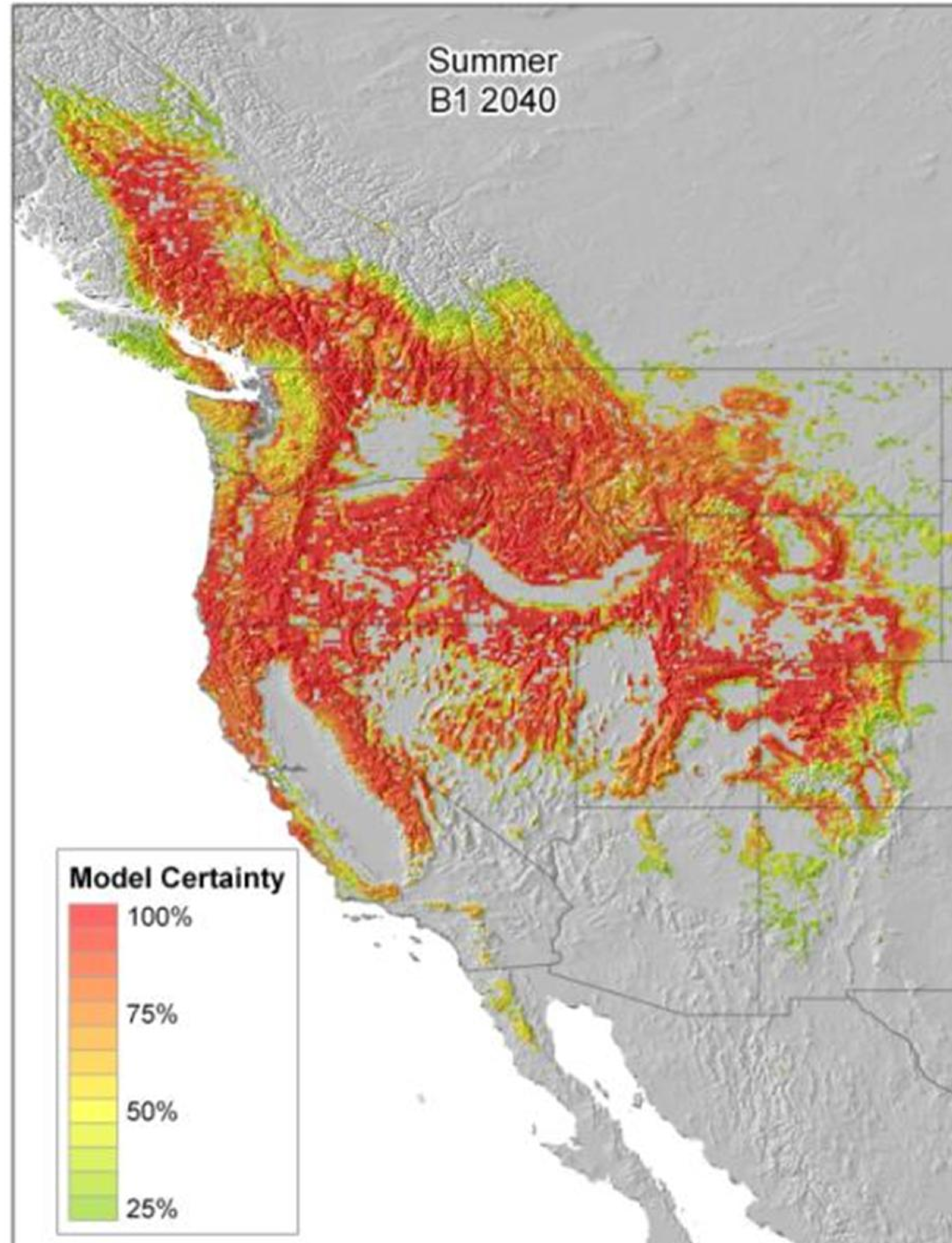
Elk Modeled Future Distributions



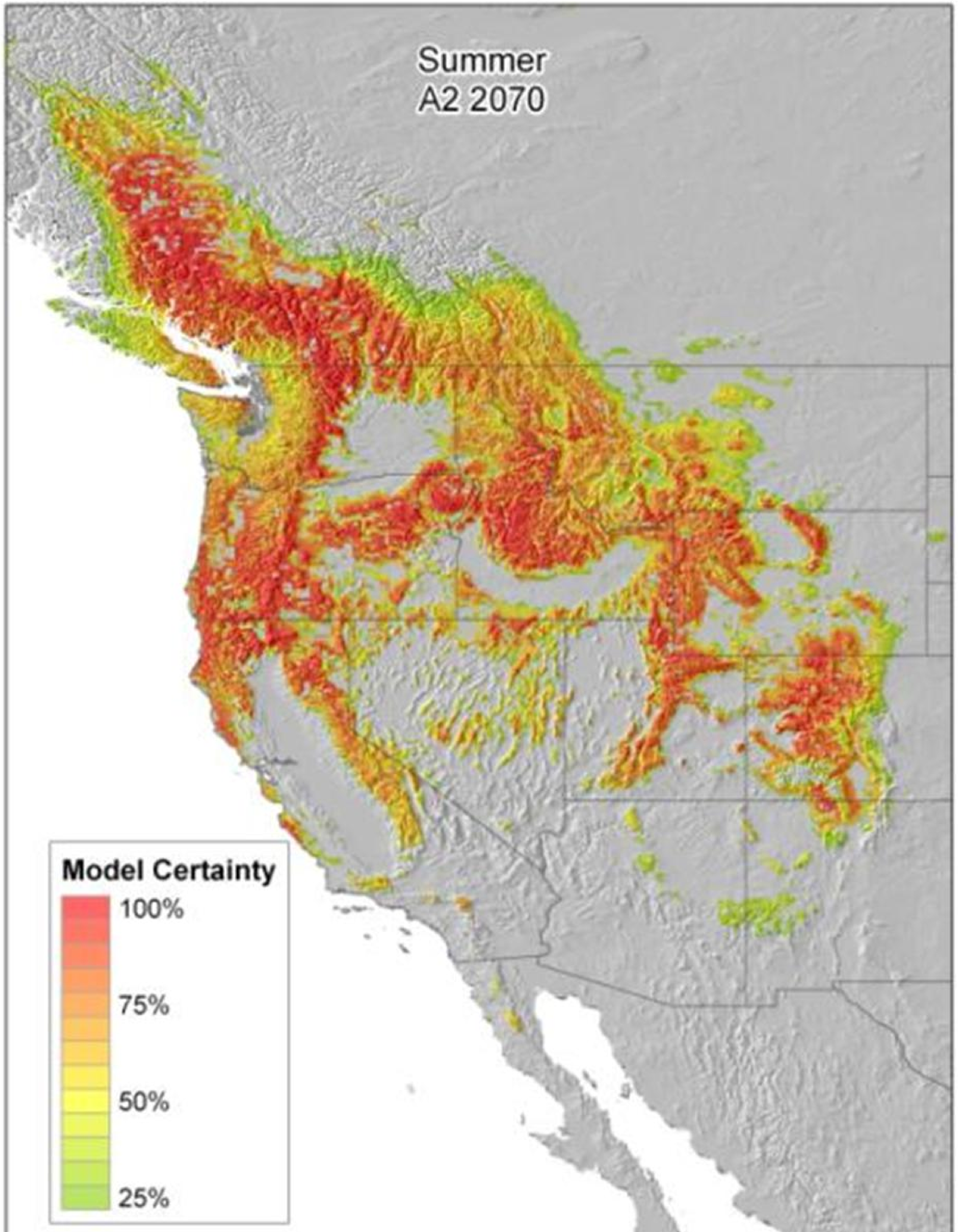


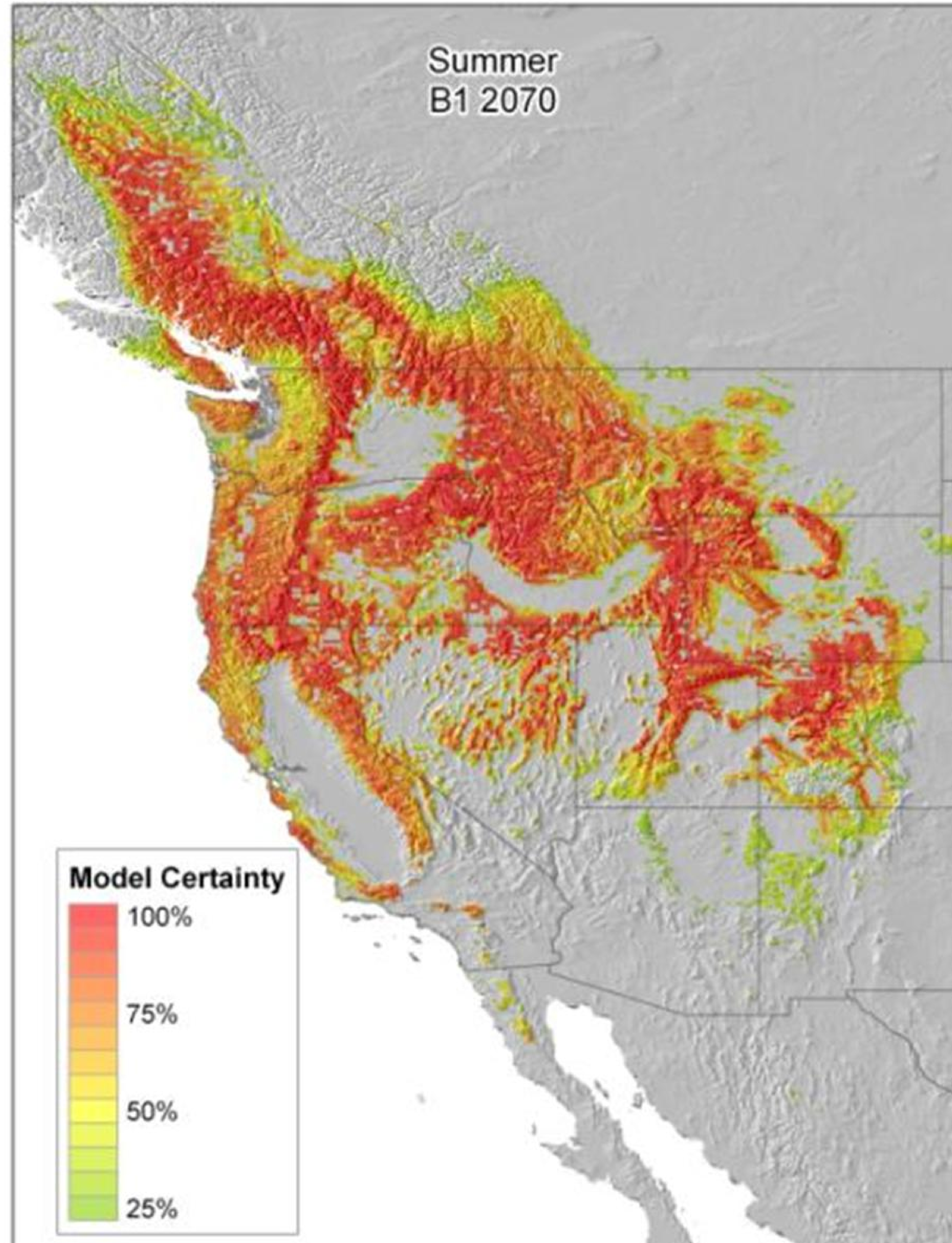
Elk Modeled Future Distributions



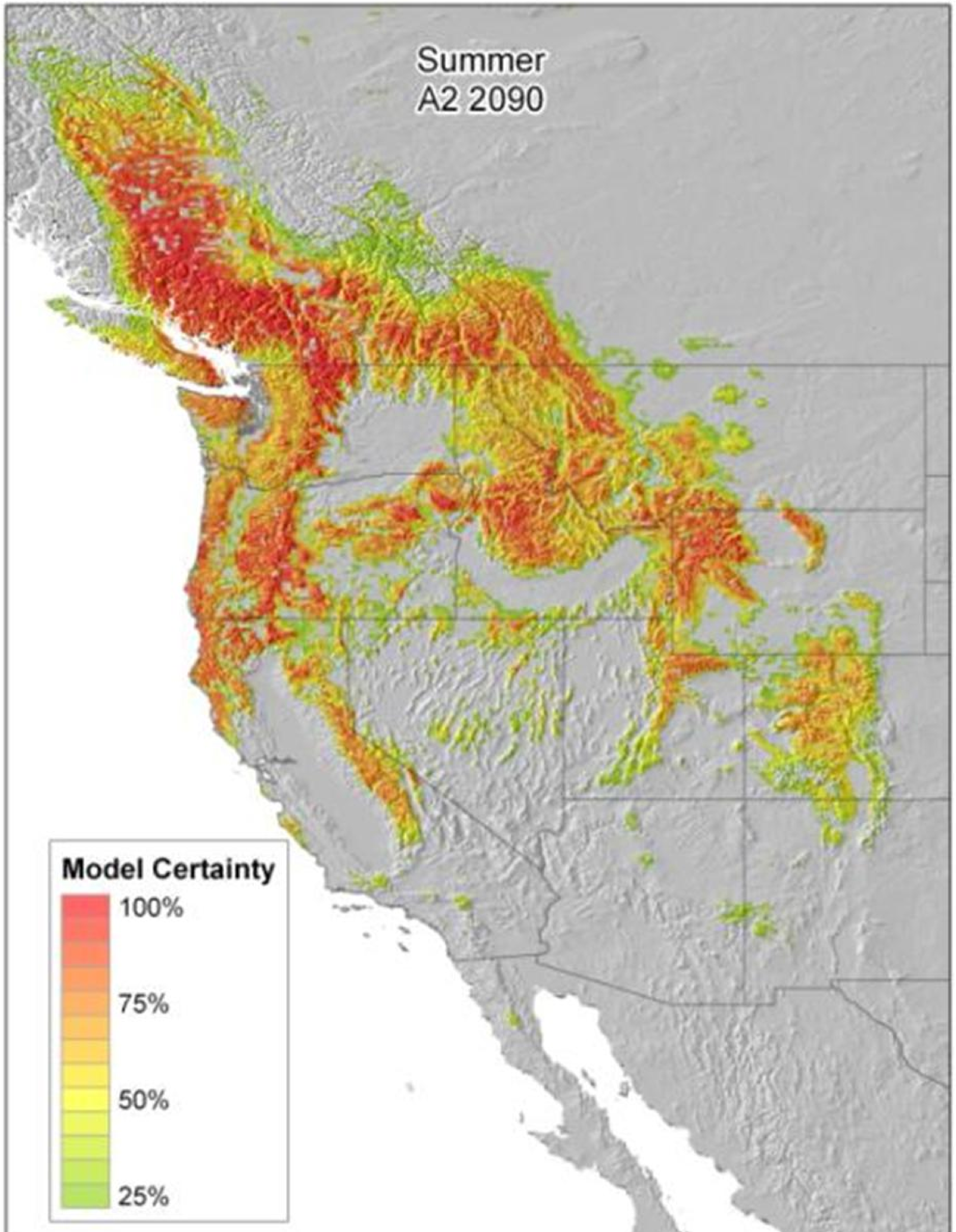


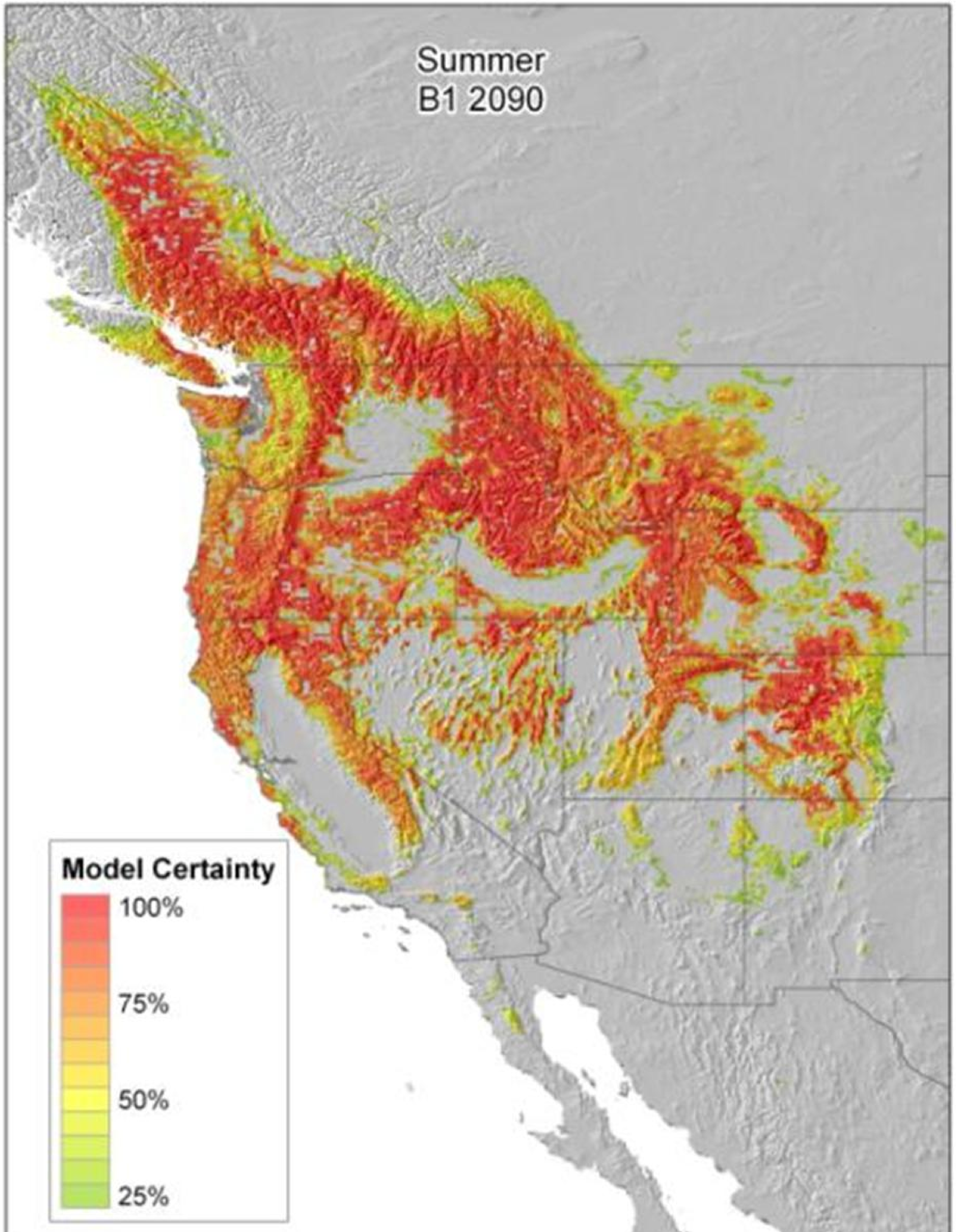
Elk Modeled Future Distributions



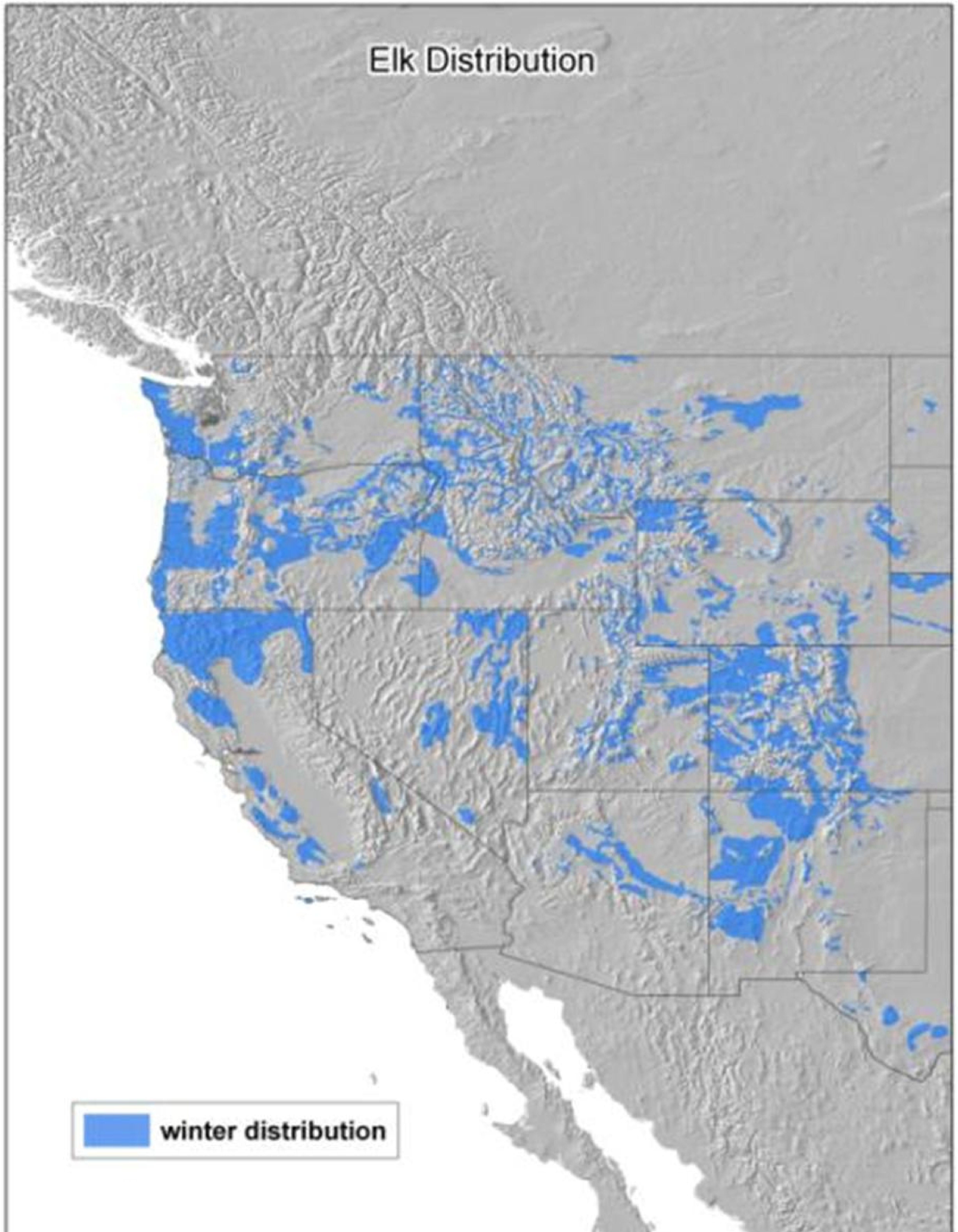


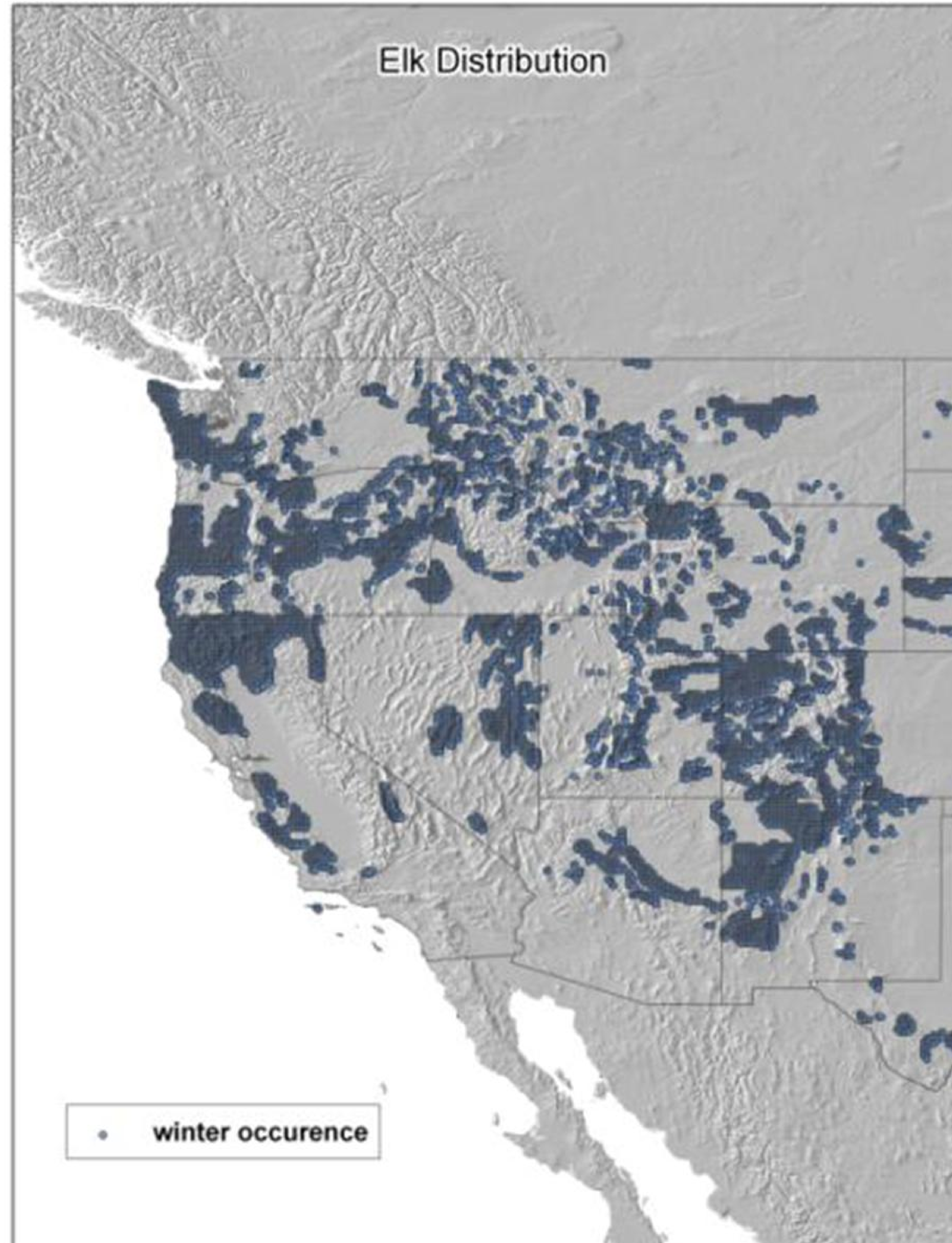
Elk Modeled Future Distributions





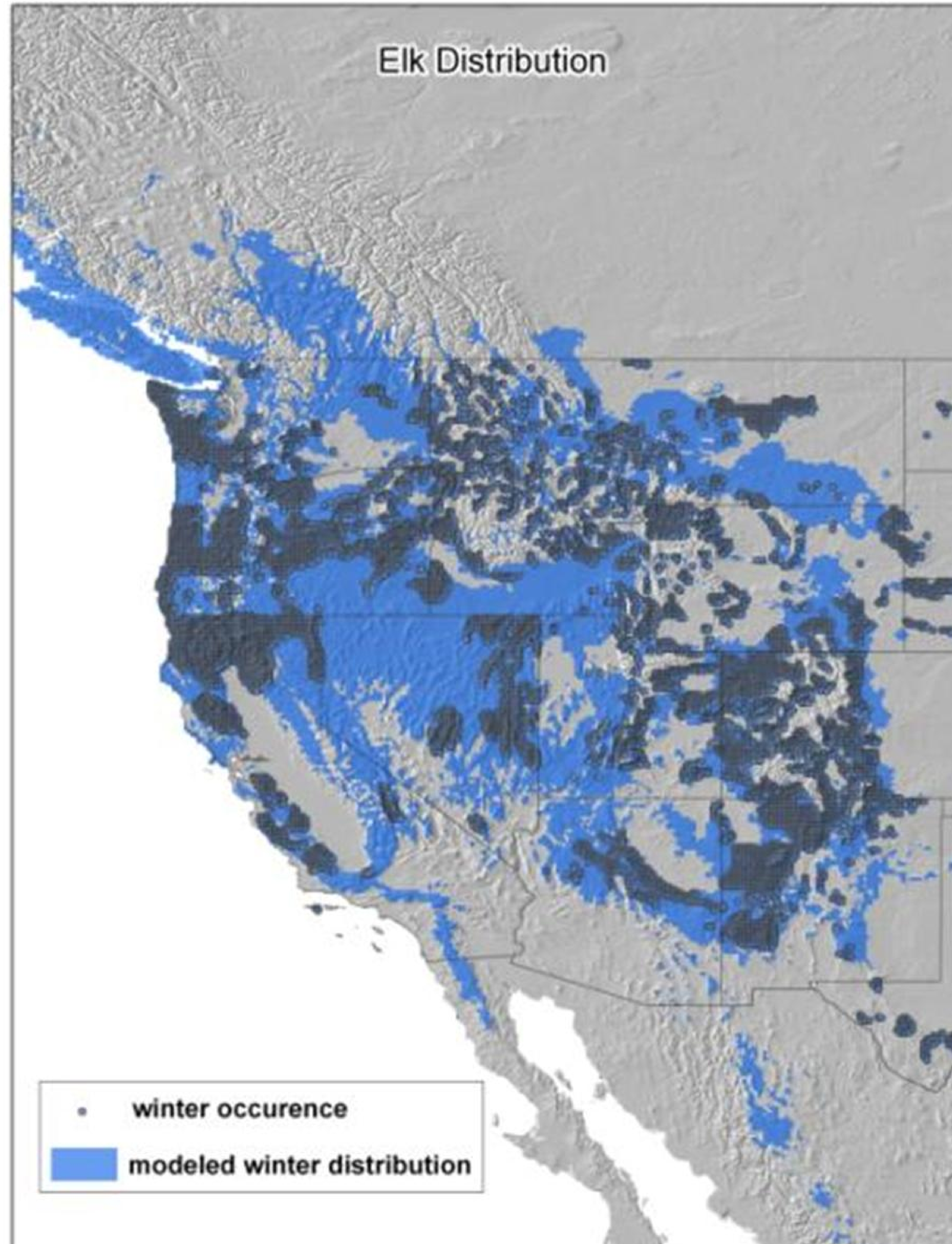
Elk


Elk Distribution
winter distribution

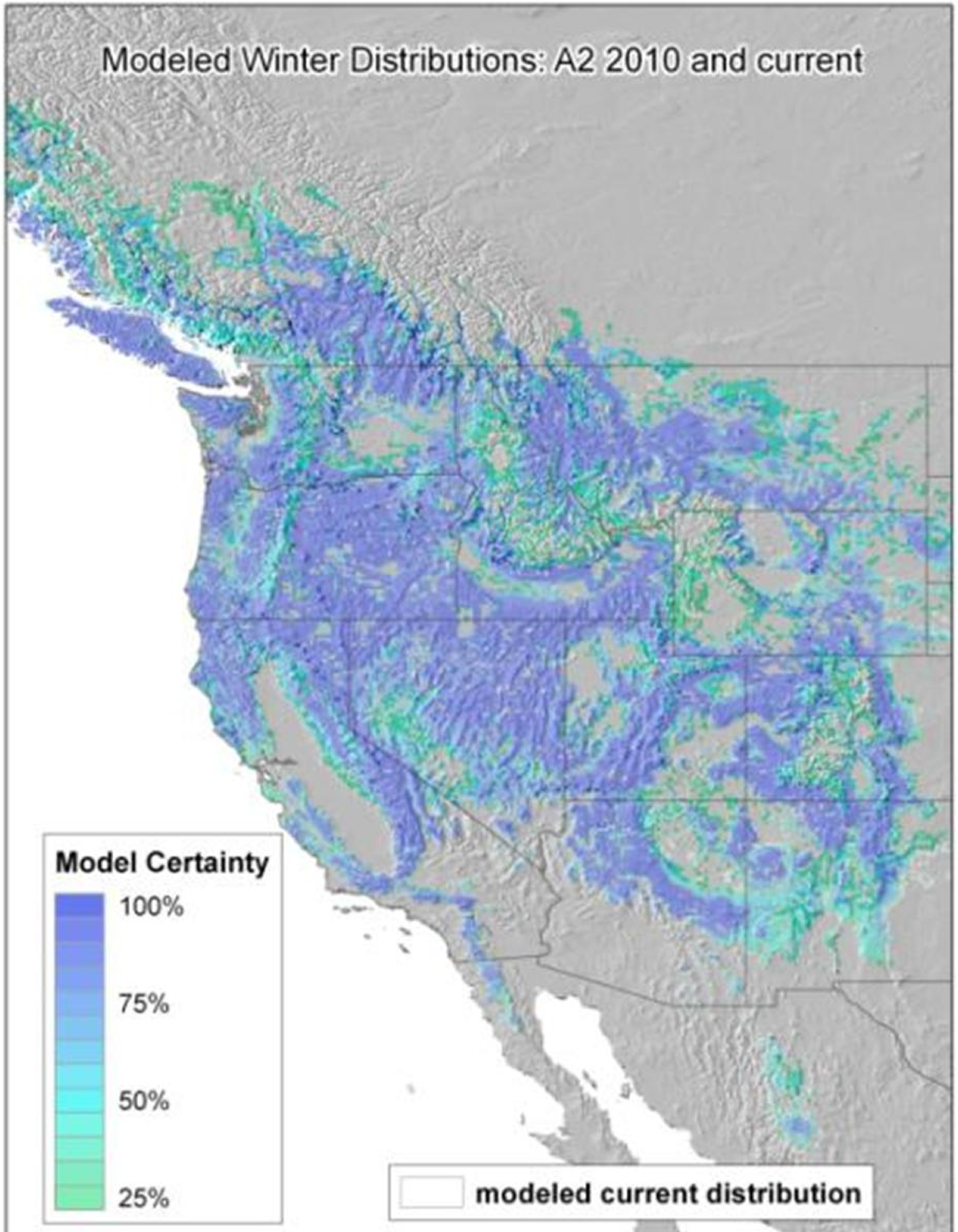

Elk Distribution
winter occurence

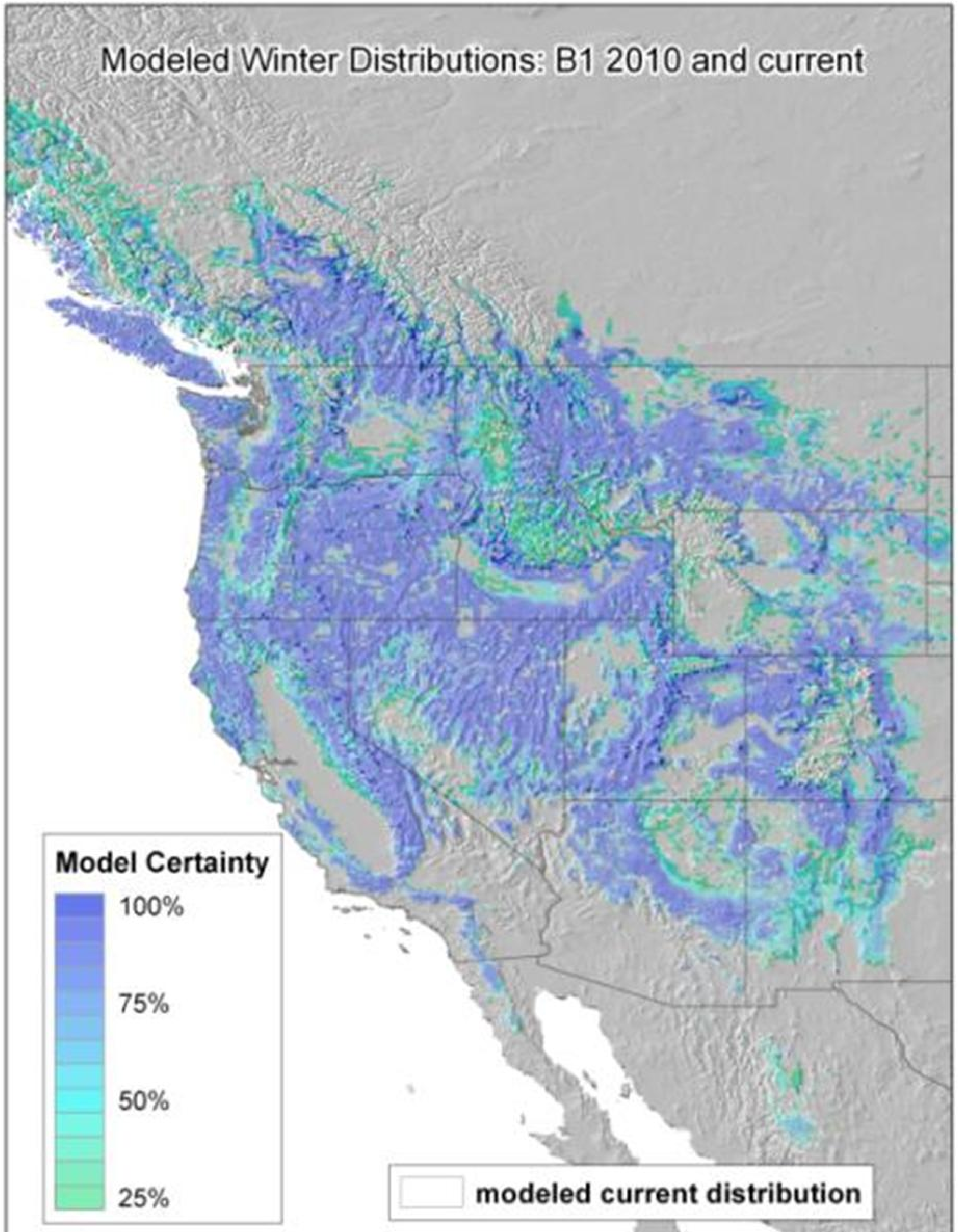
Elk


Elk Distribution
modeled winter distribution

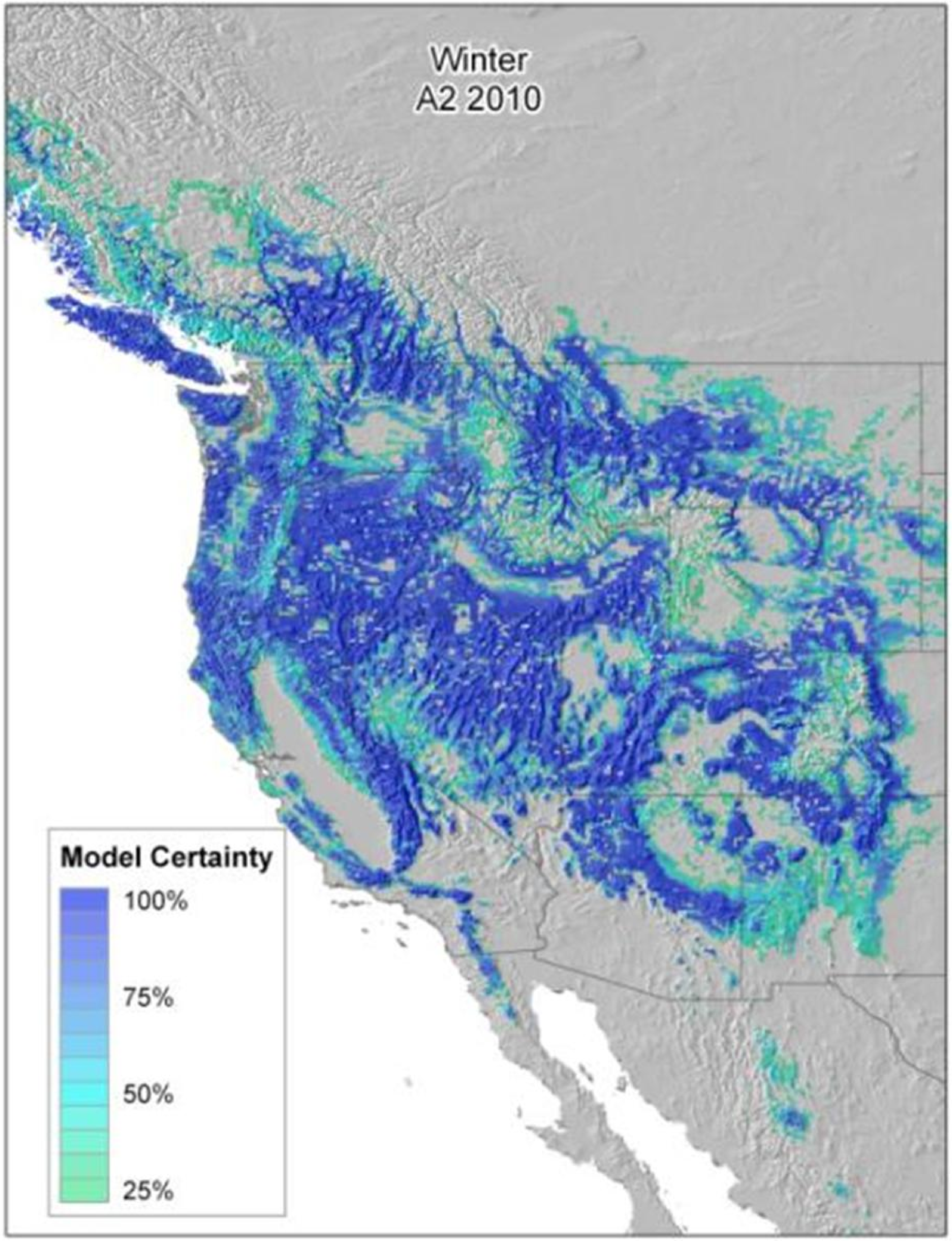

Elk Distribution
winter occurence
modeled winter distribution

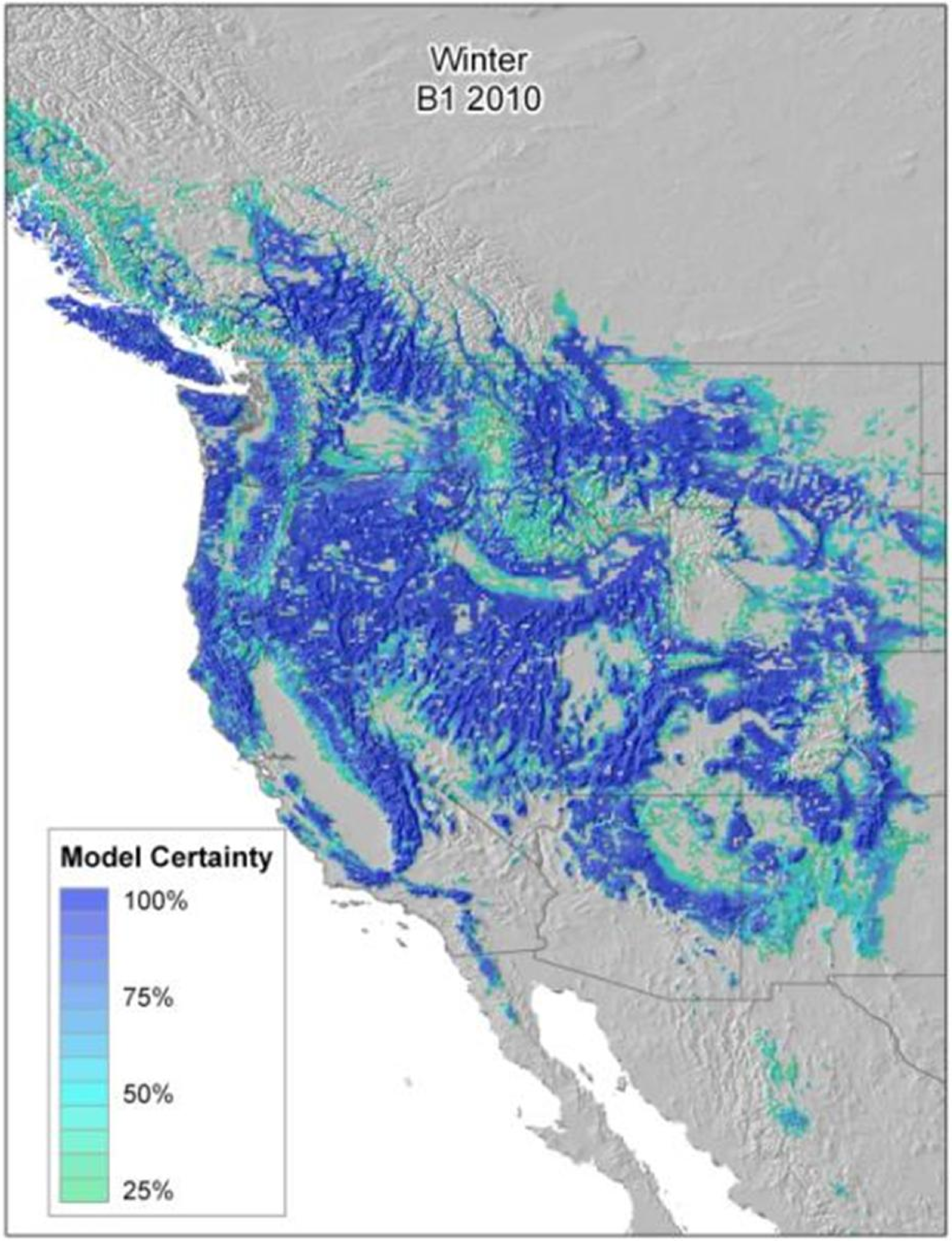
Elk


Modeled Winter Distributions: A2 2010 and current
Model Certainty
100%
75%
50%
25%
modeled current distribution

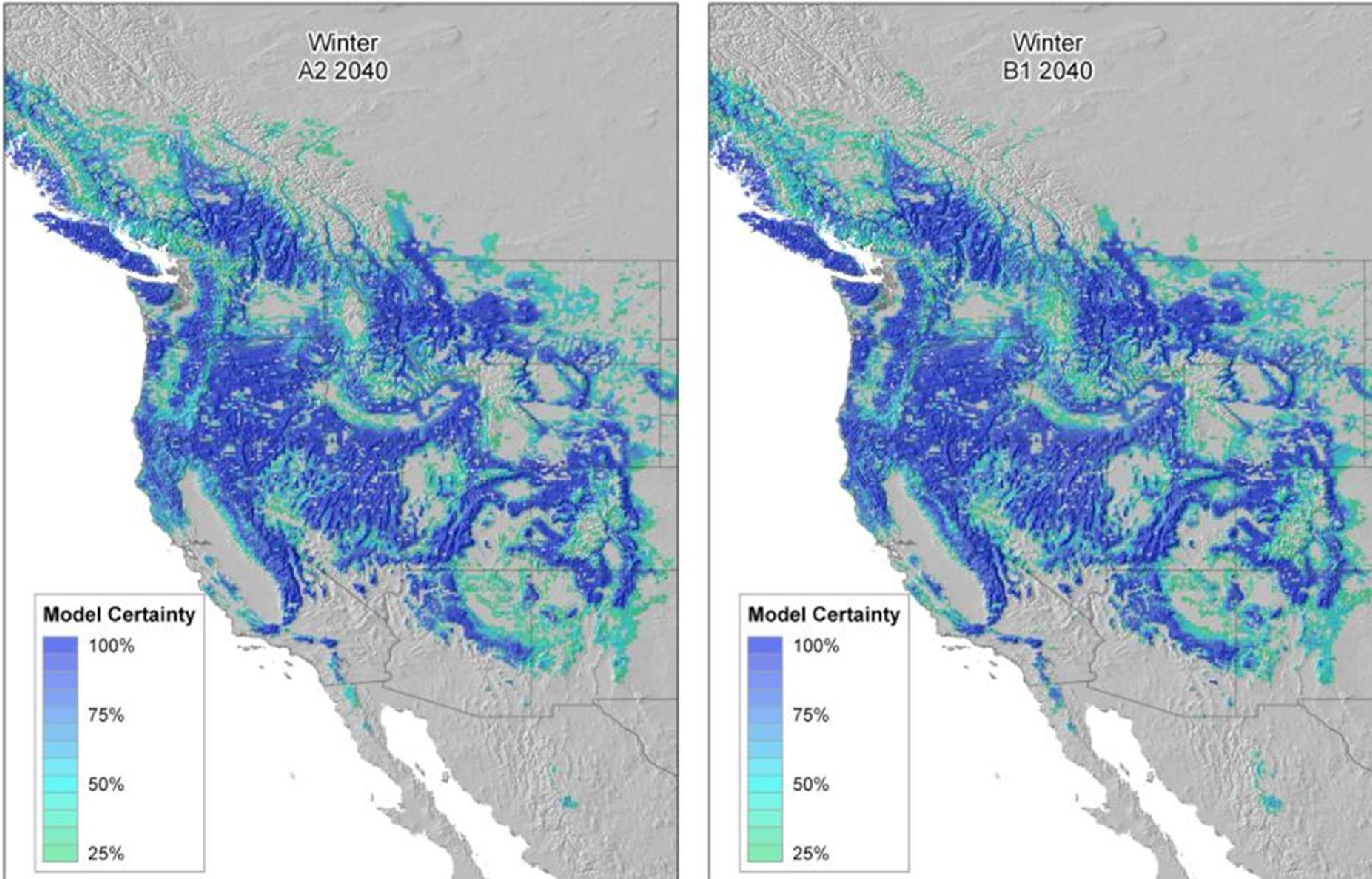

Modeled Winter Distributions: B1 2010 and current
Model Certainty
100%
75%
50%
25%
modeled current distribution

Elk Modeled Future Distributions

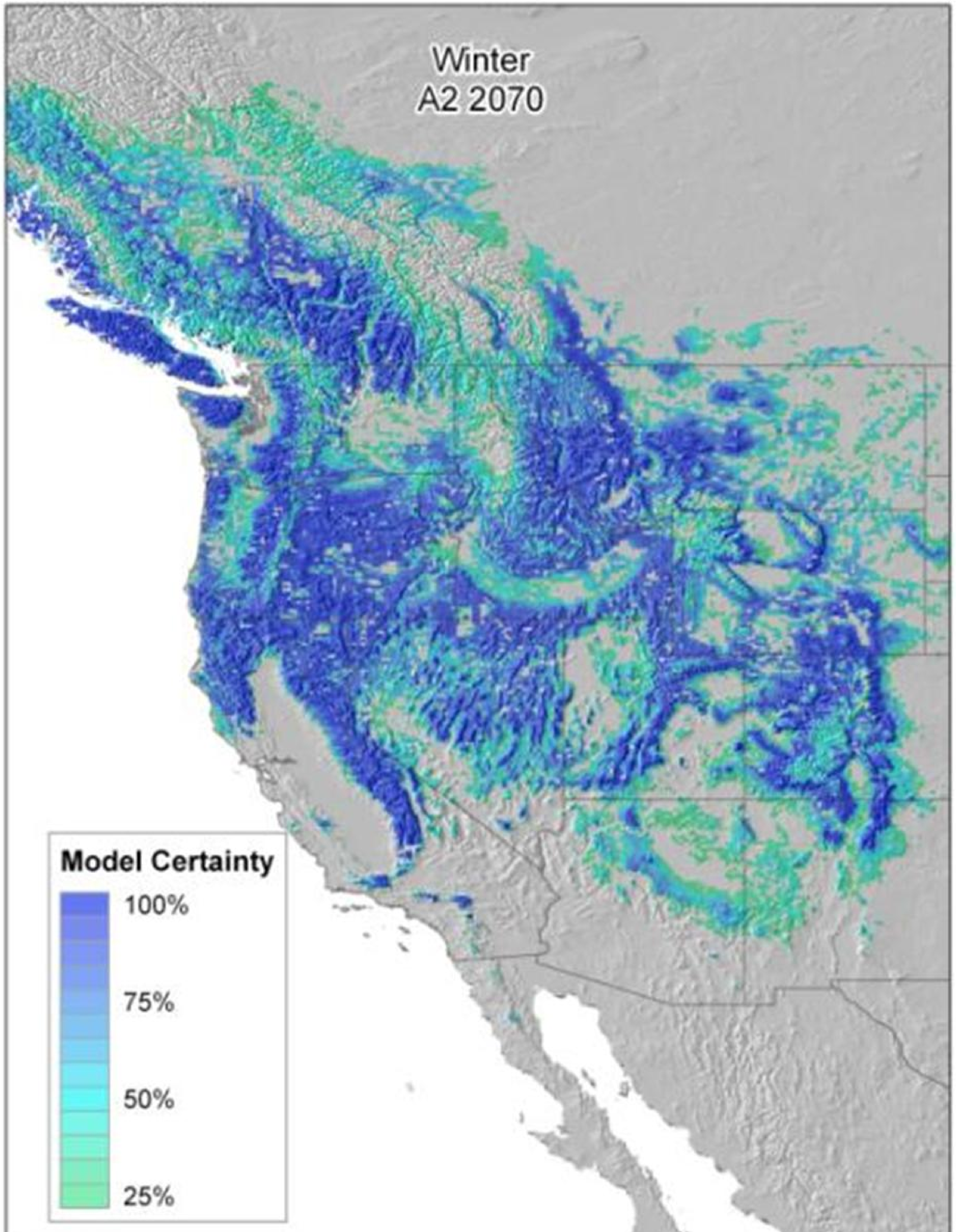


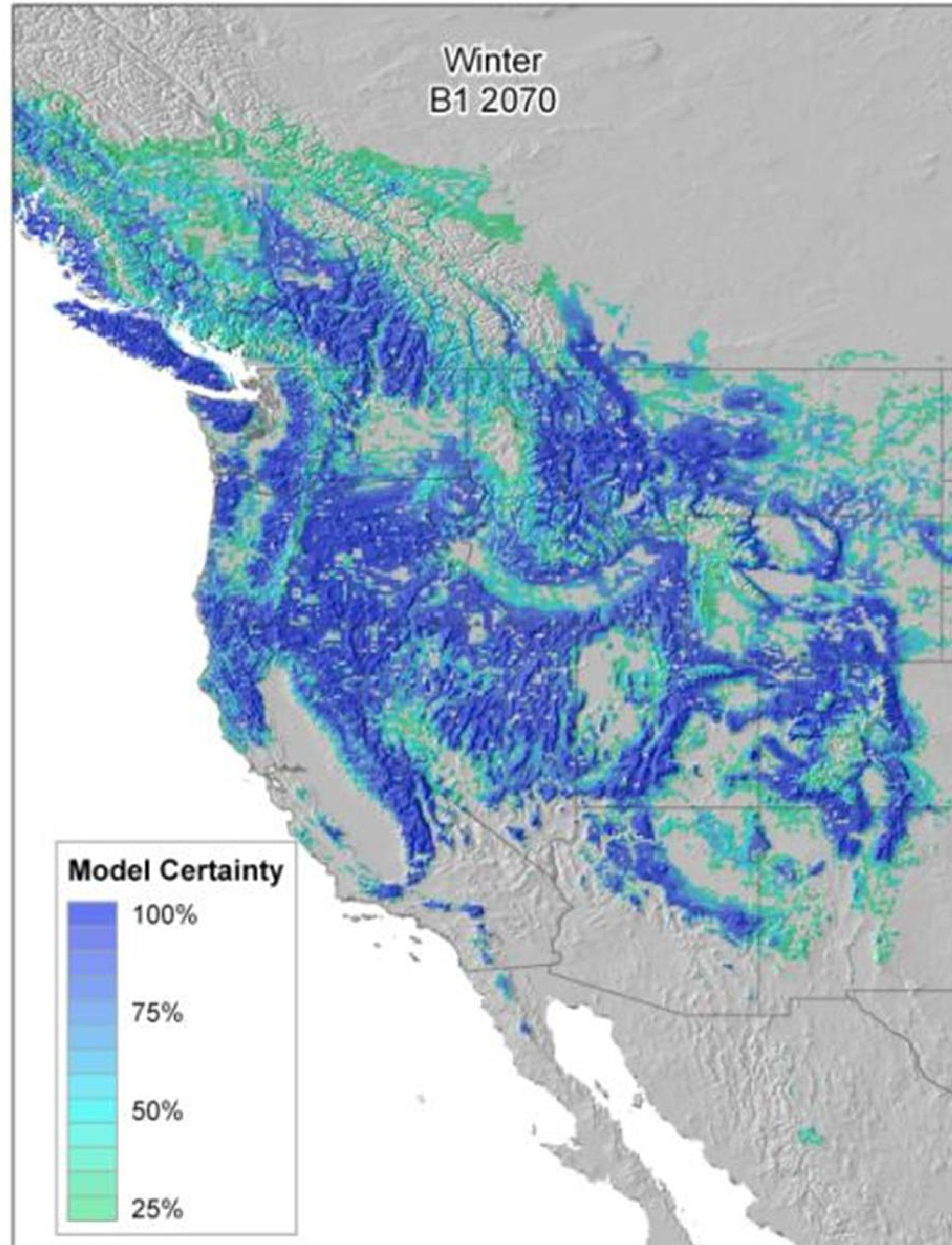


Elk Modeled Future Distributions

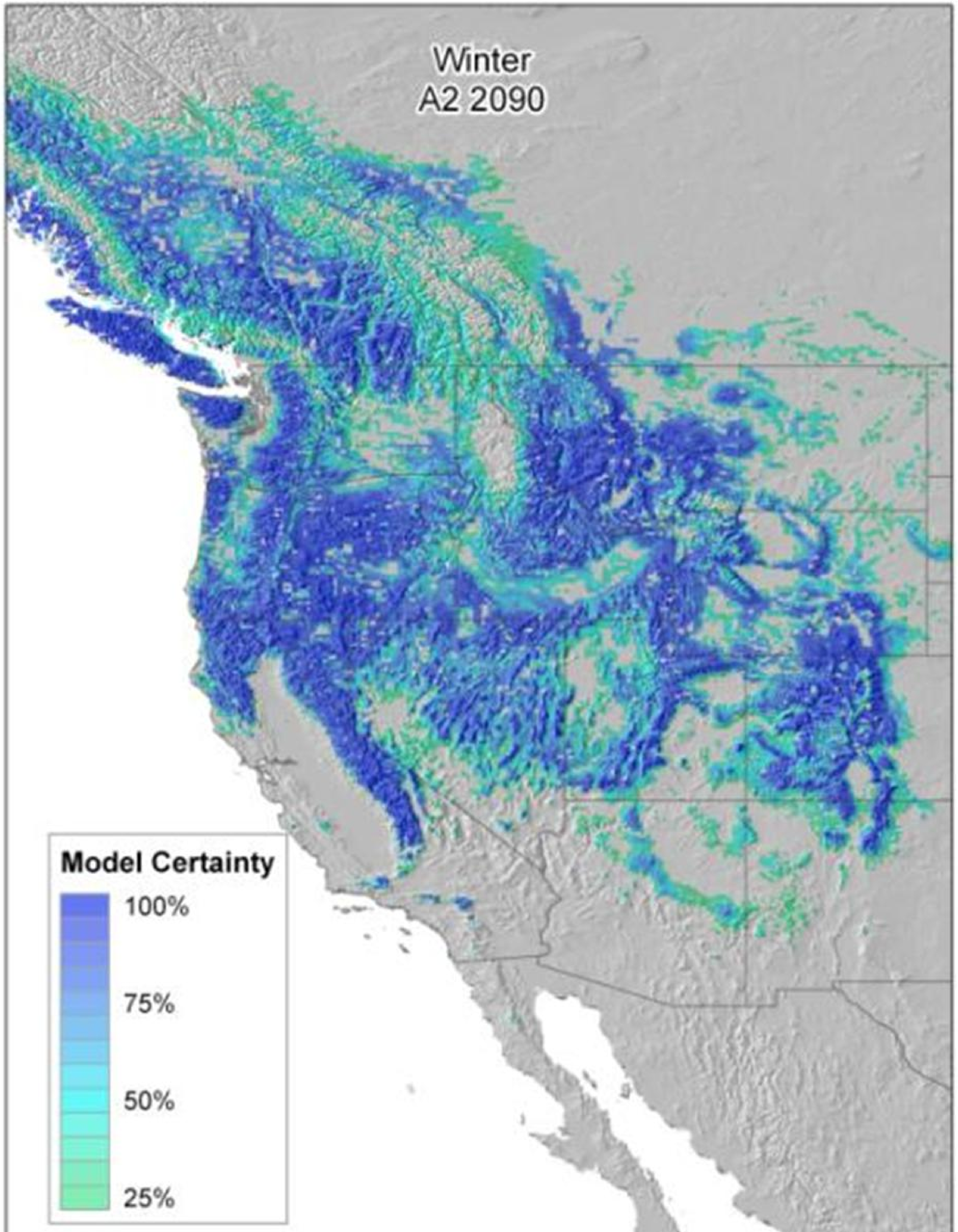


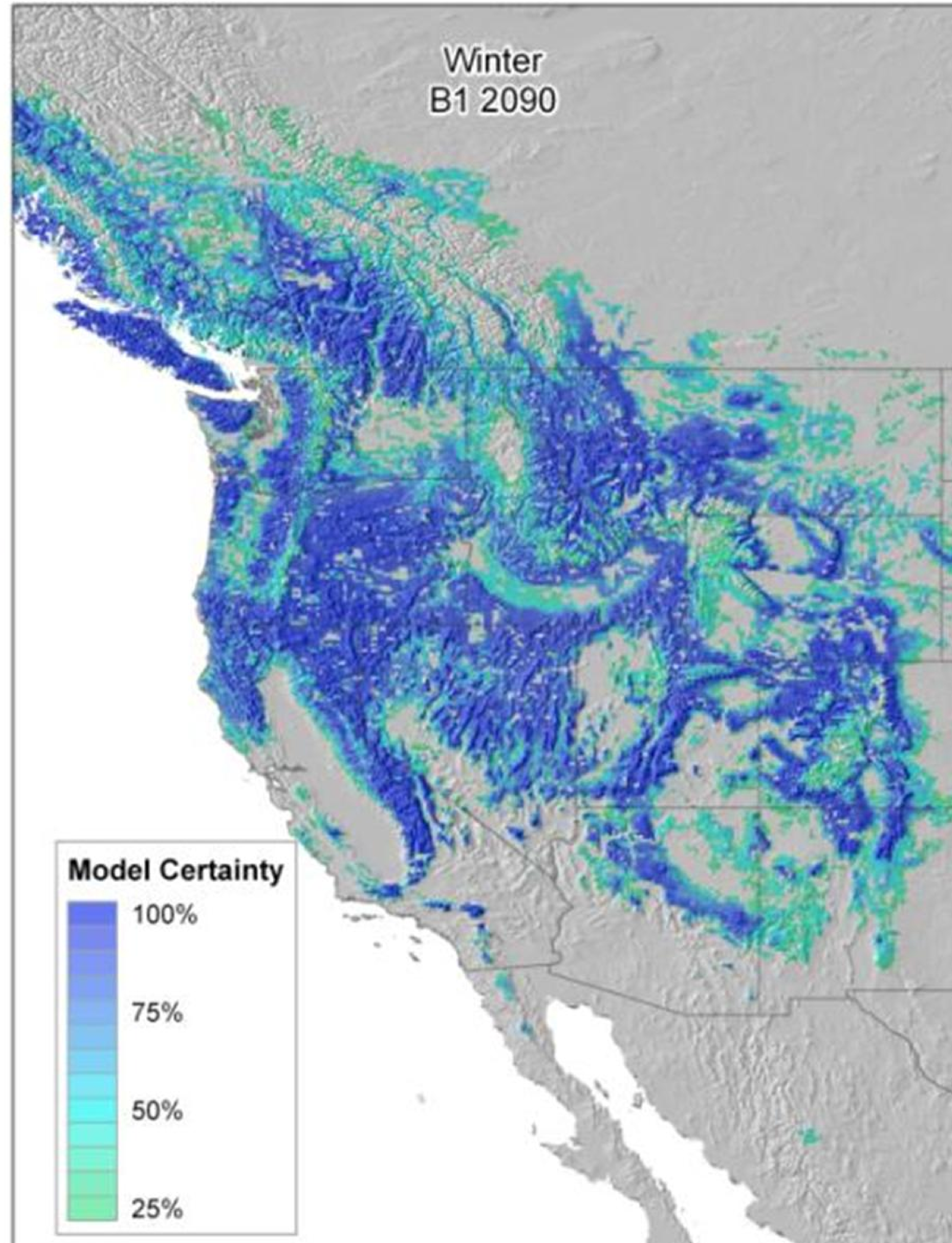
Elk Modeled Future Distributions





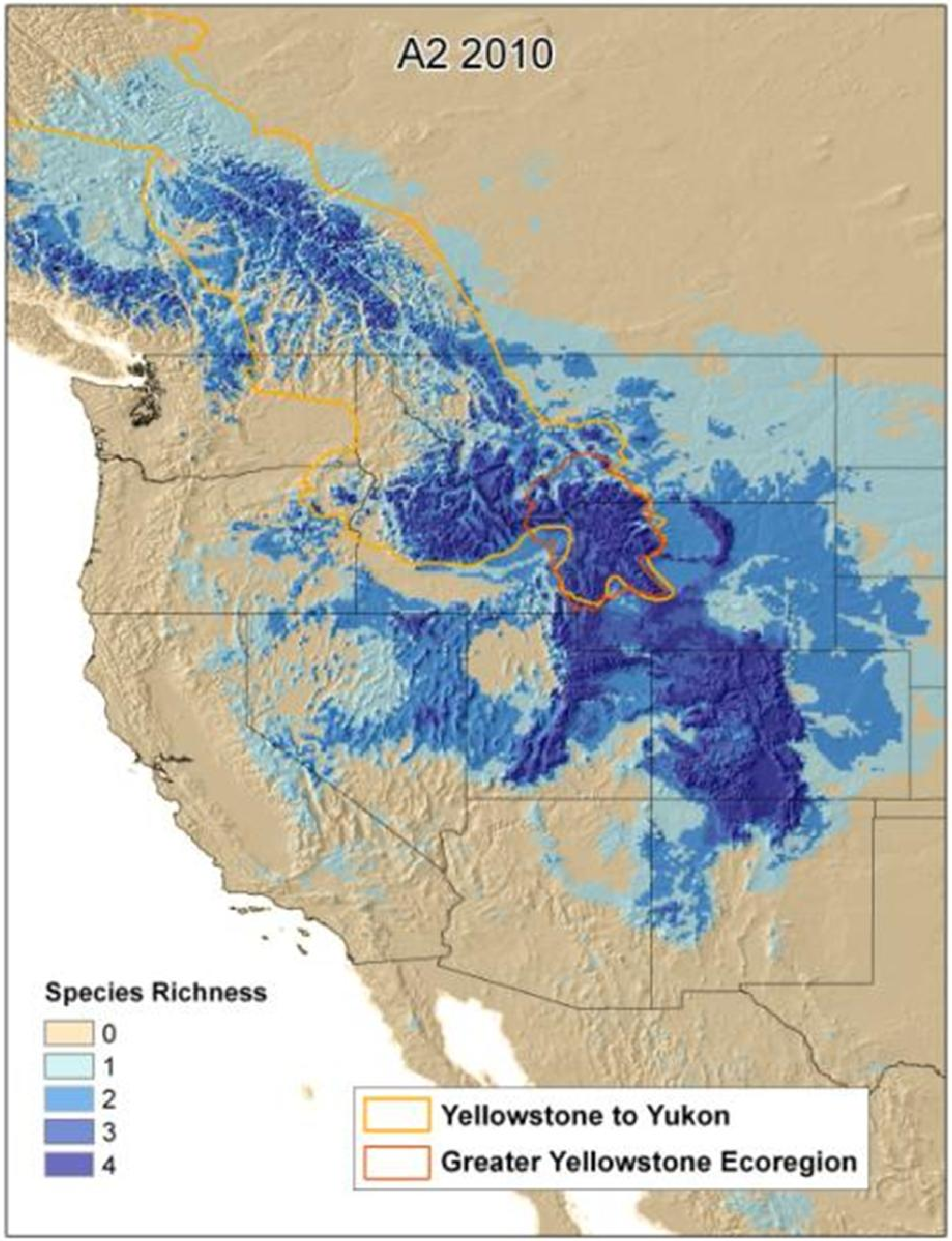
Elk Modeled Future Distributions

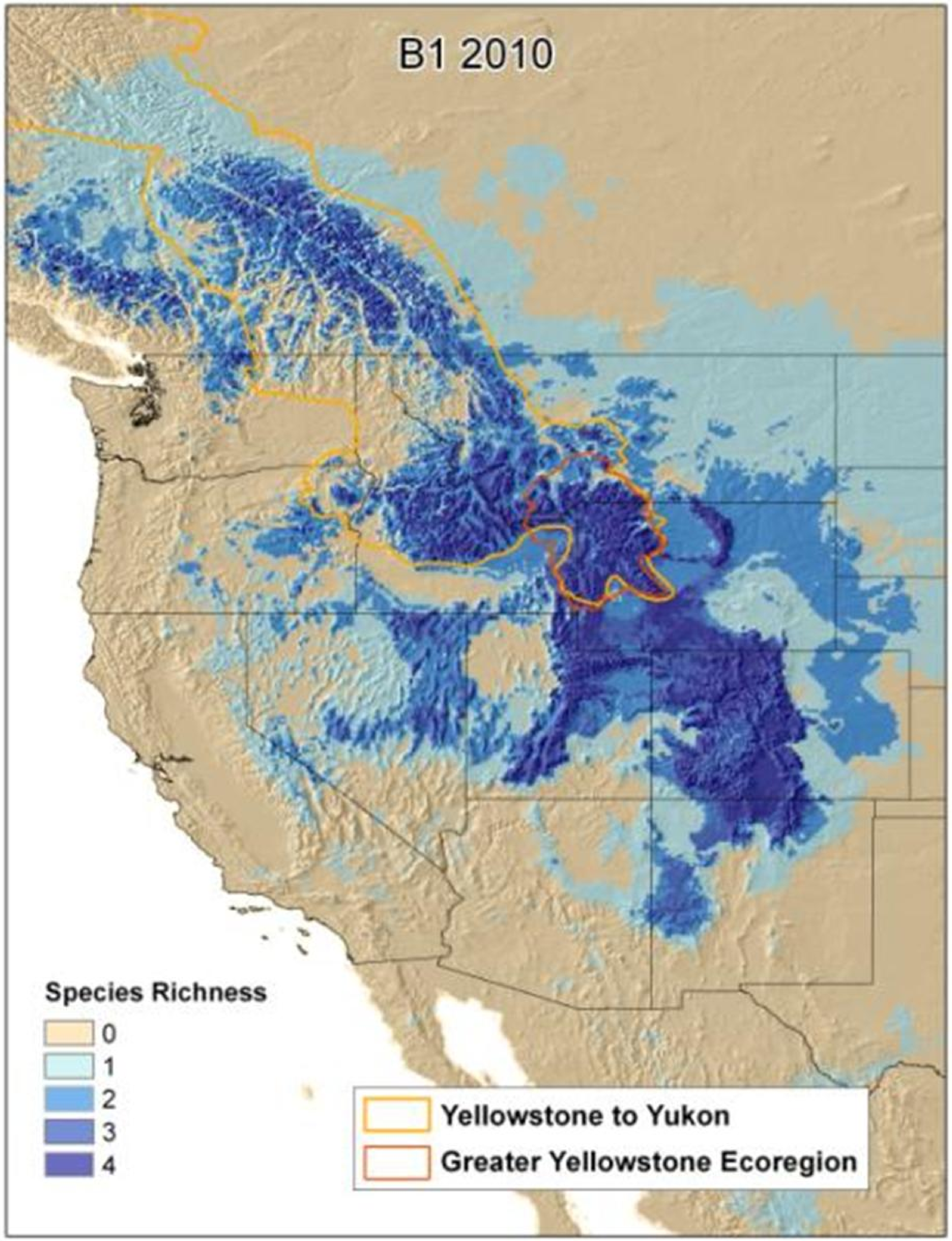




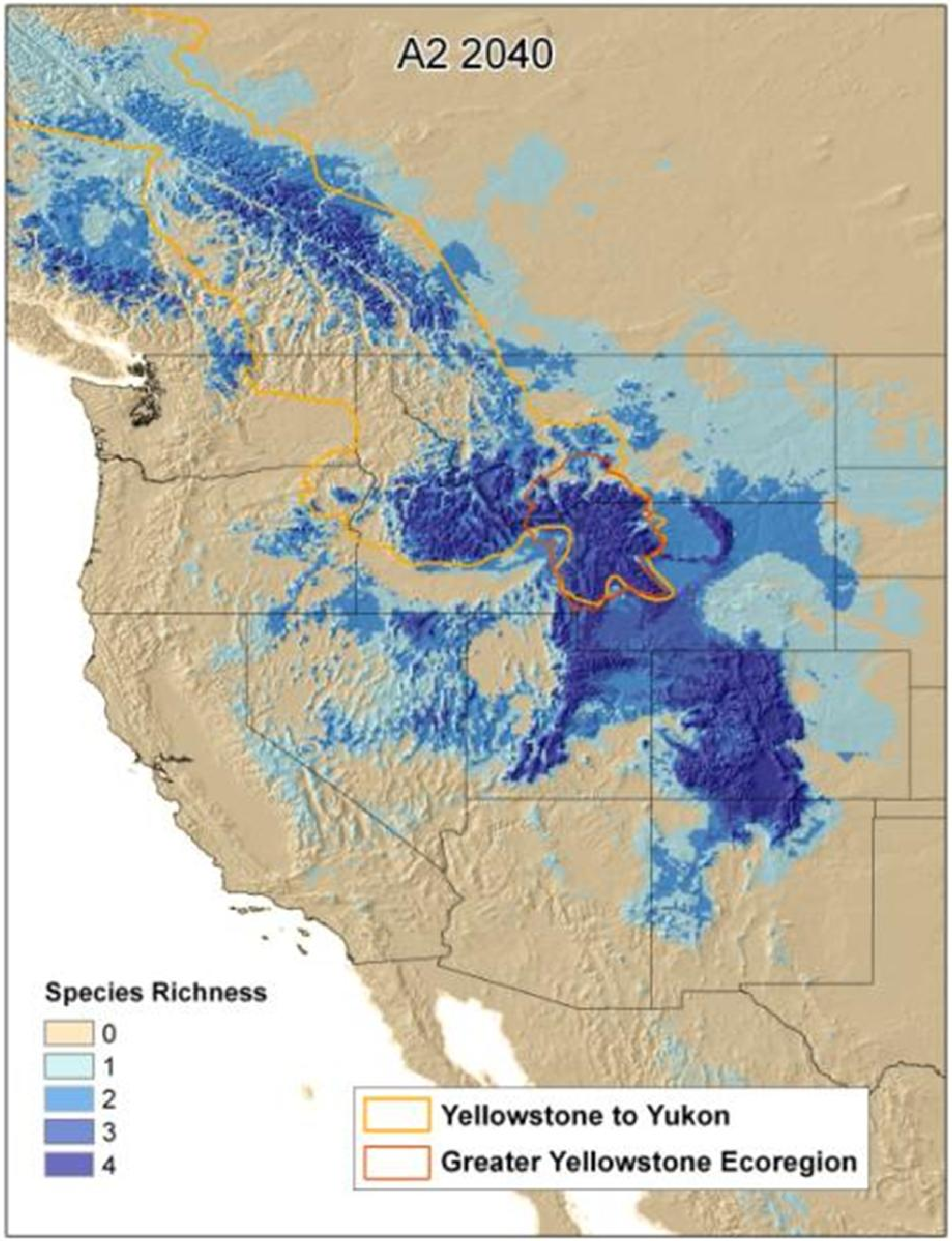
Modeled Winter Ranges:

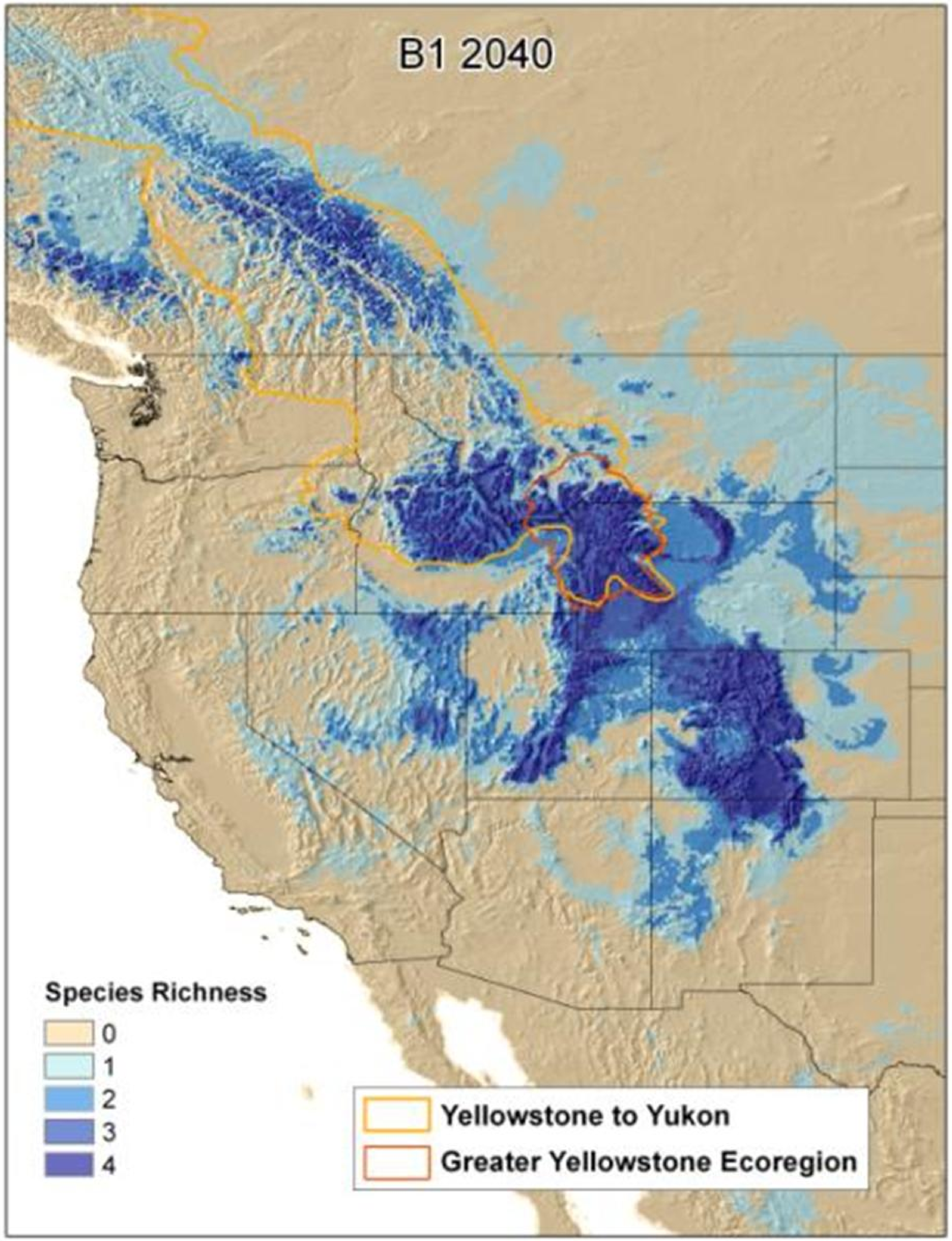
Bighorn Sheep, Mule Deer, Elk, and Moose





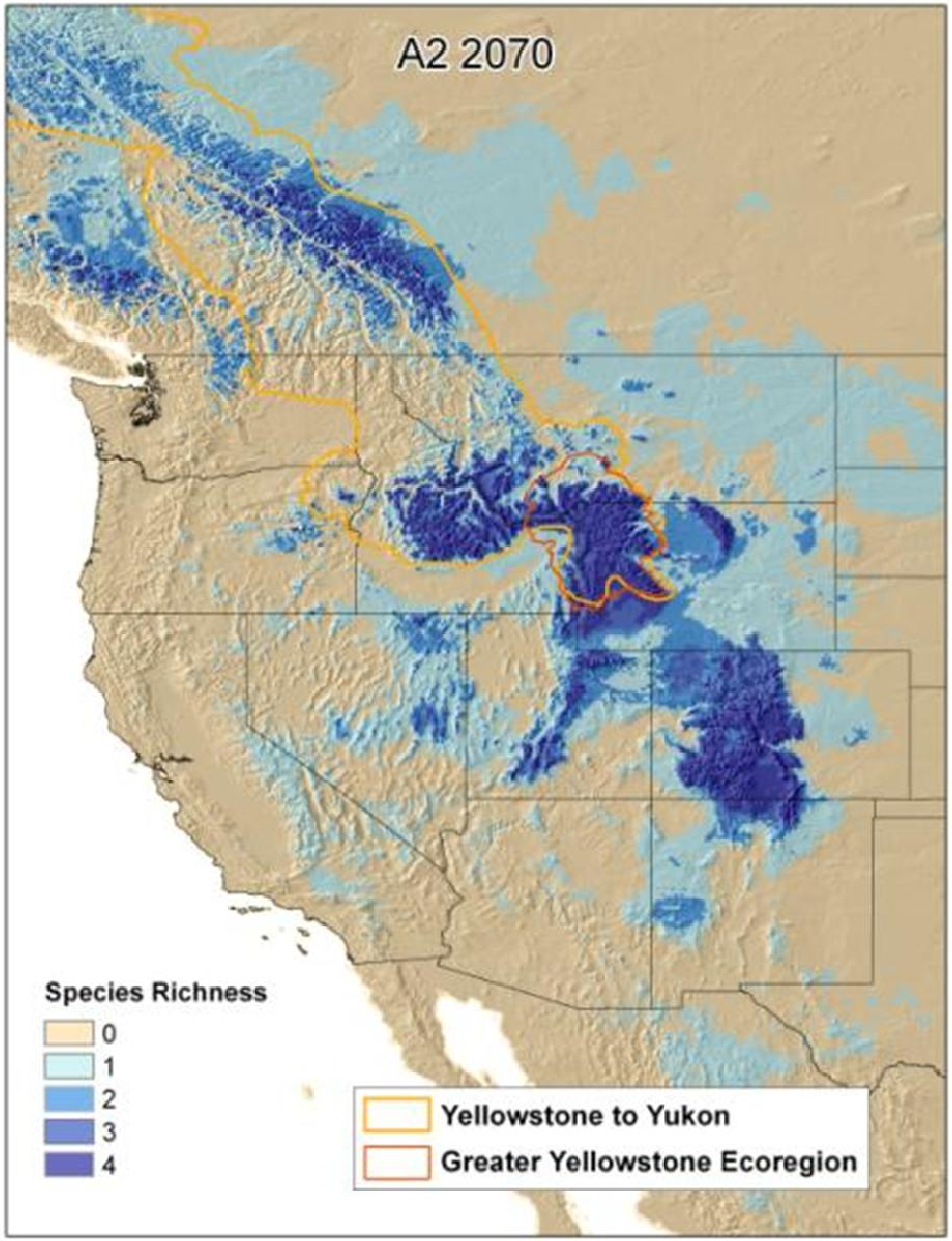
Modeled Winter Ranges: Bighorn Sheep, Mule Deer, Elk, and Moose

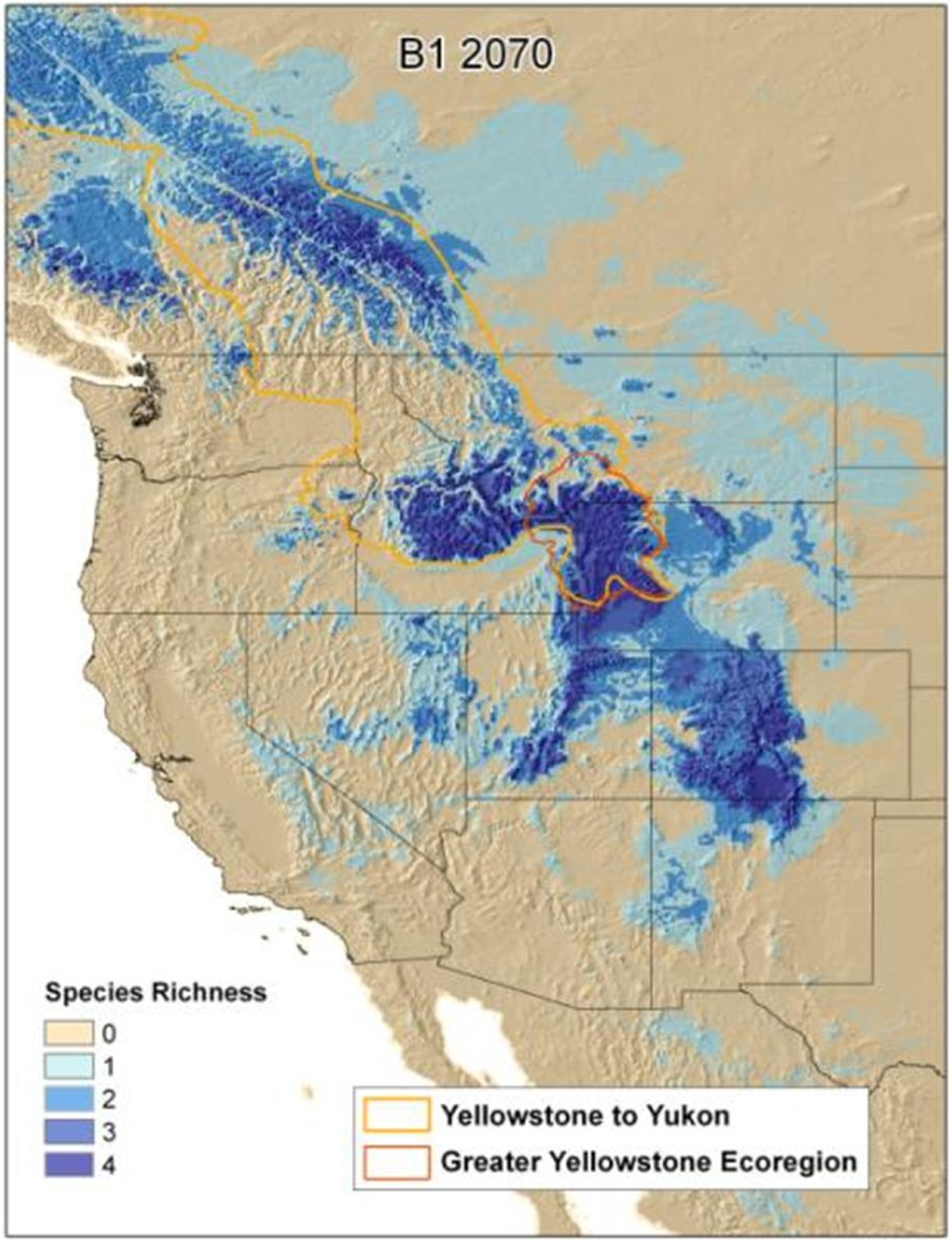




Modeled Winter Ranges:

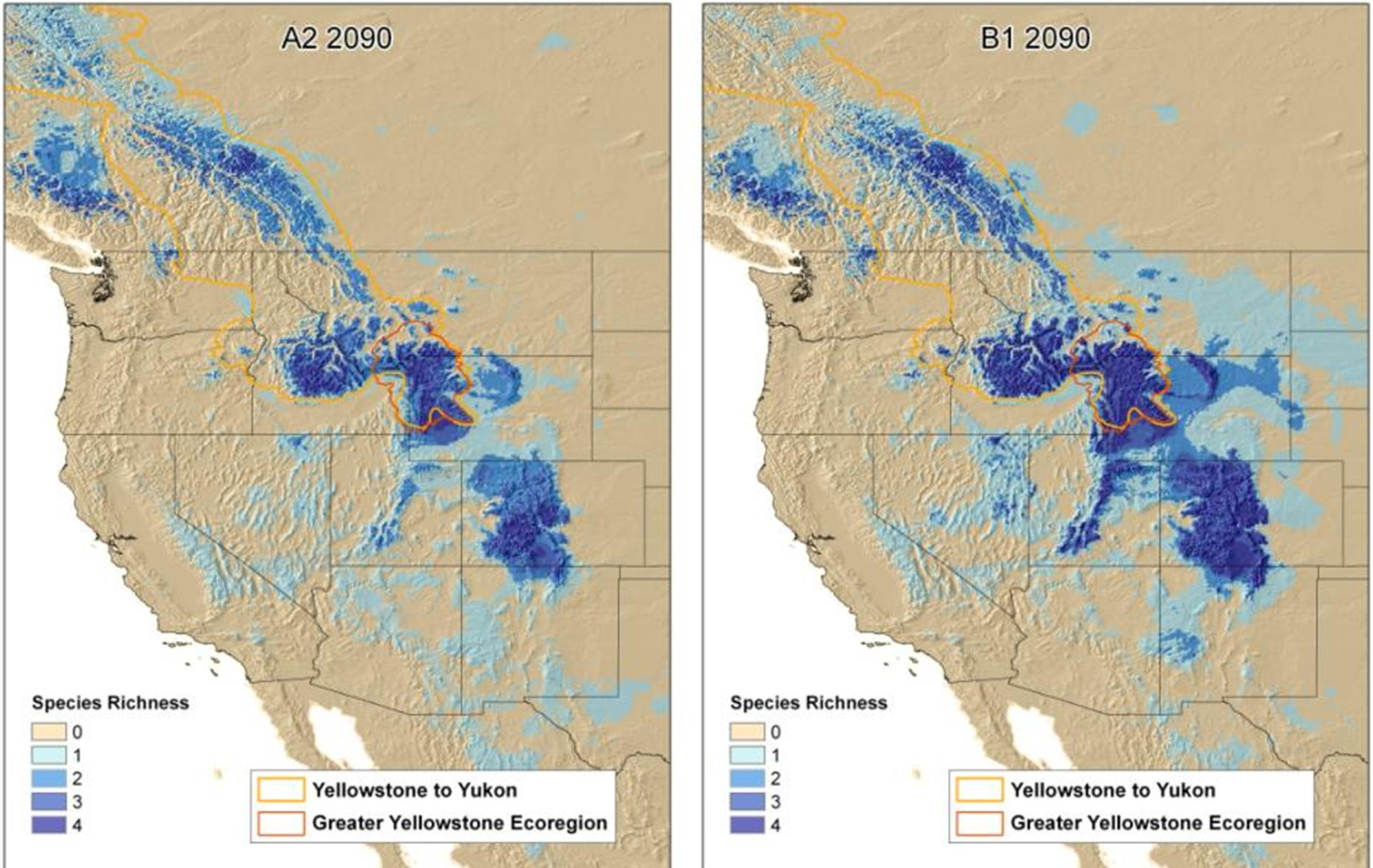
Bighorn Sheep, Mule Deer, Elk, and Moose

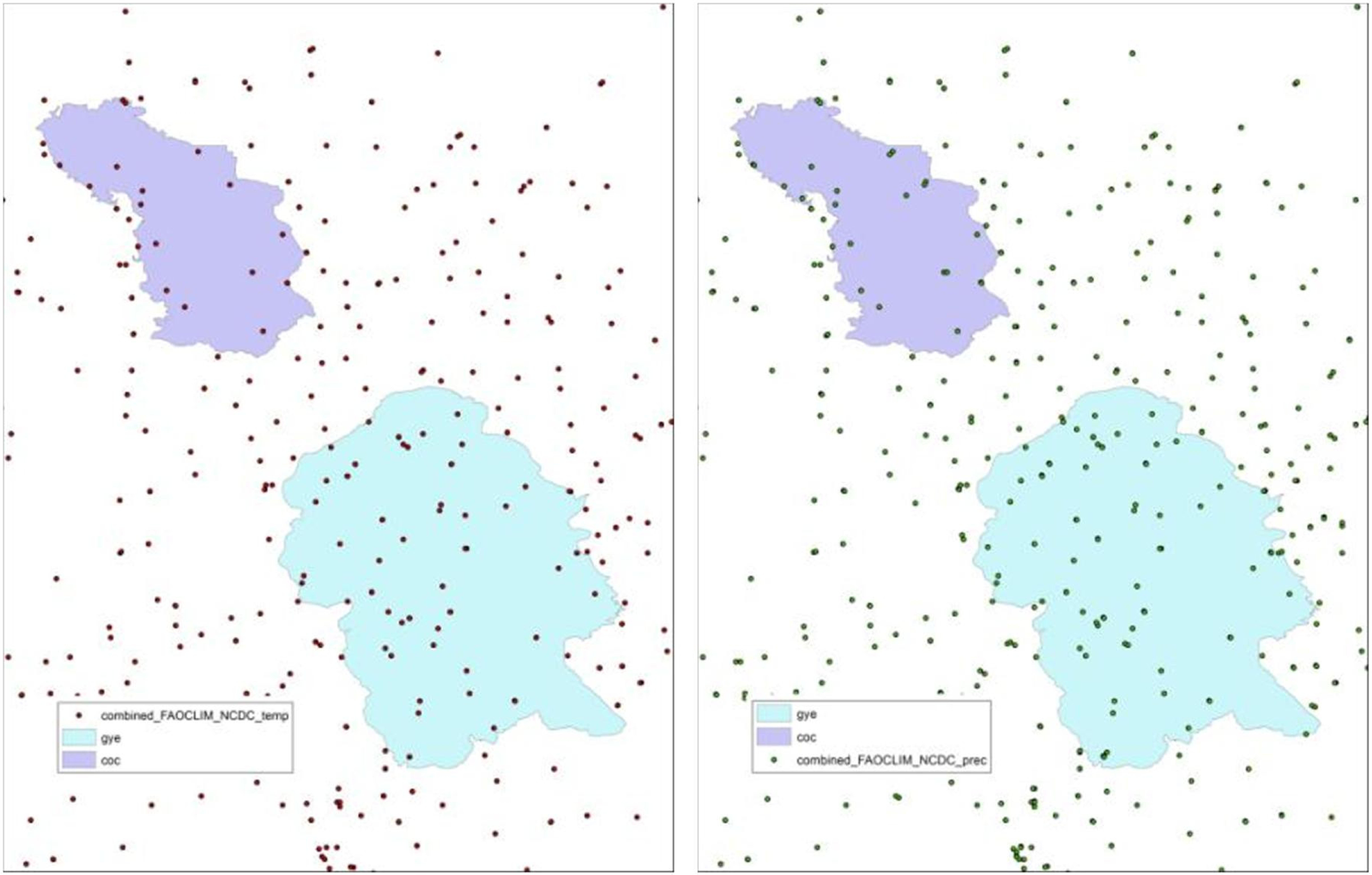


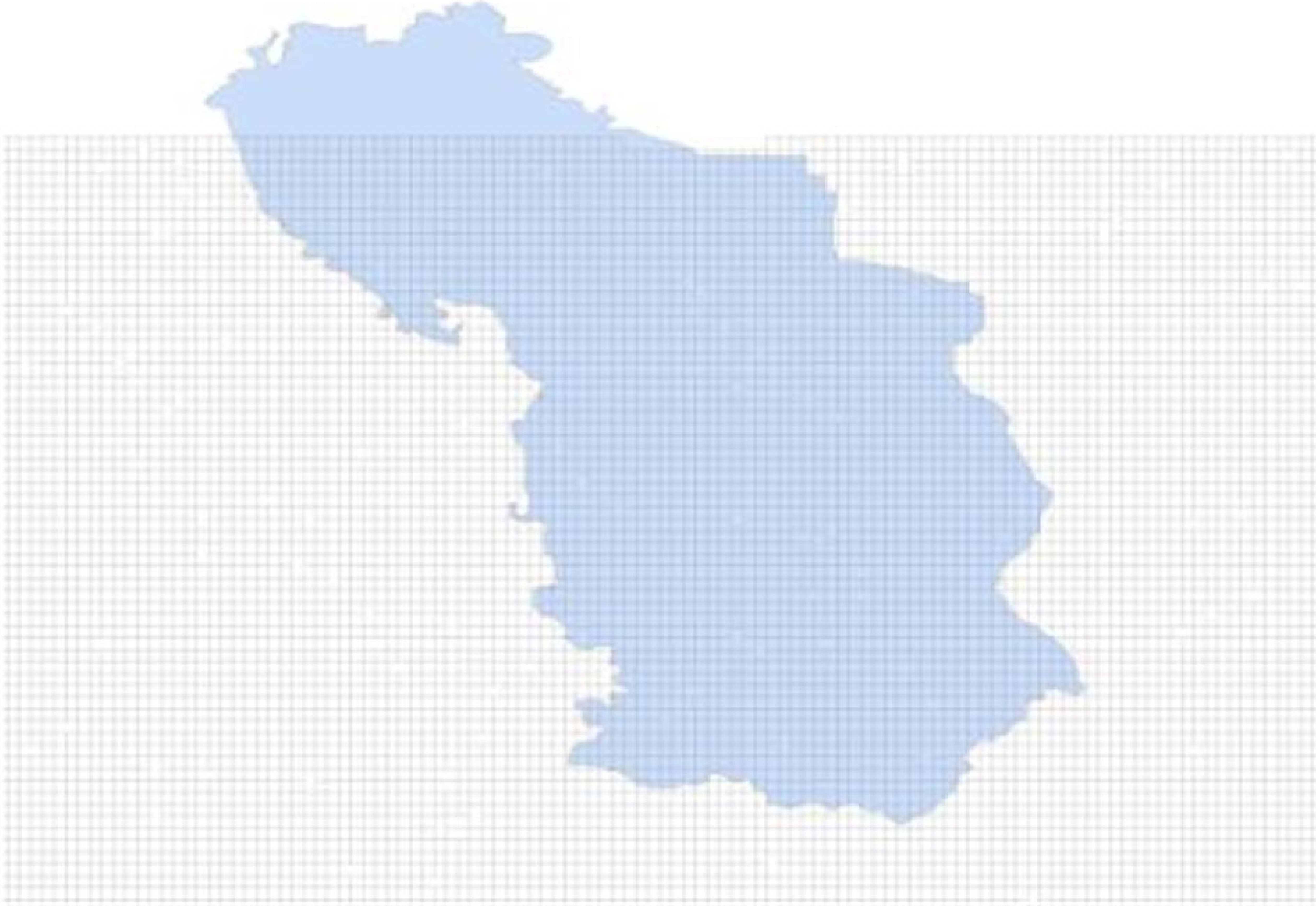


Modeled Winter Ranges:

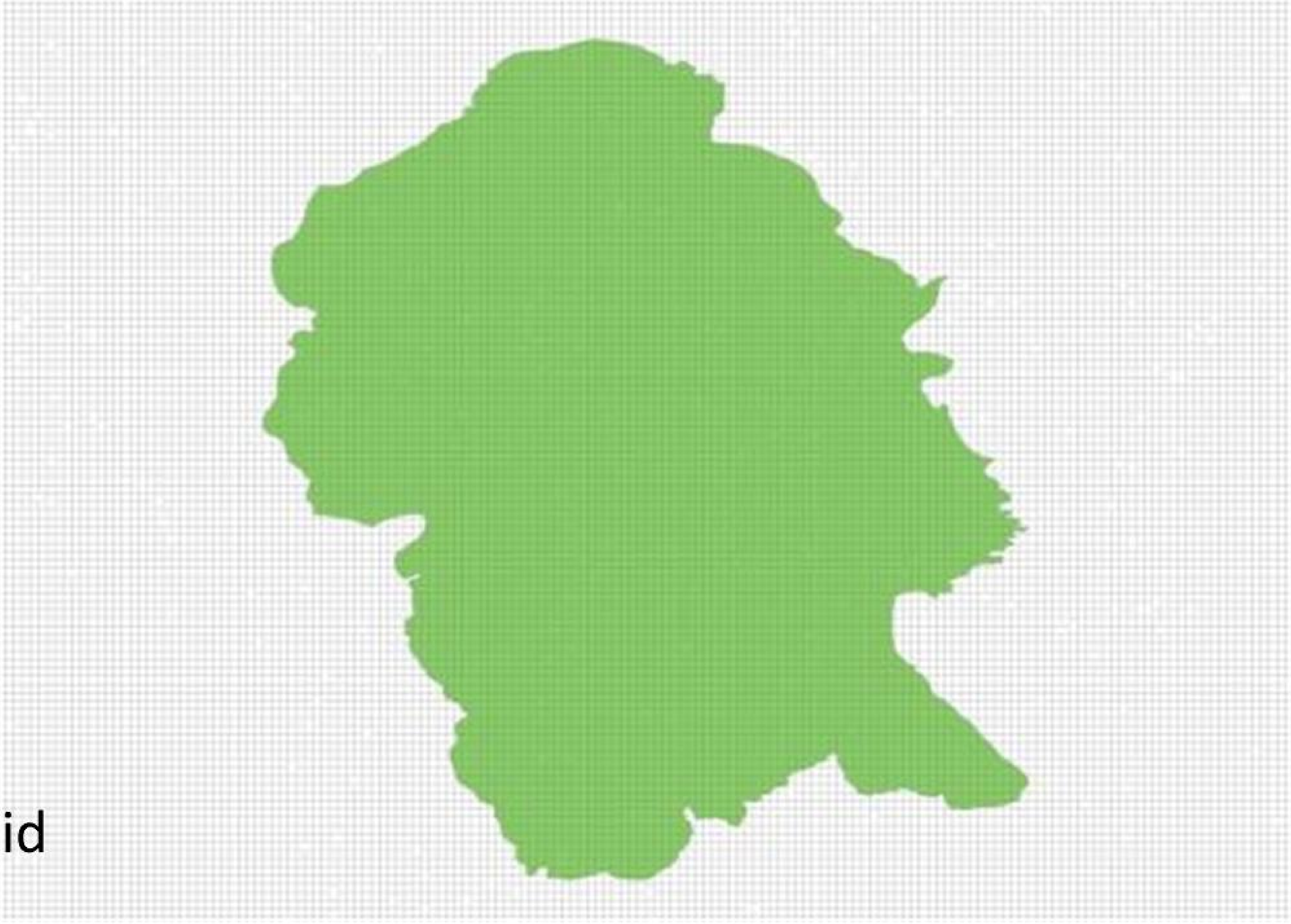
Bighorn Sheep, Mule Deer, Elk, and Moose



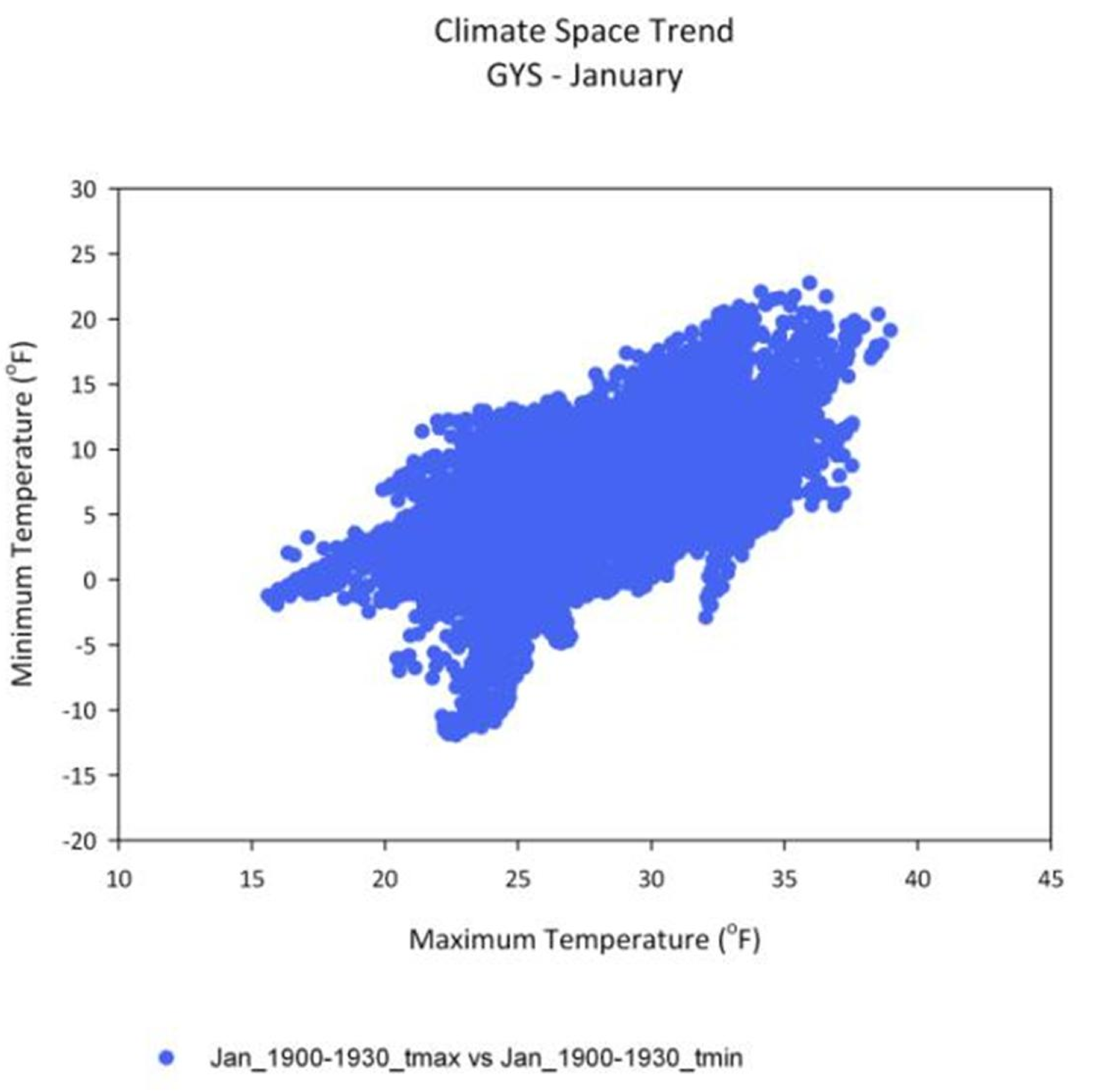

combined_FAOCLIM_NCDC_temp
gye
coc
gye
coc
combined_FAOCLIM_NCDC_prec



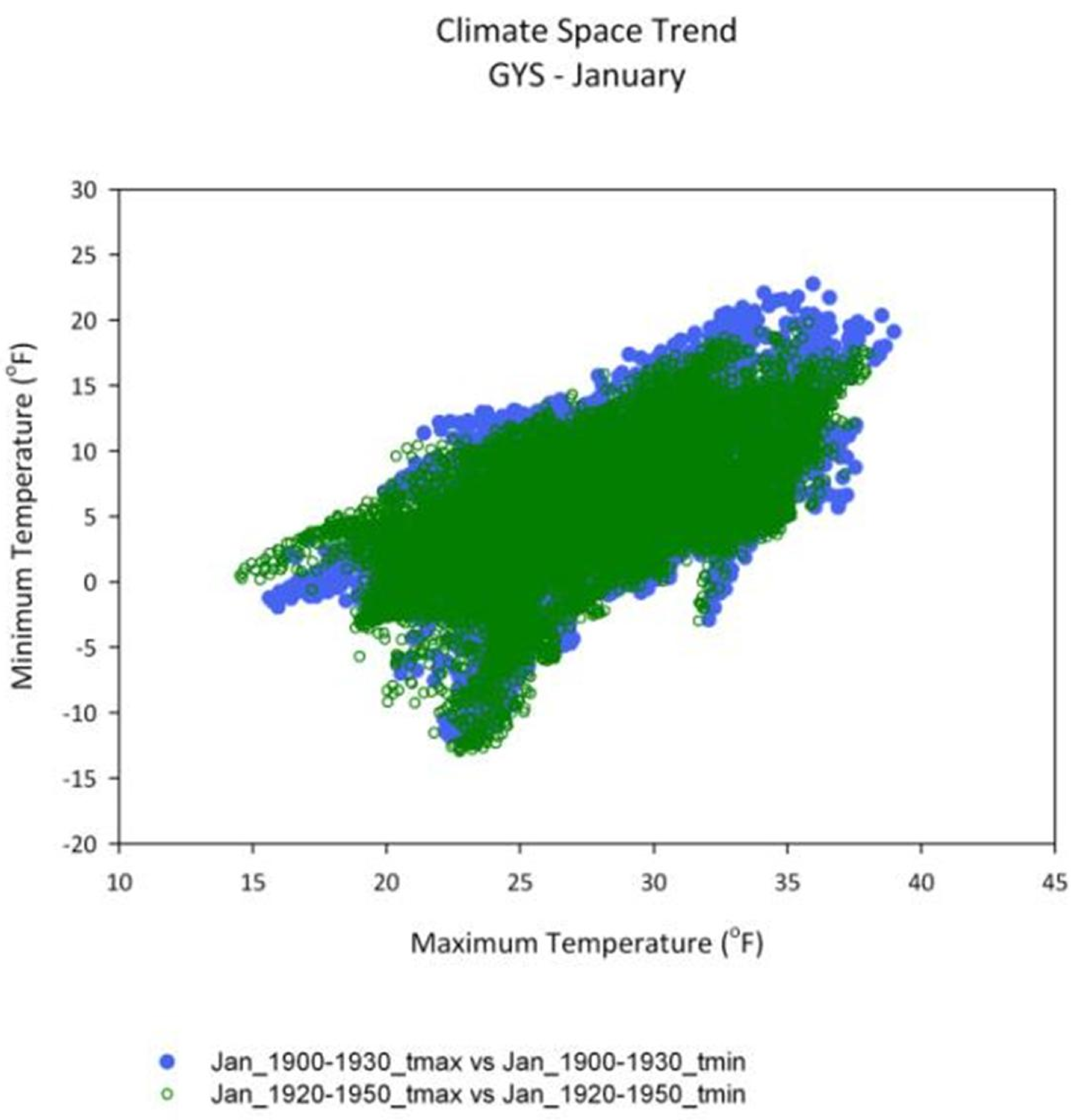
“Crown of the Continent” 4km grid



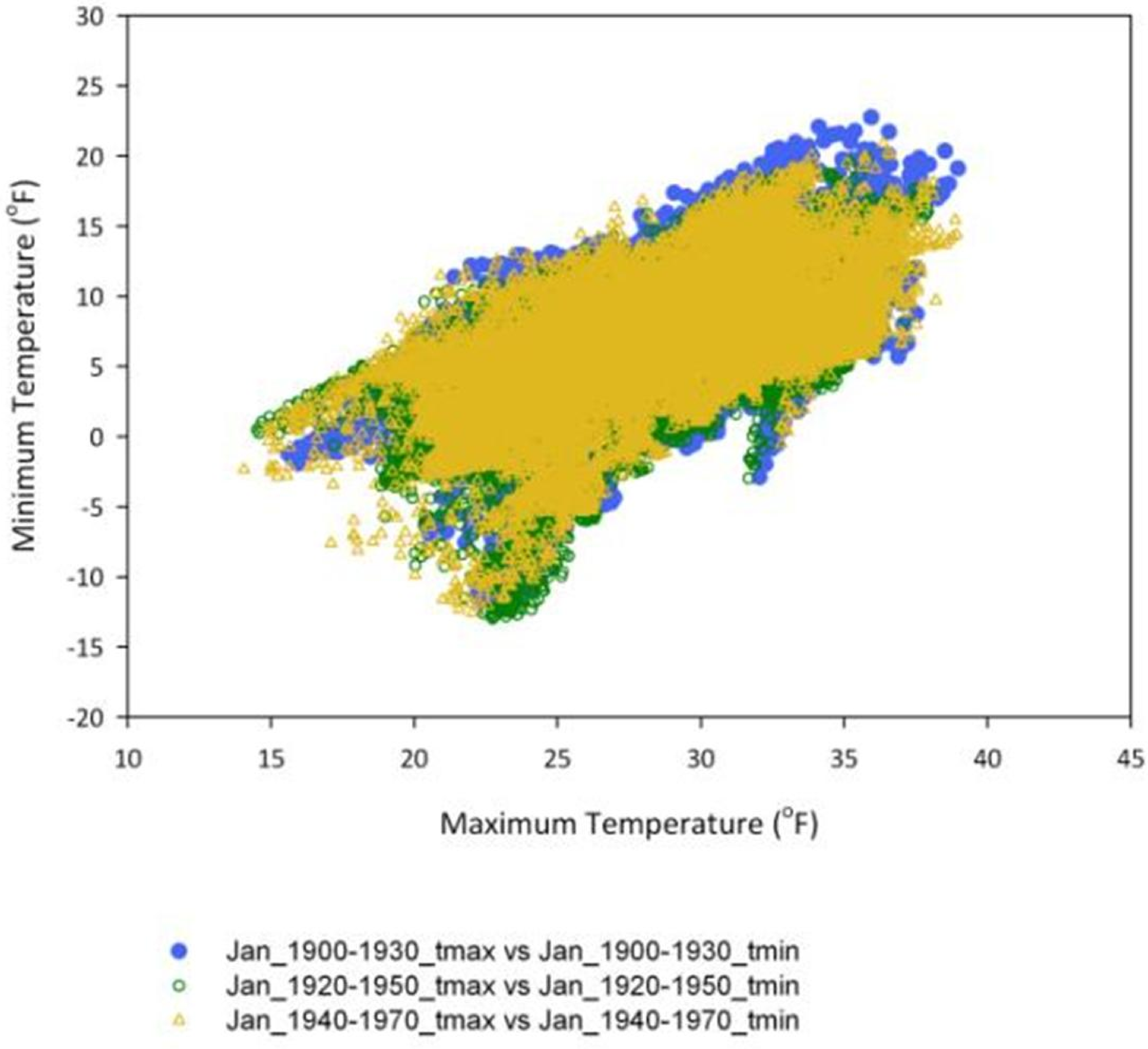
Greater Yellowstone ecoregion 4 km grid

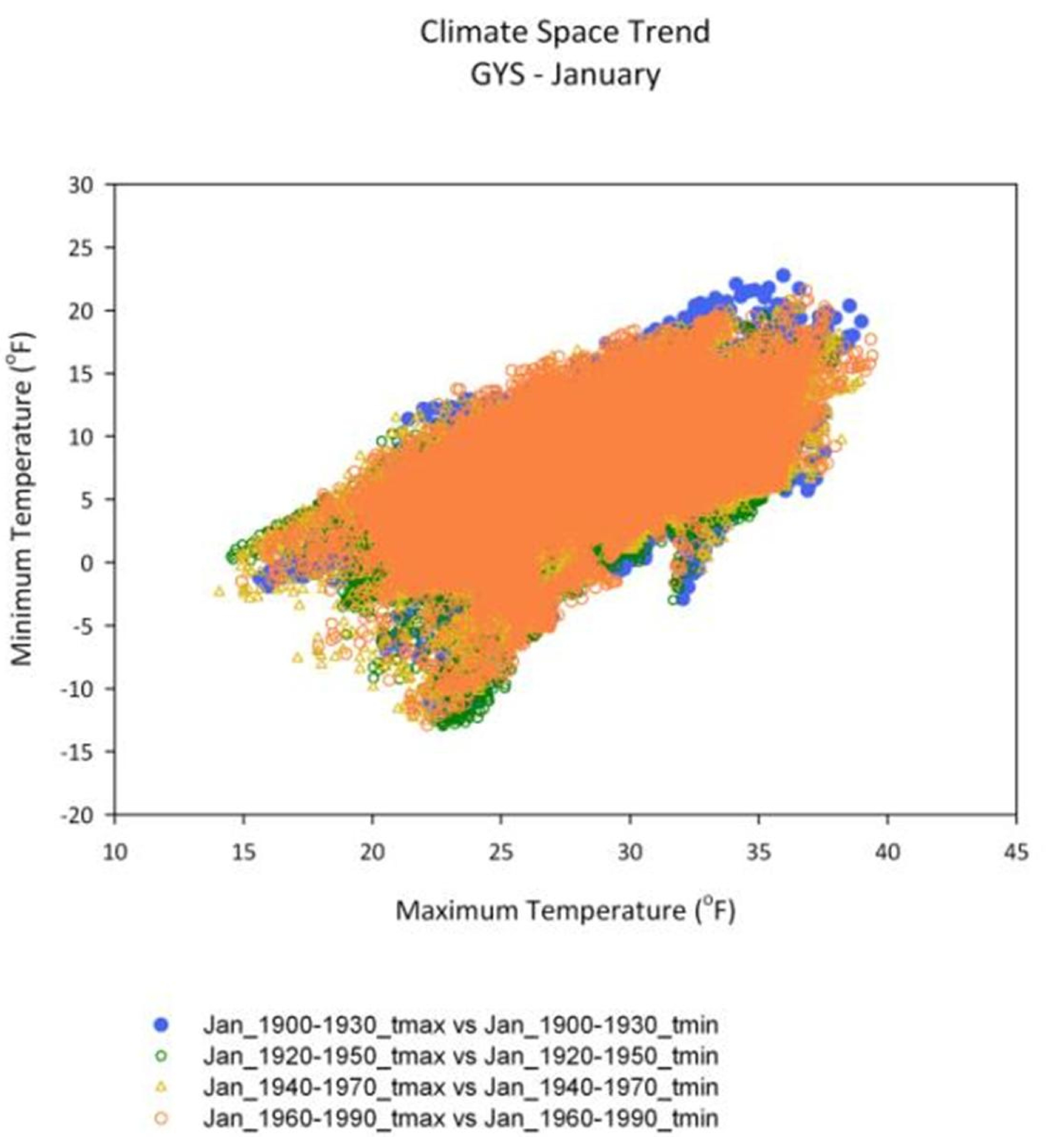


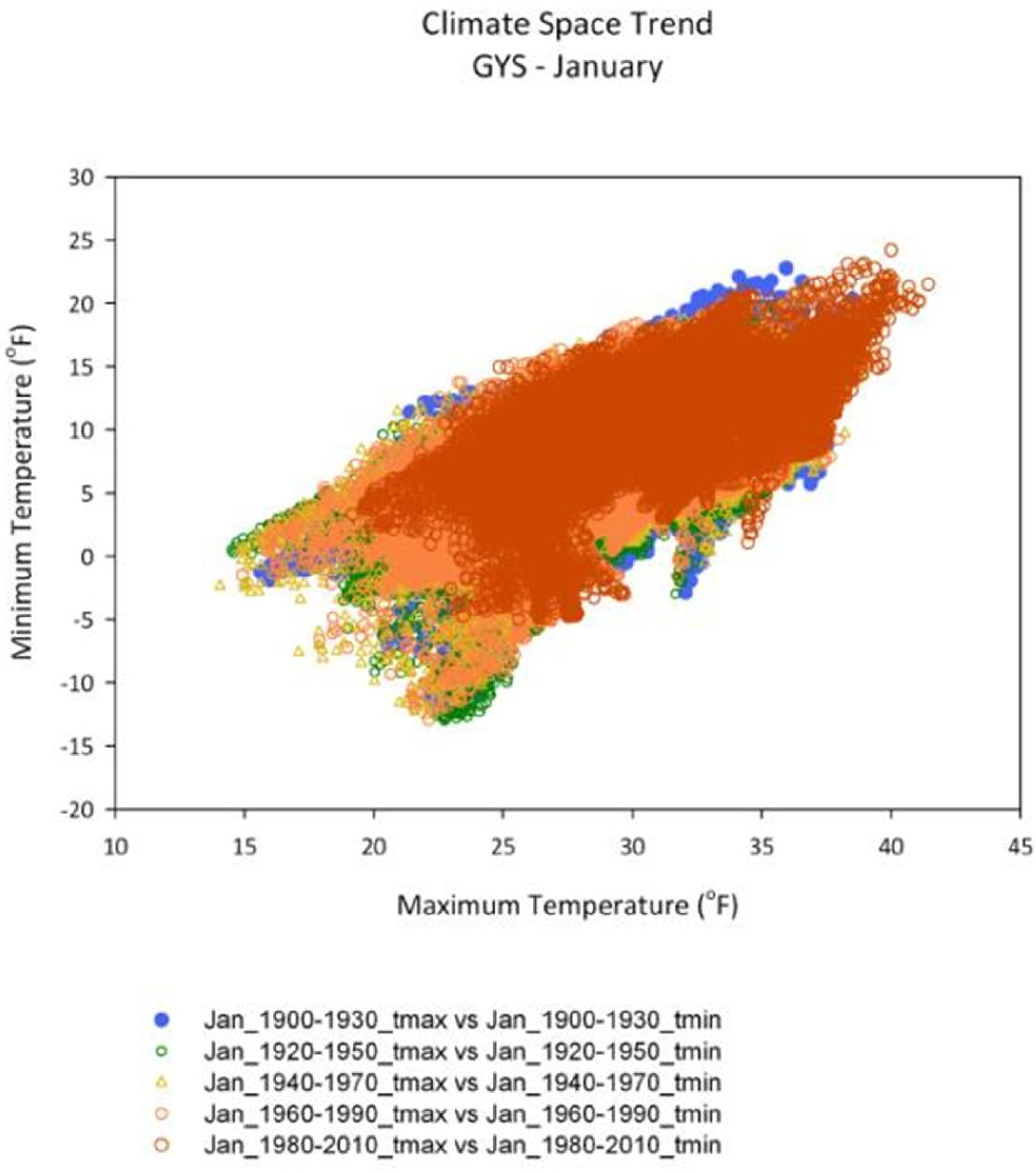
Climate Space Trend
GYS - January
Minimum Temperature (°F)
30
25
20
15
10
5
0
-5
-10
-15
-20
10
15
20
25
30
35
40
45
Maximum Temperature (°F)
Jan_1900-1930_tmax vs Jan_1900-1930_tmin


Climate Space Trend
GYS - January
Minimum Temperature (°F)
Maximum Temperature (°F)
30
25
20
15
10
5
0
-5
-10
-15
-20
10
15
20
25
30
35
40
45
Jan_1900-1930_tmax vs Jan_1900-1930_tmin
Jan_1920-1950_tmax vs Jan_1920-1950_tmin

Climate Space Trend
GYS - January

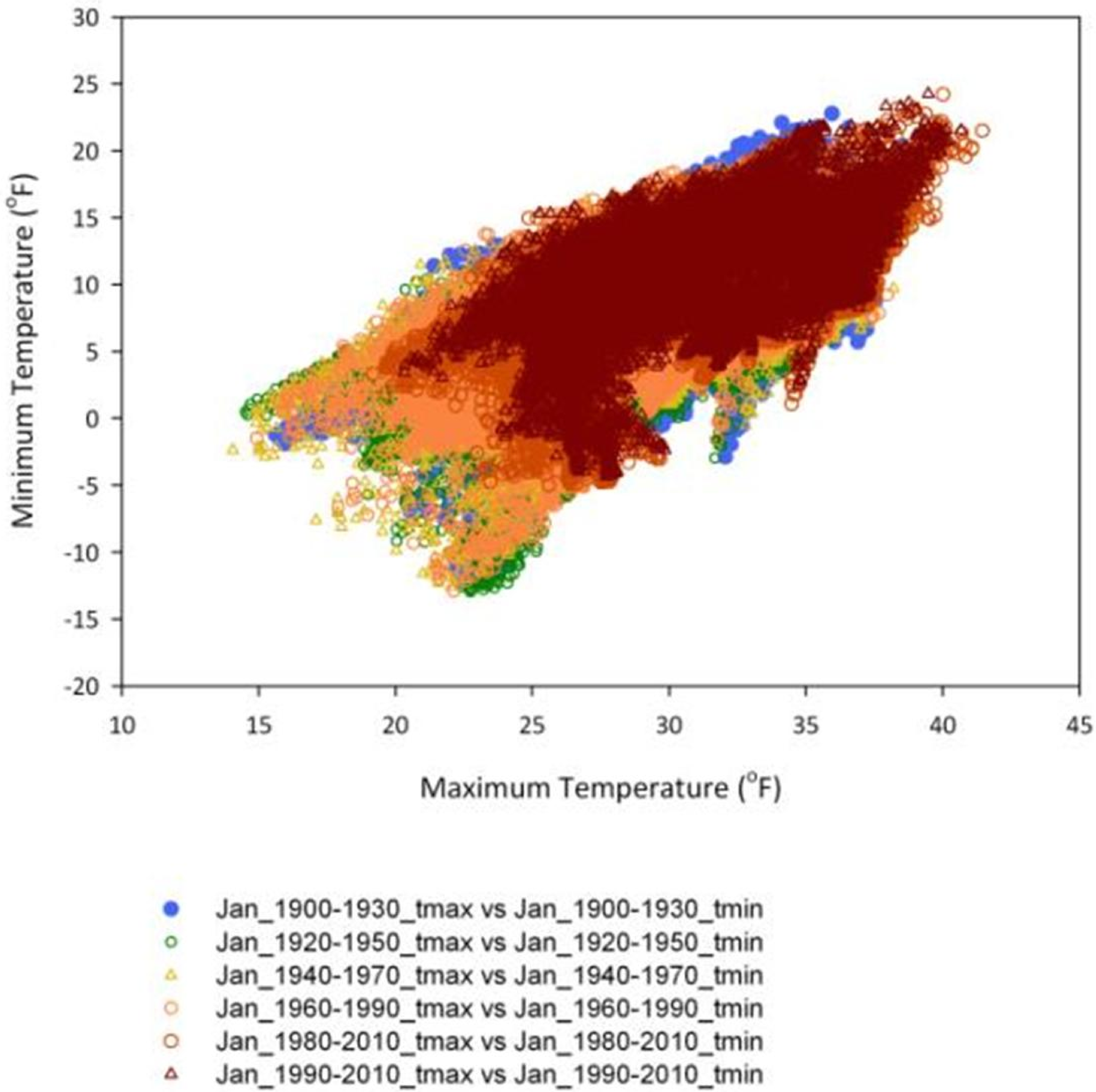


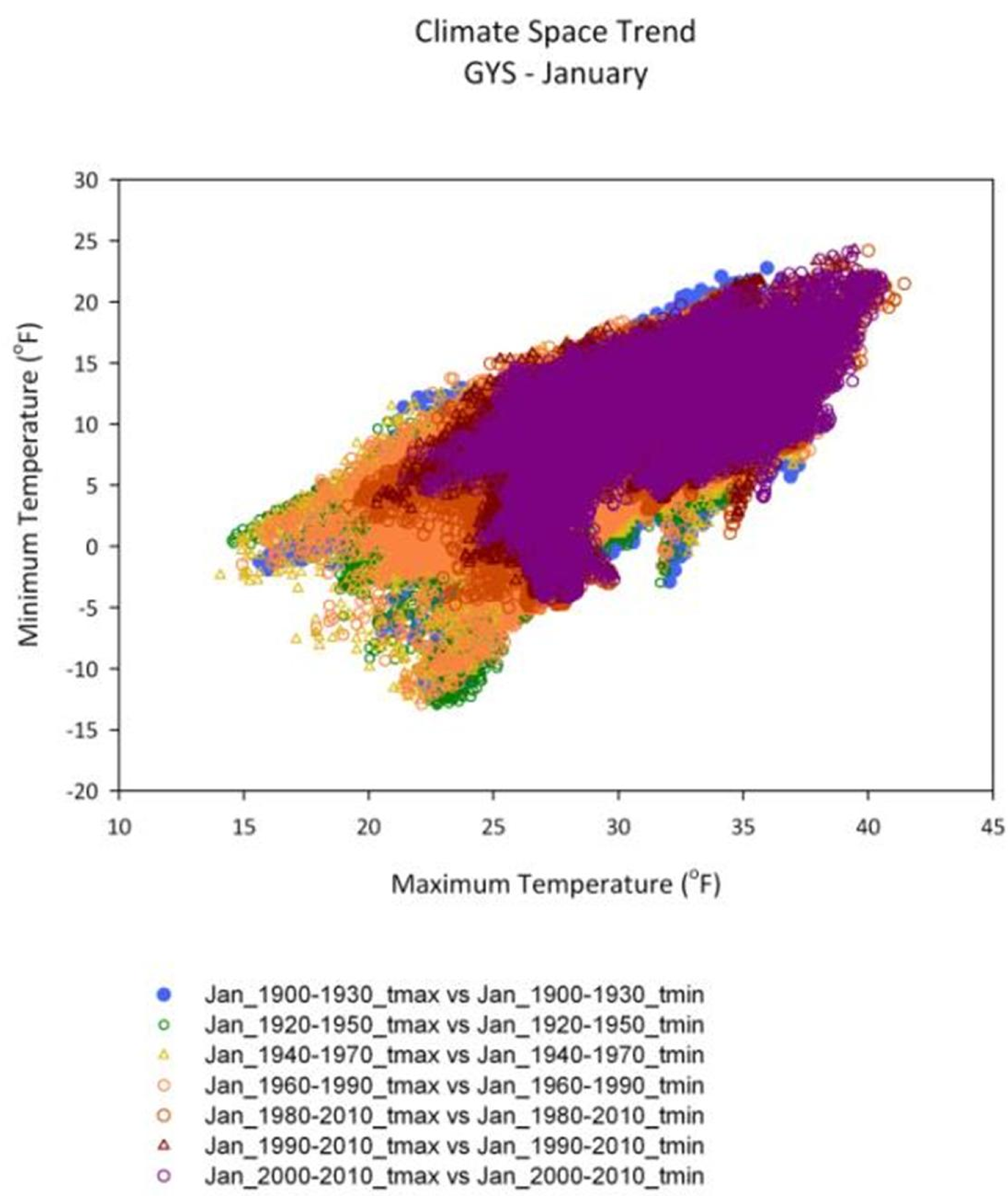

Climate Space Trend
GYS - January
Minimum Temperature (°F)
Maximum Temperature (°F)
30
25
20
15
10
5
0
-5
-10
-15
-20
10
15
20
25
30
35
40
45
Jan_1900-1930_tmax vs Jan_1900-1930_tmin
Jan_1920-1950_tmax vs Jan_1920-1950_tmin
Jan_1940-1970_tmax vs Jan_1940-1970_tmin
Jan_1960-1990_tmax vs Jan_1960-1990_tmin



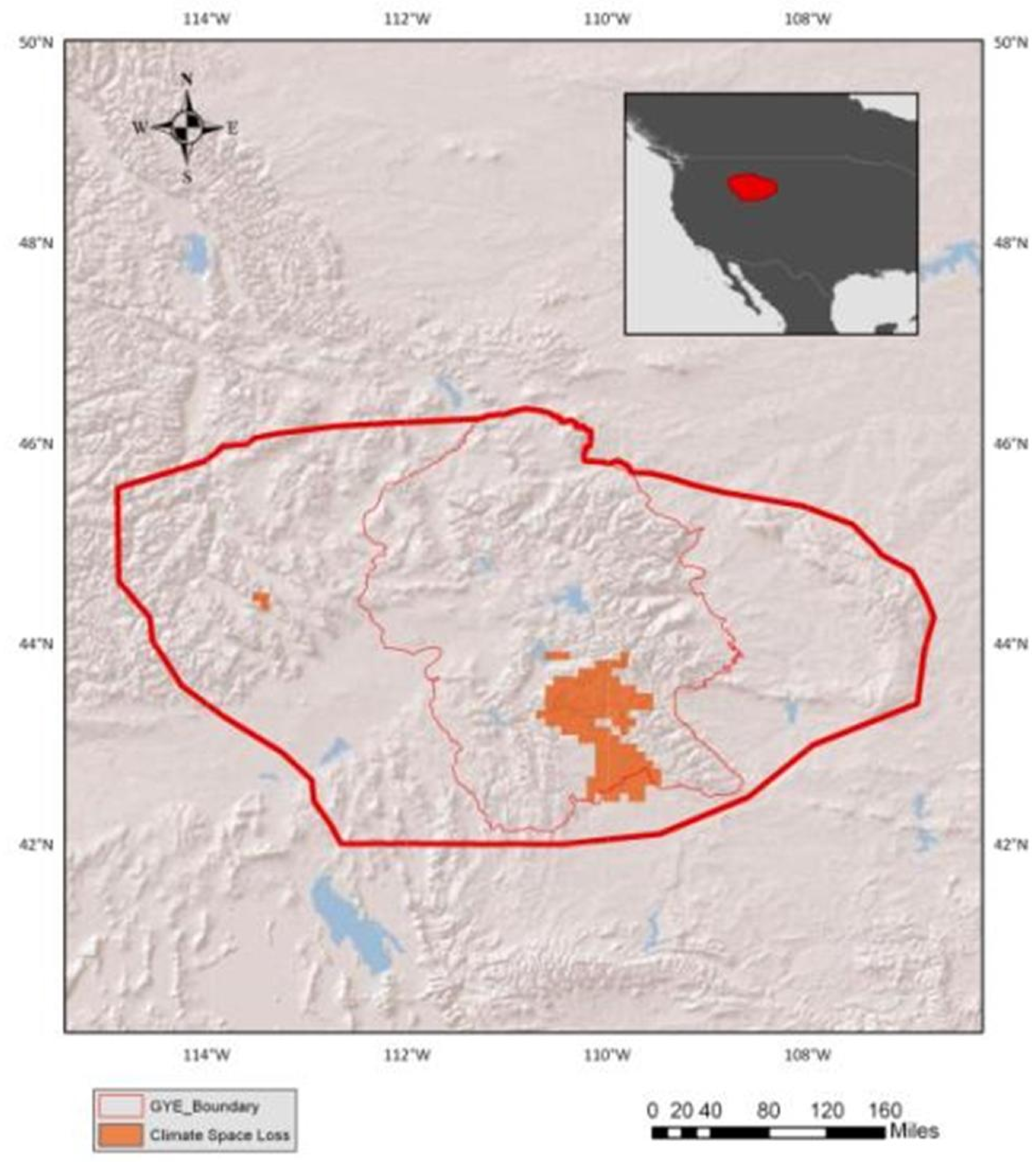
Climate Space Trend
GYS - January
Minimum Temperature (°F)
Maximum Temperature (°F)
30
25
20
15
10
5
0
-5
-10
-15
-20
10
15
20
25
30
35
40
45
Jan_1900-1930_tmax vs Jan_1900-1930_tmin
Jan_1920-1950_tmax vs Jan_1920-1950_tmin
Jan_1940-1970_tmax vs Jan_1940-1970_tmin
Jan_1960-1990_tmax vs Jan_1960-1990_tmin
Jan_1980-2010_tmax vs Jan_1980-2010_tmin

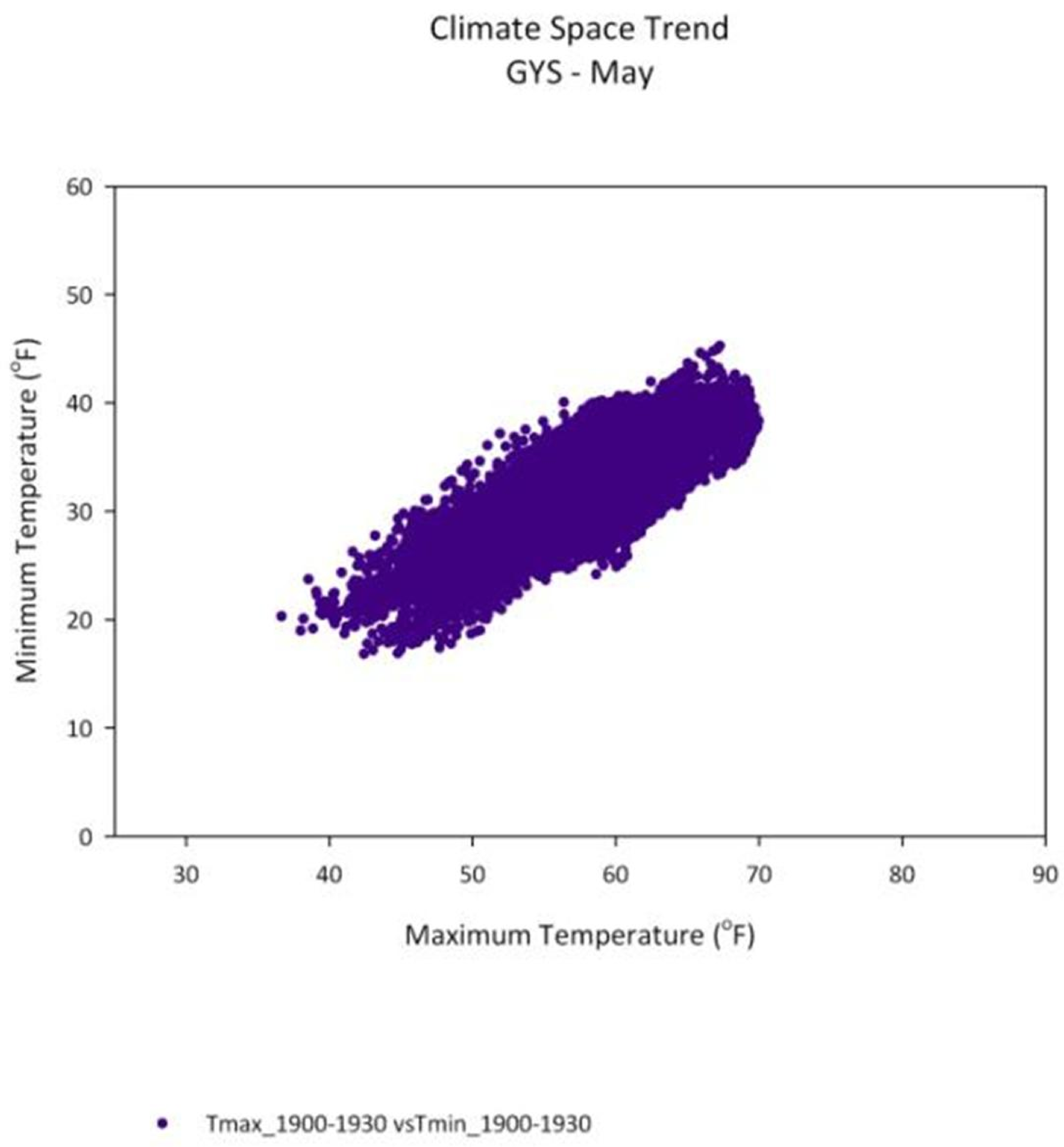
Climate Space Trend
GYS - January



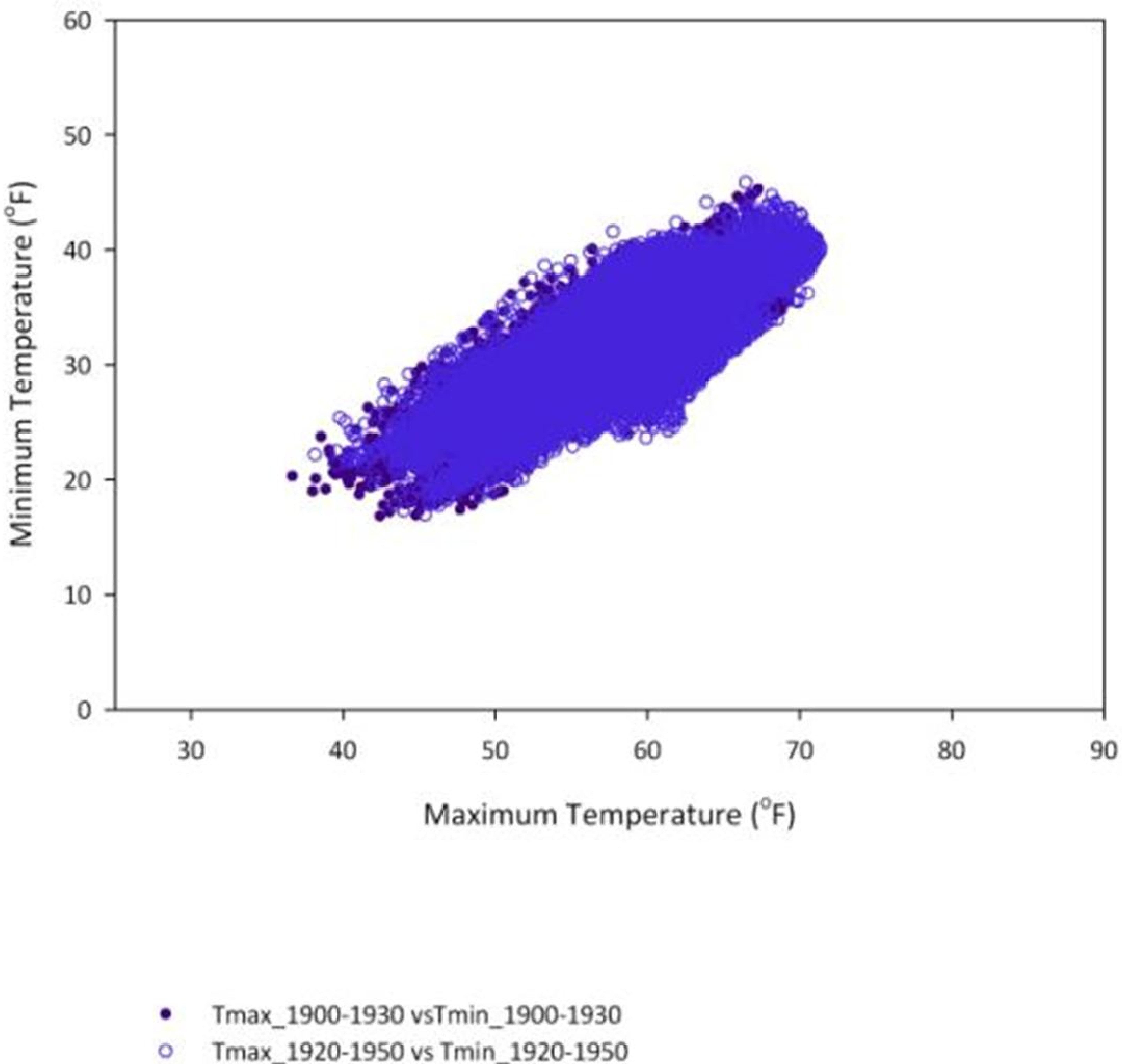

Climate Space Trend
GYS - January
Minimum Temperature (°F)
Maximum Temperature (°F)
30
25
20
15
10
5
0
-5
-10
-15
-20
10
15
20
25
30
35
40
45
Jan_1900-1930_tmax vs Jan_1900-1930_tmin
Jan_1920-1950_tmax vs Jan_1920-1950_tmin
Jan_1940-1970_tmax vs Jan_1940-1970_tmin
Jan_1960-1990_tmax vs Jan_1960-1990_tmin
Jan_1980-2010_tmax vs Jan_1980-2010_tmin
Jan_1990-2010_tmax vs Jan_1990-2010_tmin
Jan_2000-2010_tmax vs Jan_2000-2010_tmin

GYS
January Climate Space Loss
1920-1950 vs 1980-2010

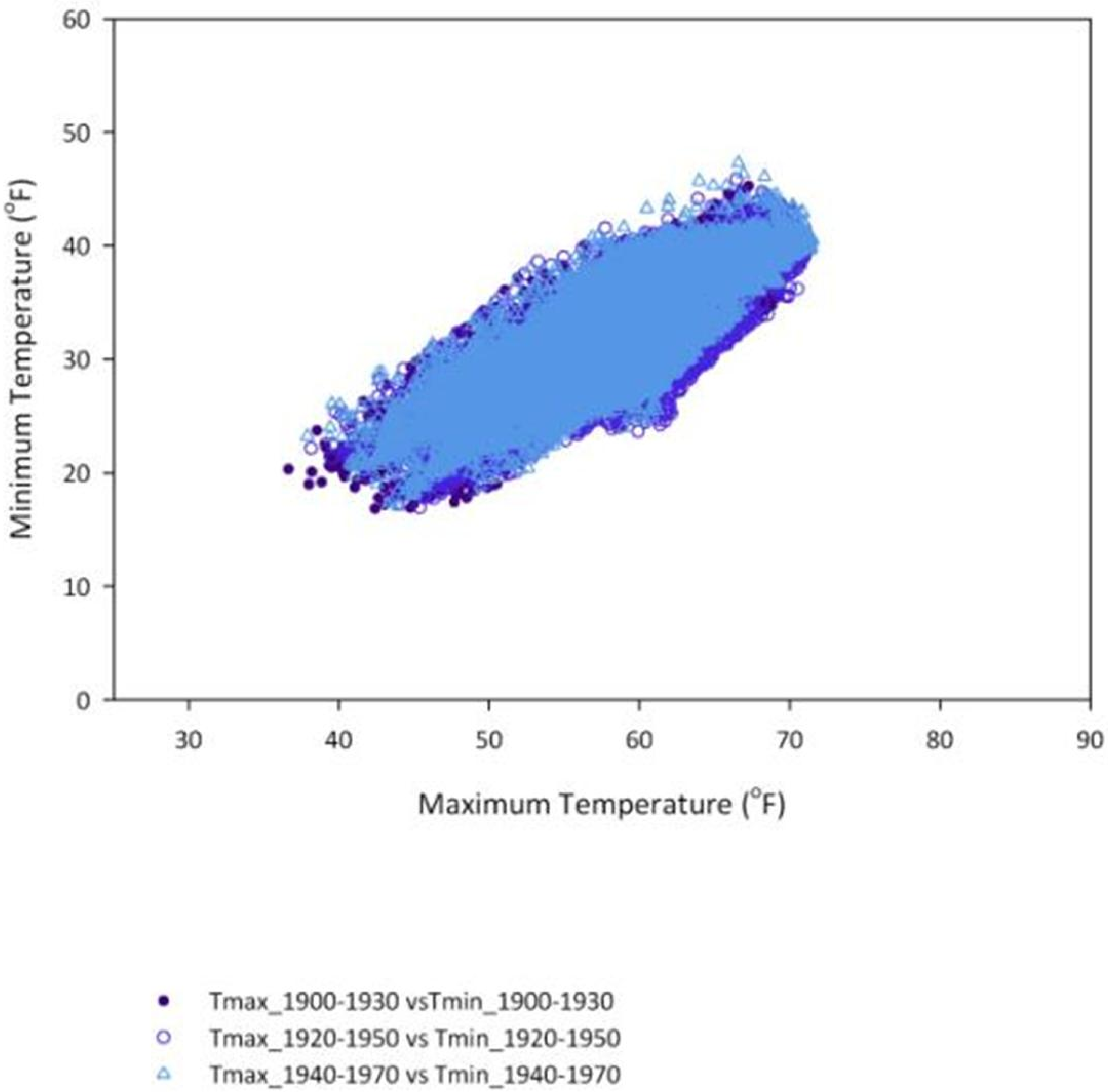



Climate Space Trend
GYS - May
Minimum Temperature (°F)
Maximum Temperature (°F)
0
10
20
30
40
50
60
30
40
50
60
70
80
90
Tmax_1900-1930 vsTmin_1900-1930

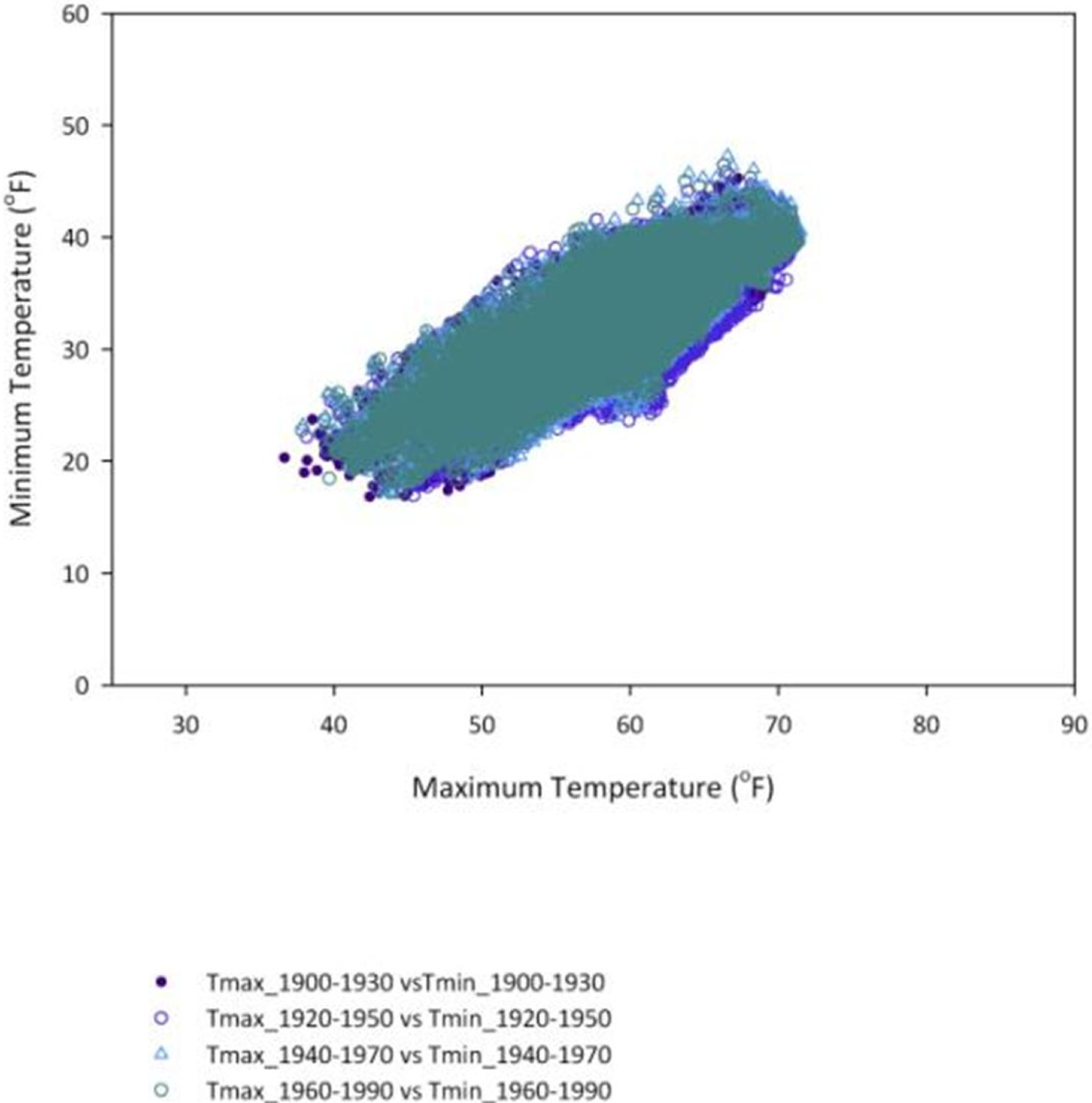
Climate Space Trend
GYS - May

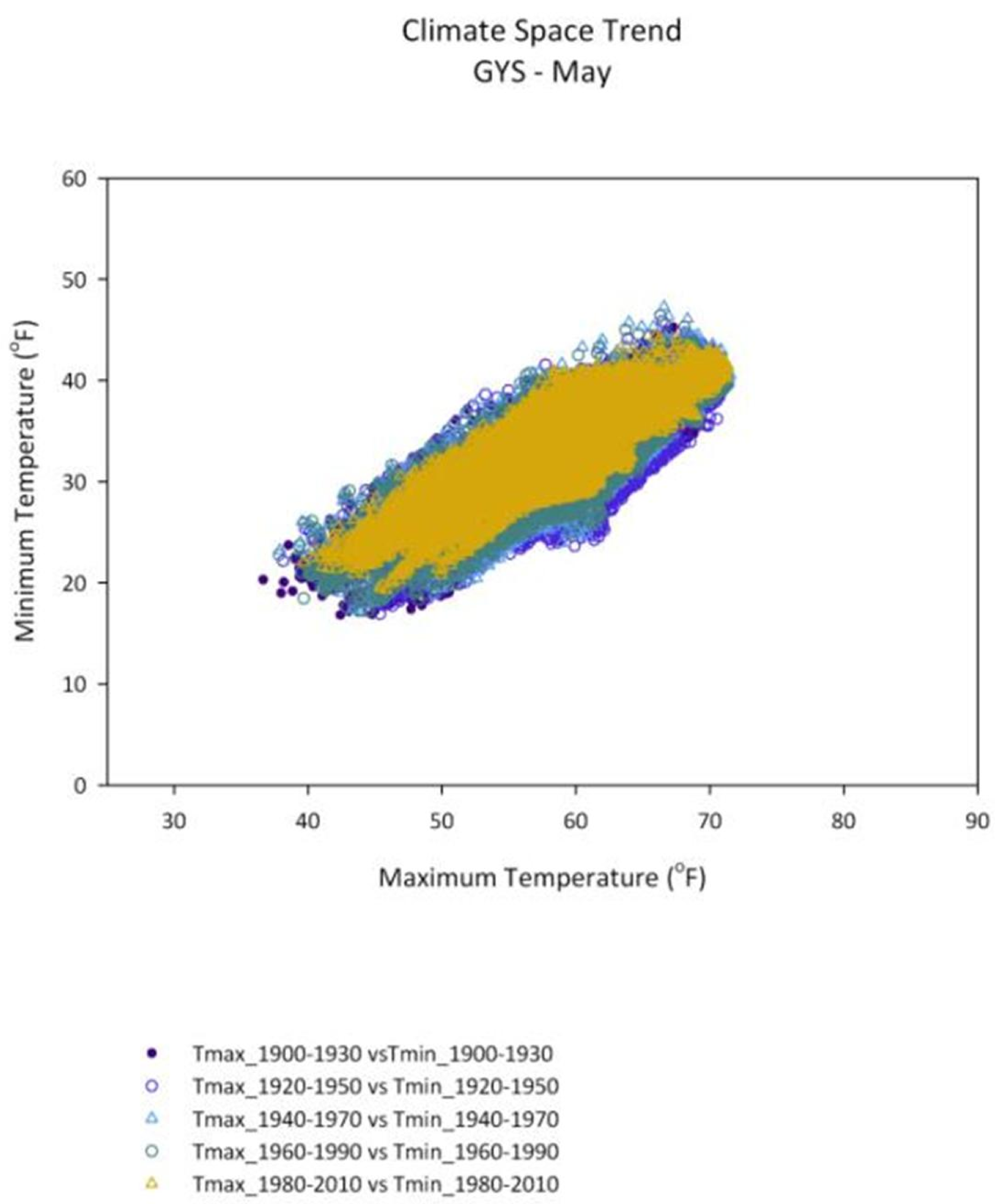


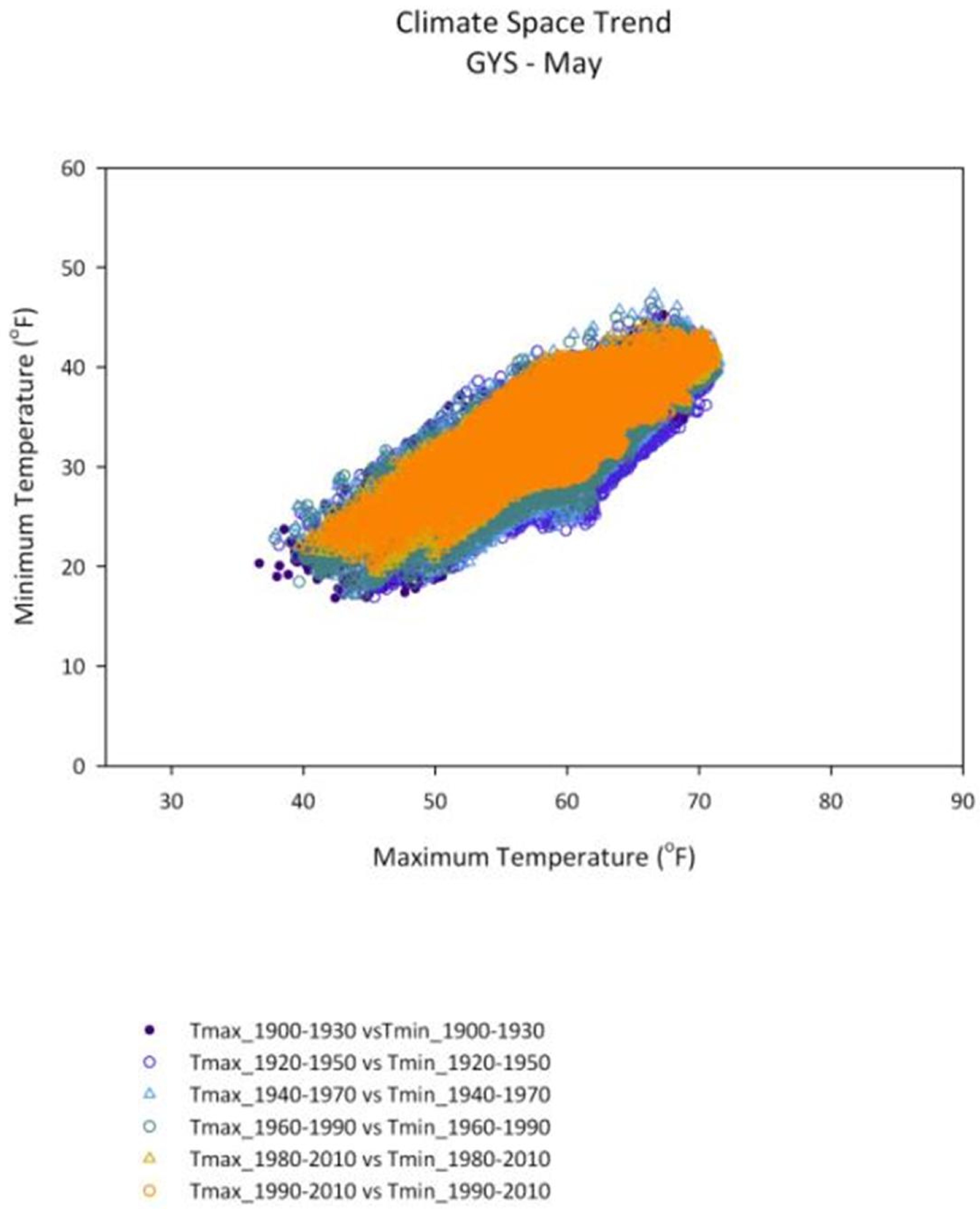
Climate Space Trend
GYS - May

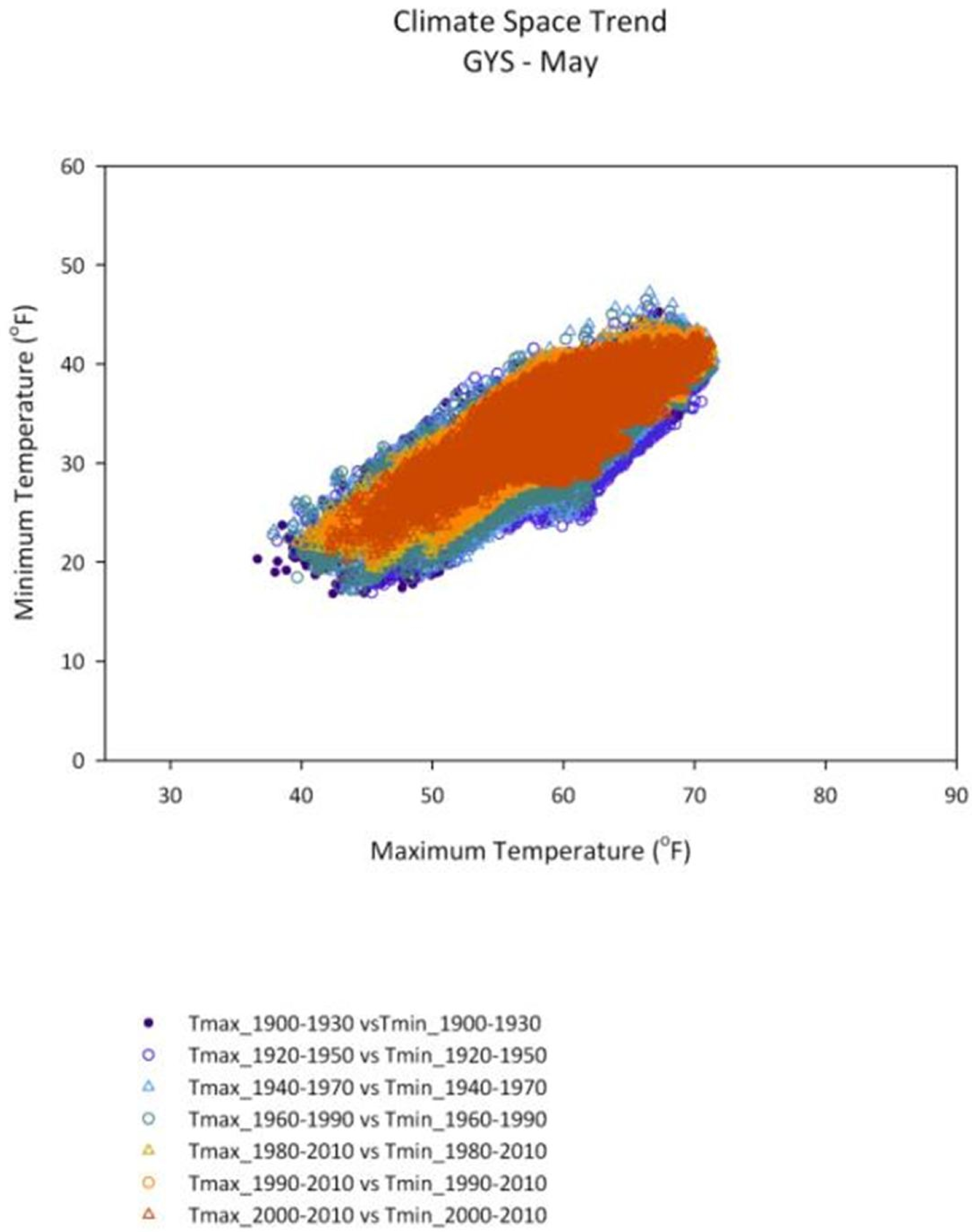


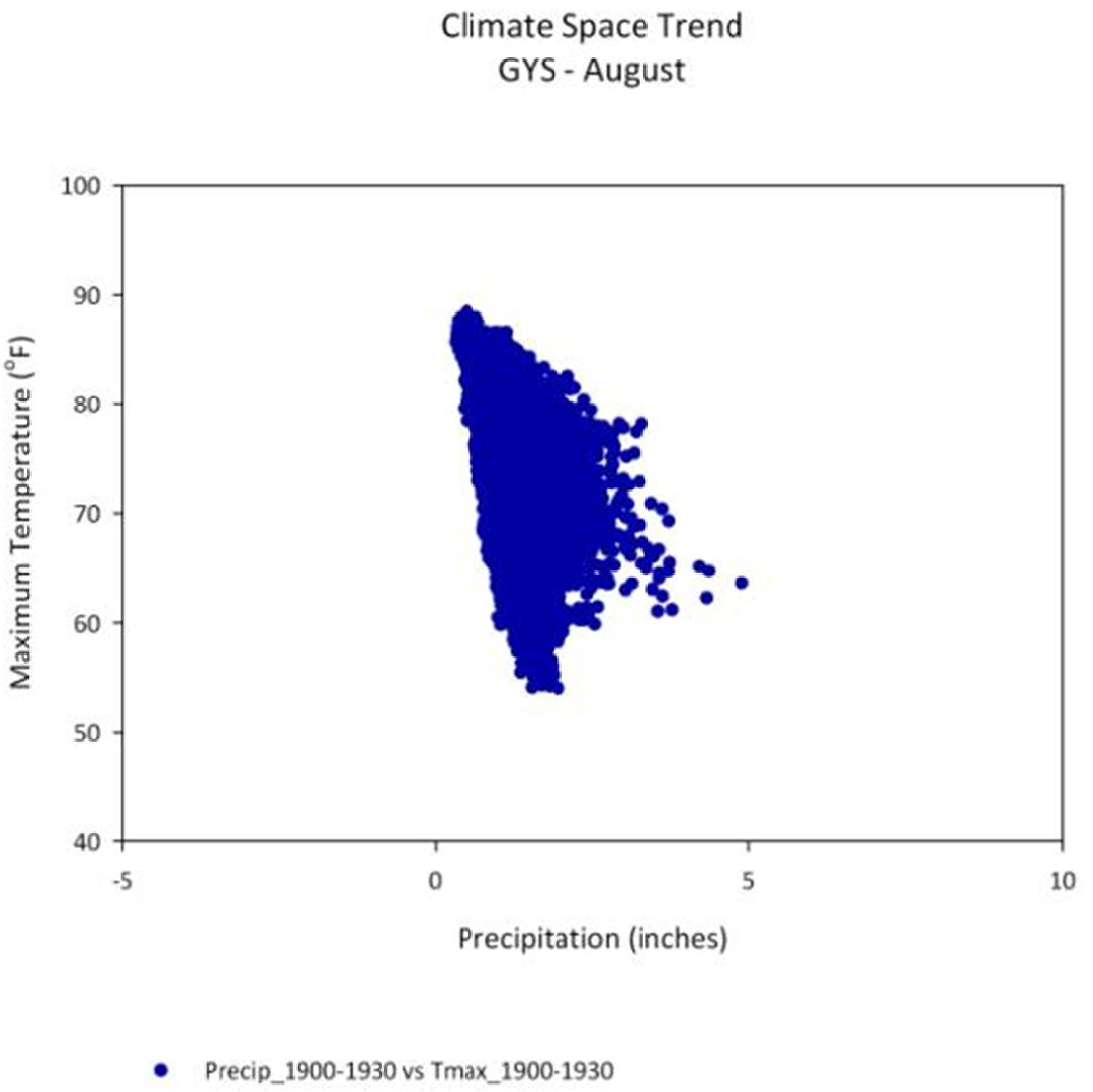
Climate Space Trend
GYS - May



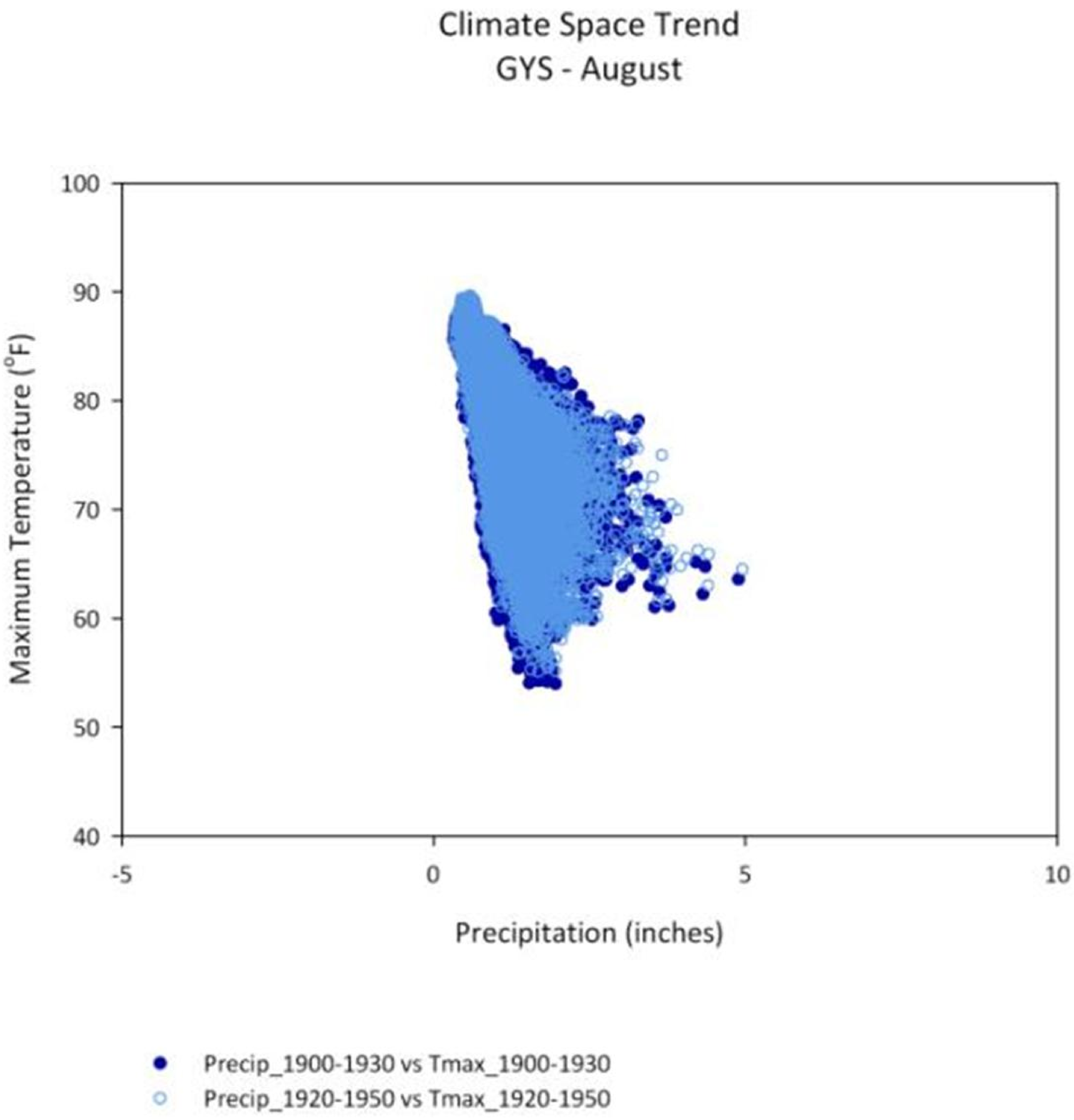

Climate Space Trend
GYS - May
Minimum Temperature (°F)
0
10
20
30
40
50
60
Maximum Temperature (°F)
30
40
50
60
70
80
90
Tmax_1900-1930 vsTmin_1900-1930
Tmax_1920-1950 vs Tmin_1920-1950
Tmax_1940-1970 vs Tmin_1940-1970
Tmax_1960-1990 vs Tmin_1960-1990
Tmax_1980-2010 vs Tmin_1980-2010

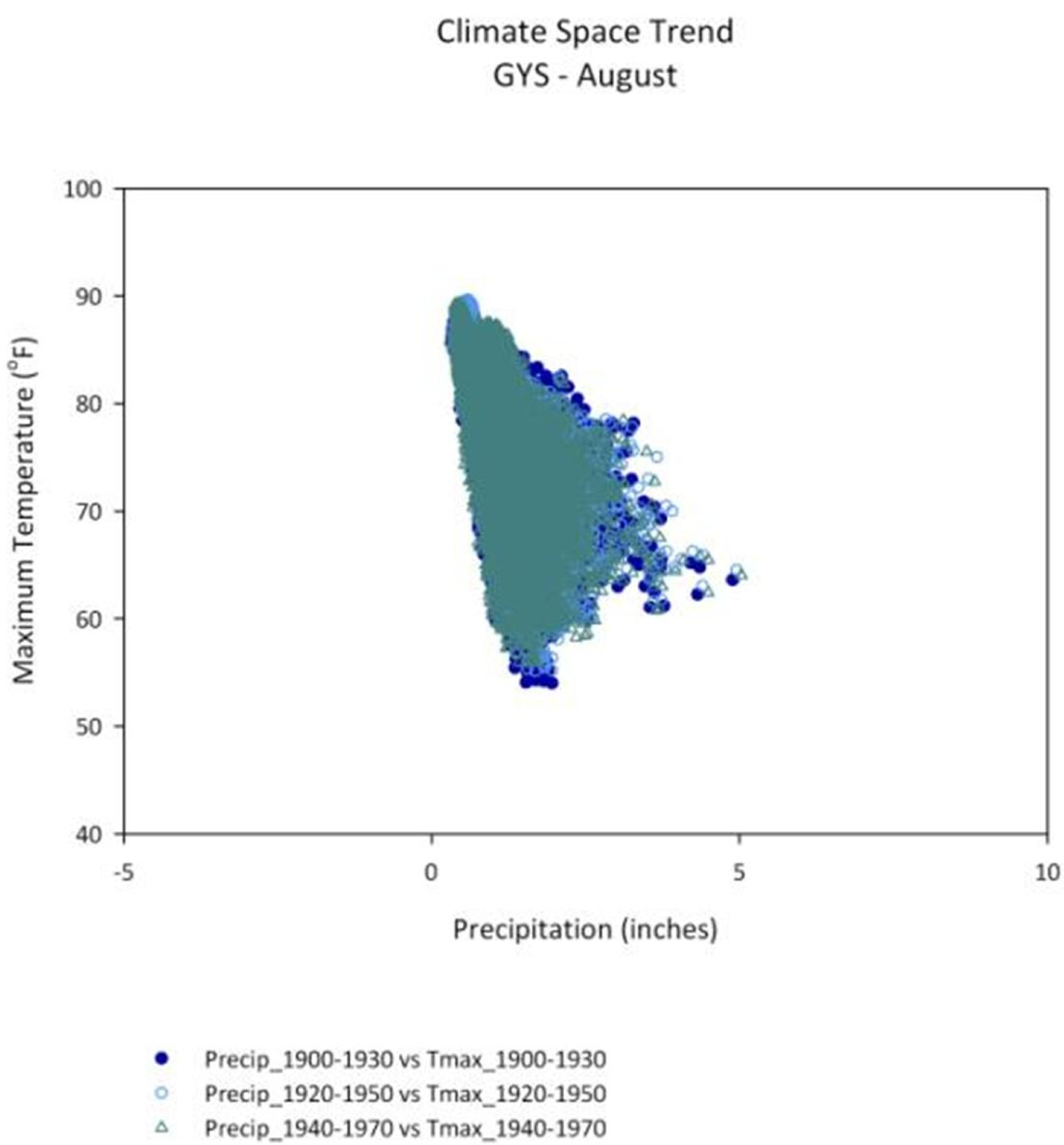

Climate Space Trend
GYS - May
Minimum Temperature (°F)
Maximum Temperature (°F)
60
50
40
30
20
10
0
30
40
50
60
70
80
90
Tmax_1900-1930 vsTmin_1900-1930
Tmax_1920-1950 vs Tmin_1920-1950
Tmax_1940-1970 vs Tmin_1940-1970
Tmax_1960-1990 vs Tmin_1960-1990
Tmax_1980-2010 vs Tmin_1980-2010
Tmax_1990-2010 vs Tmin_1990-2010


Climate Space Trend
GYS - May
60
50
40
30
20
10
0
30
40
50
60
70
80
90
Minimum Temperature (°F)
Maximum Temperature (°F)
Tmax_1900-1930 vsTmin_1900-1930
Tmax_1920-1950 vs Tmin_1920-1950
Tmax_1940-1970 vs Tmin_1940-1970
Tmax_1960-1990 vs Tmin_1960-1990
Tmax_1980-2010 vs Tmin_1980-2010
Tmax_1990-2010 vs Tmin_1990-2010
Tmax_2000-2010 vs Tmin_2000-2010



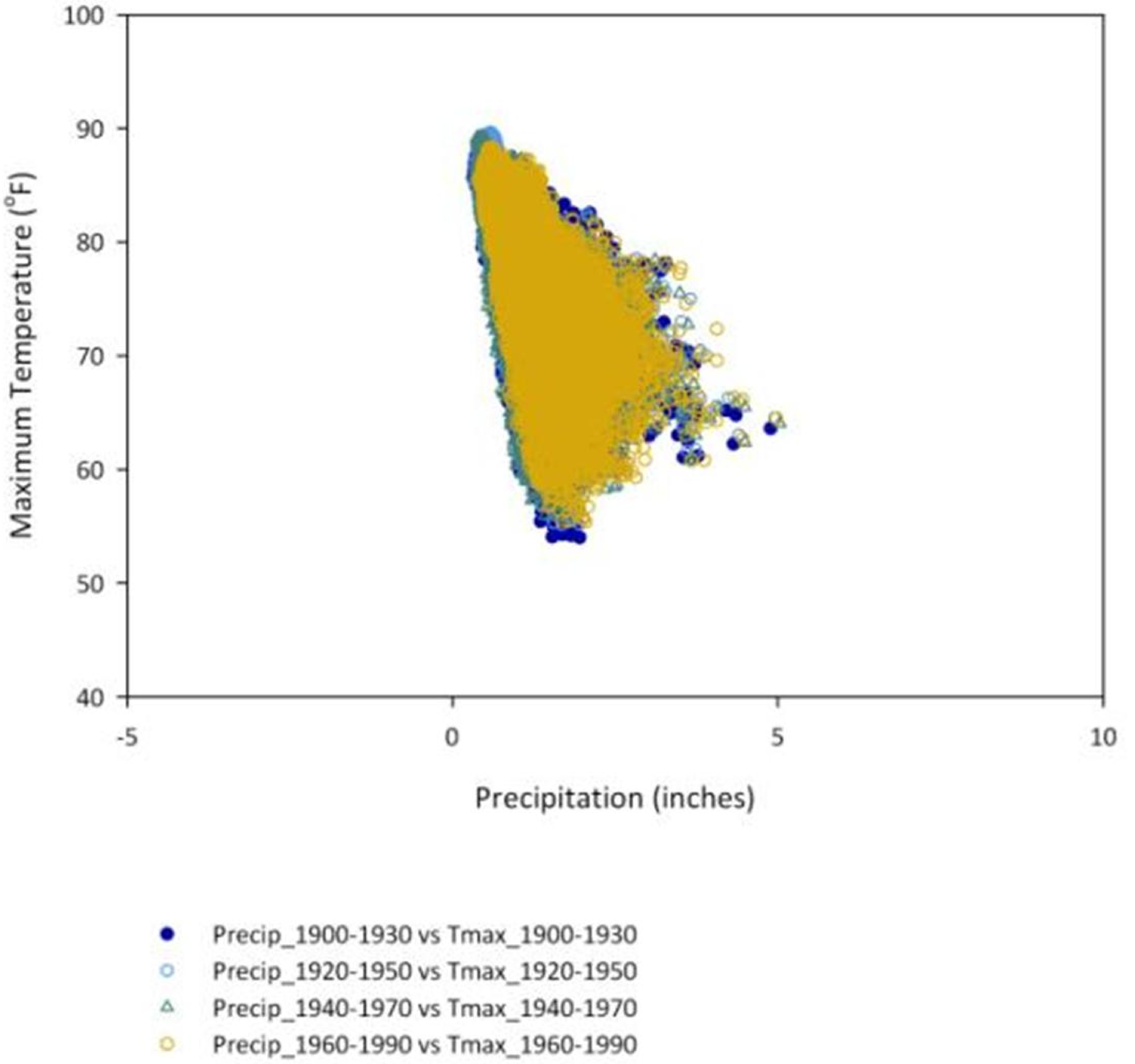
Climate Space Trend
GYS - August
Maximum Temperature (°F)
100
90
80
70
60
50
40
-5
0
5
10
Precipitation (inches)
Precip_1900-1930 vs Tmax_1900-1930

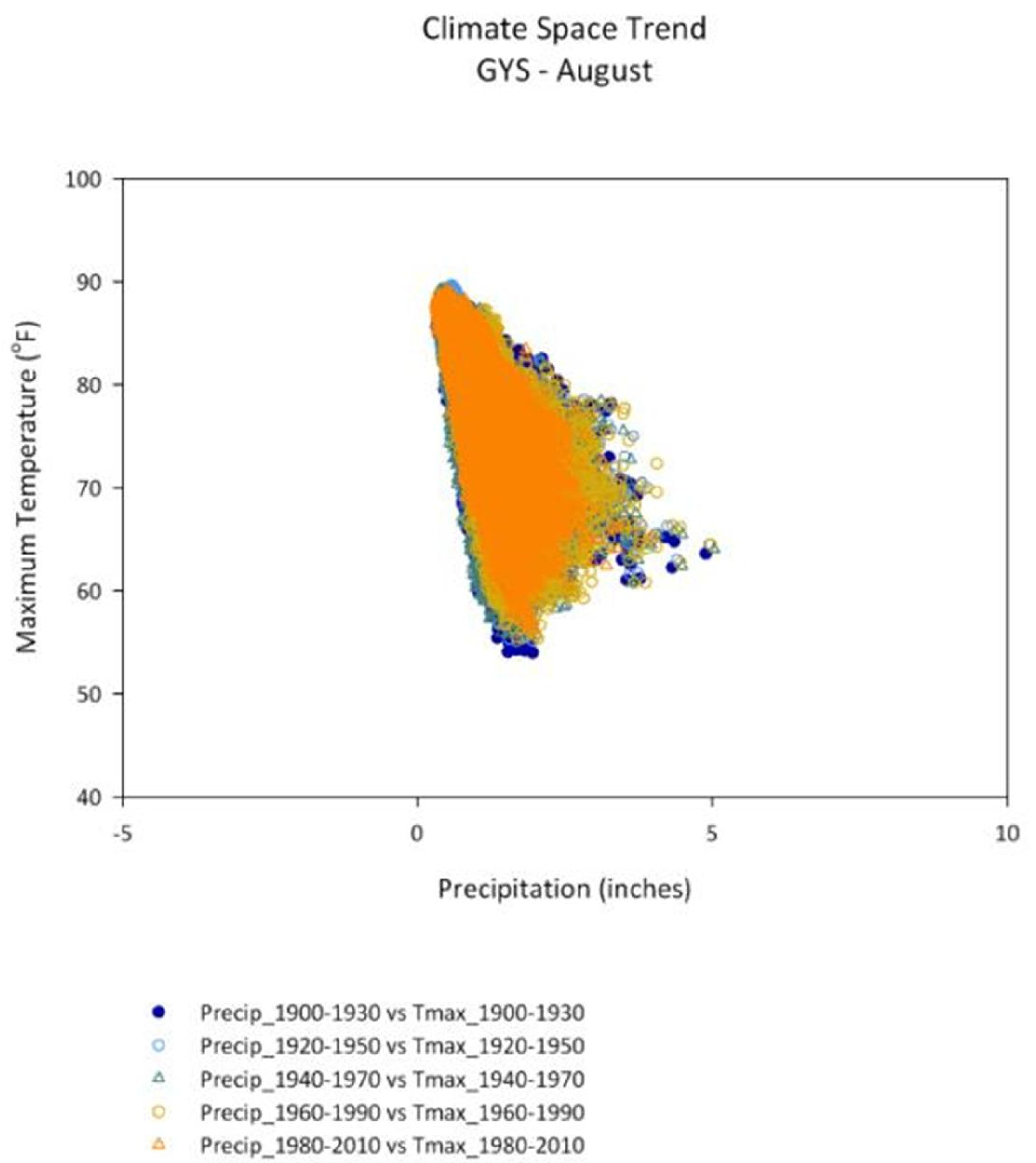

Climate Space Trend
GYS - August
Maximum Temperature (°F)
100
90
80
70
60
50
40
-5
0
5
10
Precipitation (inches)
Precip_1900-1930 vs Tmax_1900-1930
Precip_1920-1950 vs Tmax_1920-1950



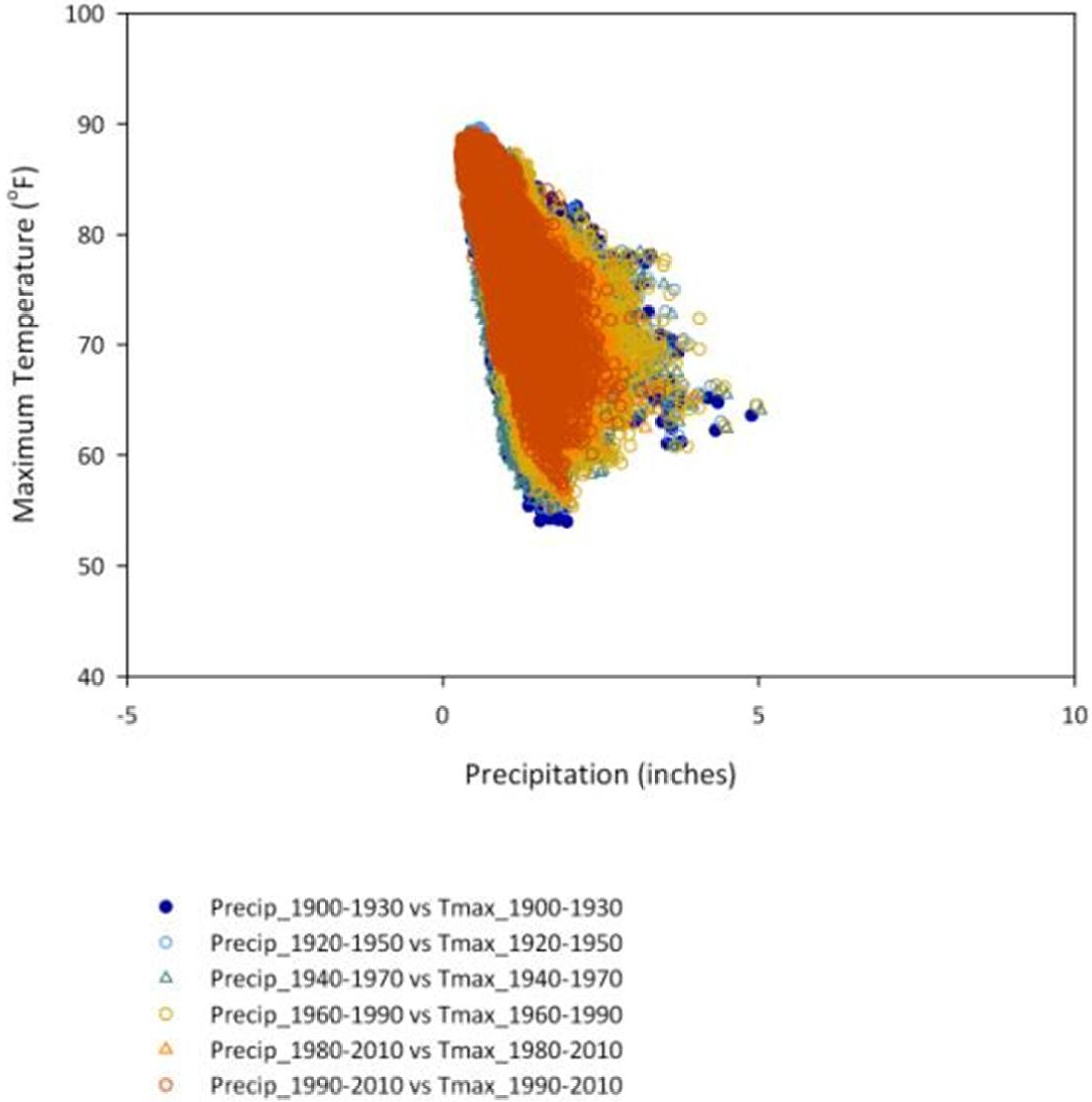
Climate Space Trend
GYS - August
Maximum Temperature (°F)
100
90
80
70
60
50
40
-5
0
5
10
Precipitation (inches)
Precip_1900-1930 vs Tmax_1900-1930
Precip_1920-1950 vs Tmax_1920-1950
Precip_1940-1970 vs Tmax_1940-1970

Climate Space Trend
GYS - August

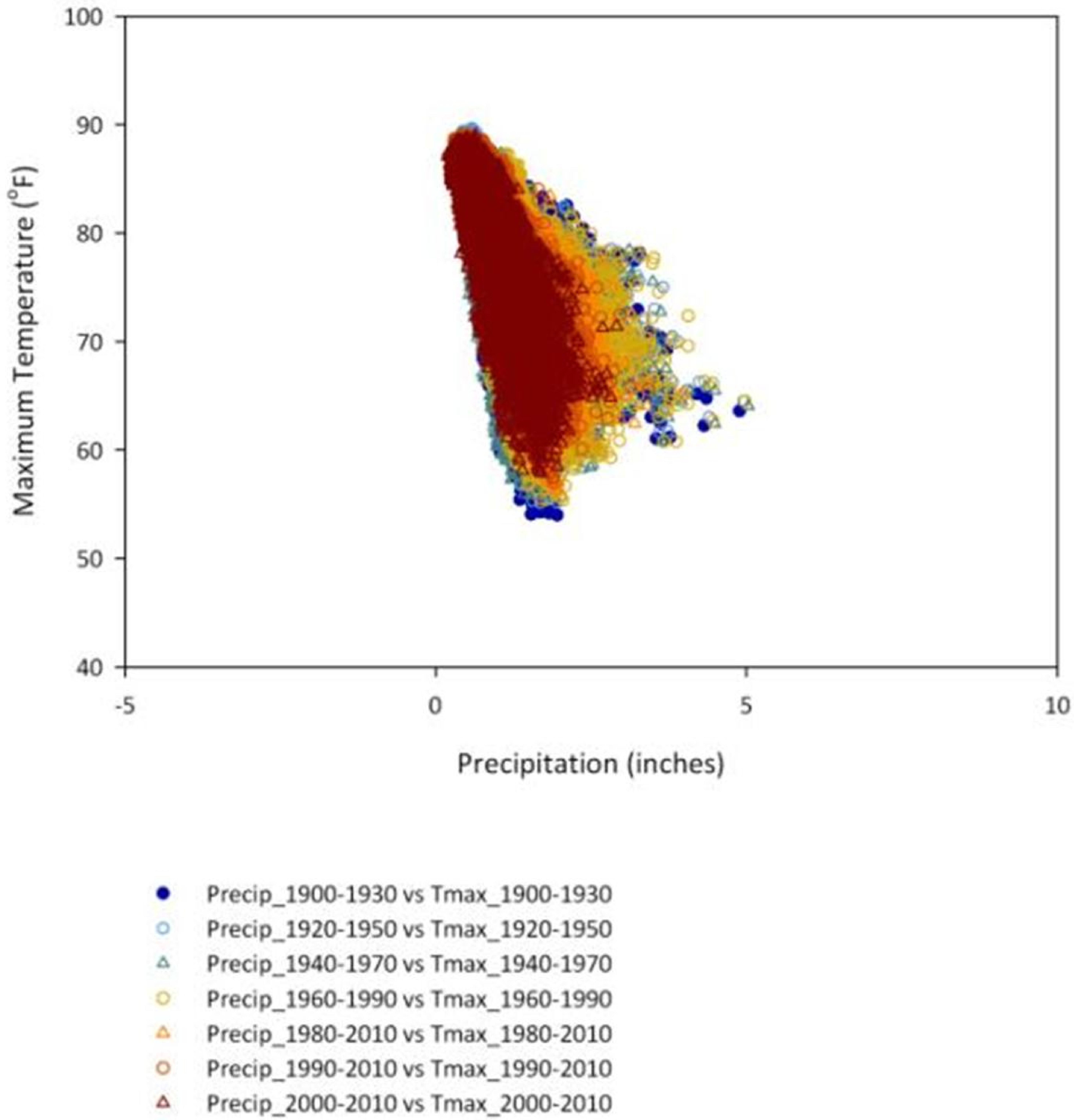


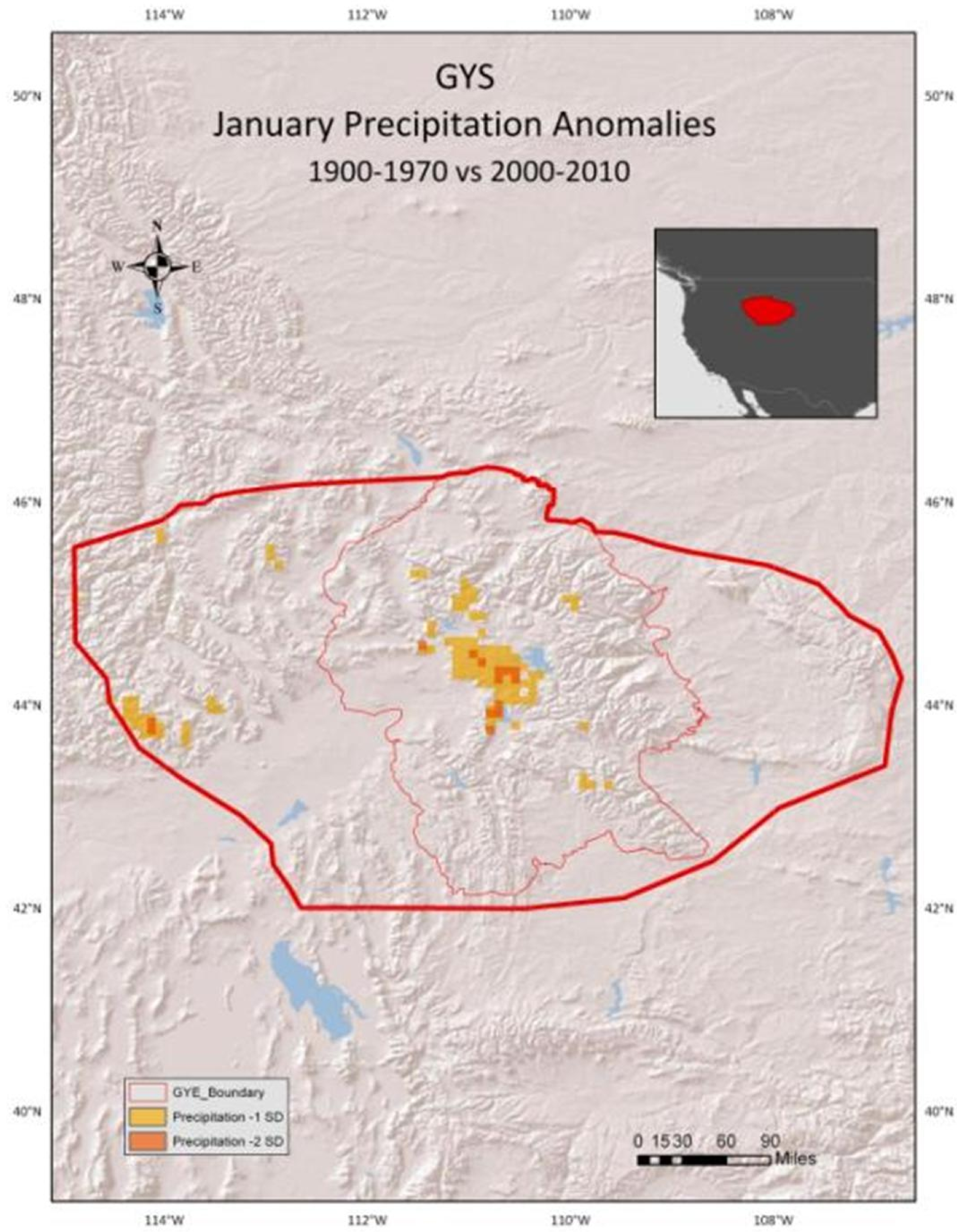

Climate Space Trend
GYS - August
Maximum Temperature (°F)
100
90
80
70
60
50
40
-5
0
5
10
Precipitation (inches)
Precip_1900-1930 vs Tmax_1900-1930
Precip_1920-1950 vs Tmax_1920-1950
Precip_1940-1970 vs Tmax_1940-1970
Precip_1960-1990 vs Tmax_1960-1990
Precip_1980-2010 vs Tmax_1980-2010

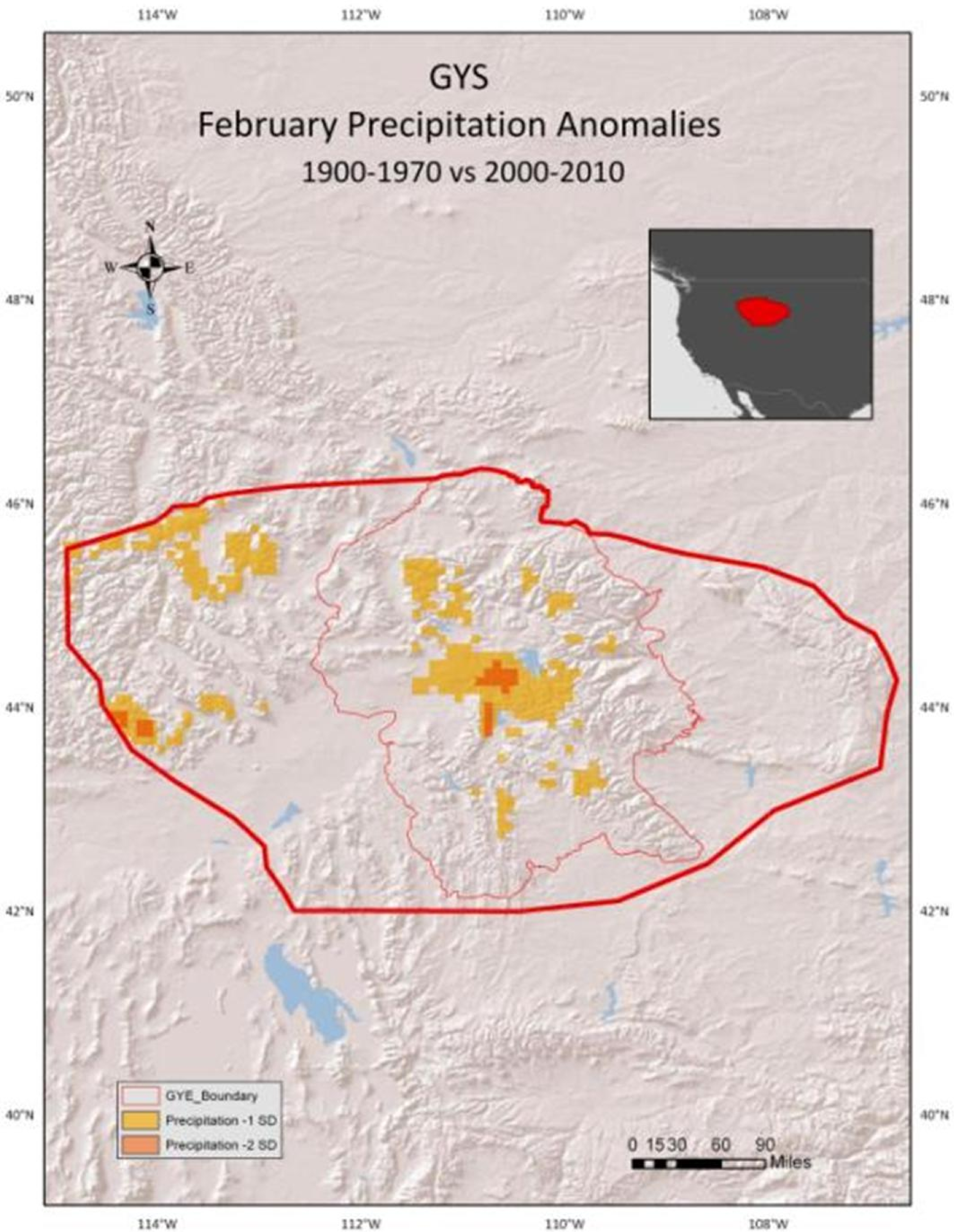
Climate Space Trend
GYS - August



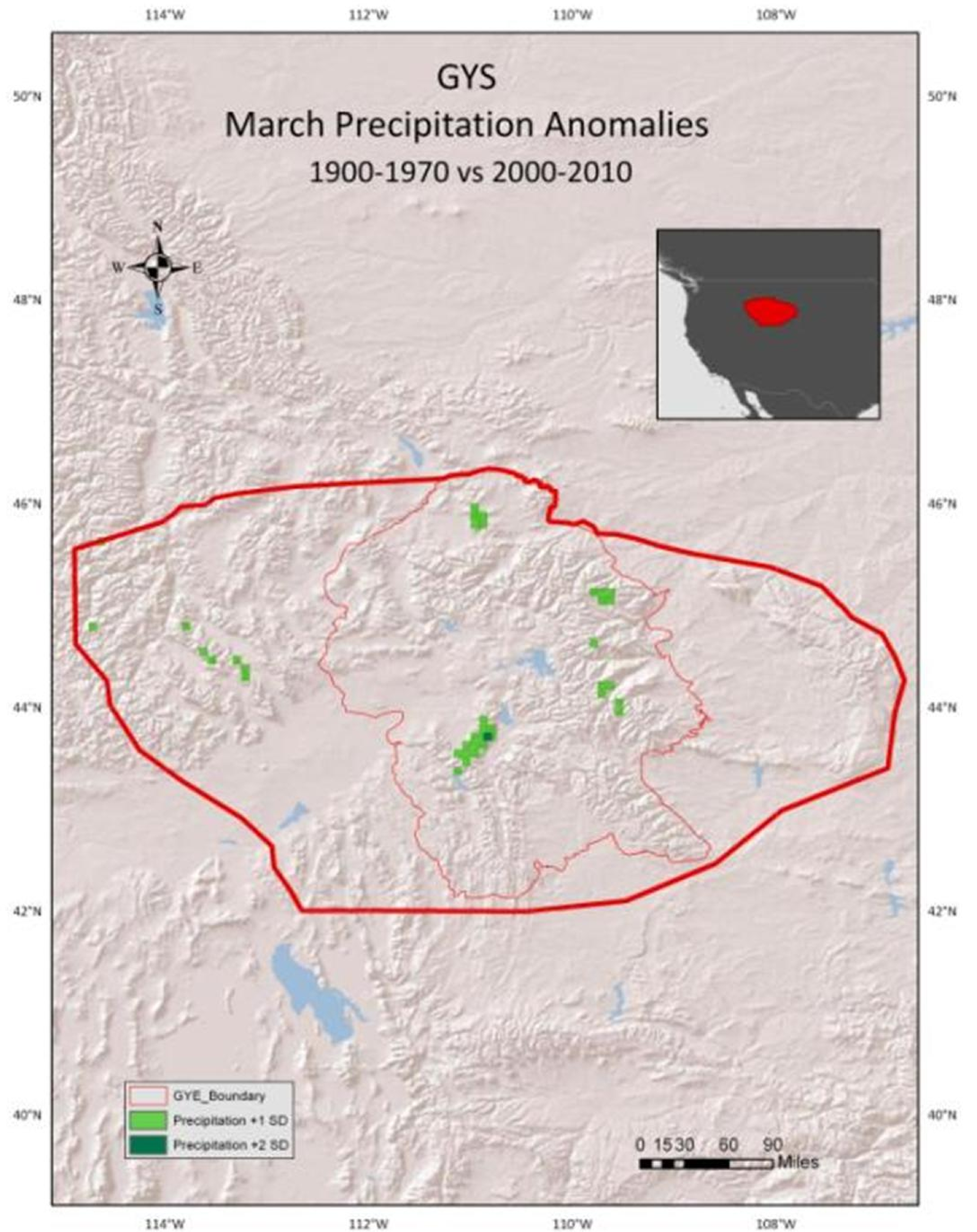
Climate Space Trend
GYS - August



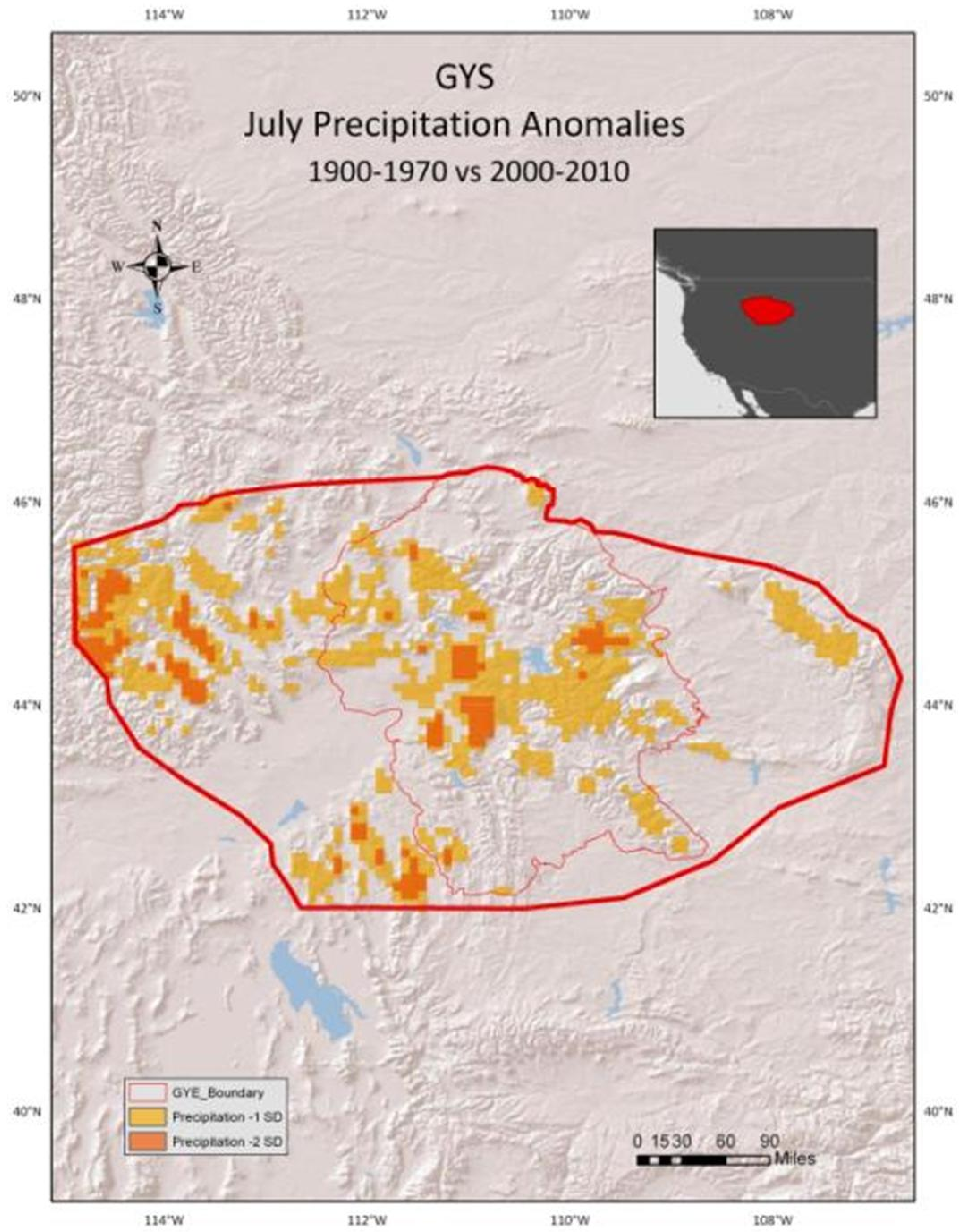

GYS
January Precipitation Anomalies
1900-1970 vs 2000-2010
114°W
112°W
110°W
108°W
50°N
48°N
46°N
44°N
42°N
40°N
N
S
E
W
GYE_Boundary
Precipitation -1 SD
Precipitation -2 SD
0 15 30 60 90
Miles



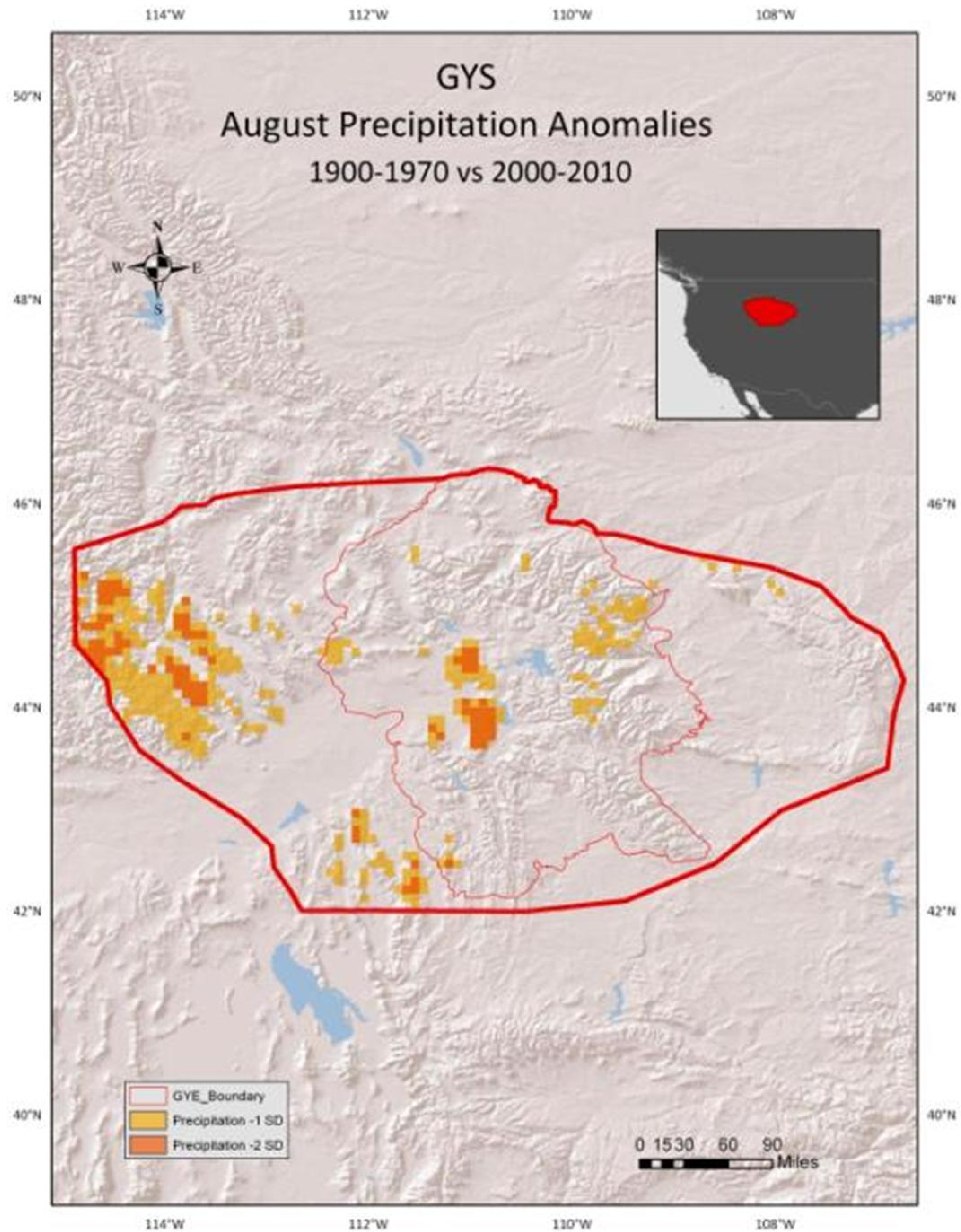
GYS
February Precipitation Anomalies
1900-1970 vs 2000-2010
114°W
112°W
110°W
108°W
50°N
48°N
46°N
44°N
42°N
40°N
N
S
E
W
GYE_Boundary
Precipitation -1 SD
Precipitation -2 SD
0 15 30 60 90
Miles



GYS
March Precipitation Anomalies
1900-1970 vs 2000-2010
114°W
112°W
110°W
108°W
50°N
48°N
46°N
44°N
42°N
40°N
N
S
E
W
GYE_Boundary
Precipitation +1 SD
Precipitation +2 SD
0 15 30 60 90
Miles



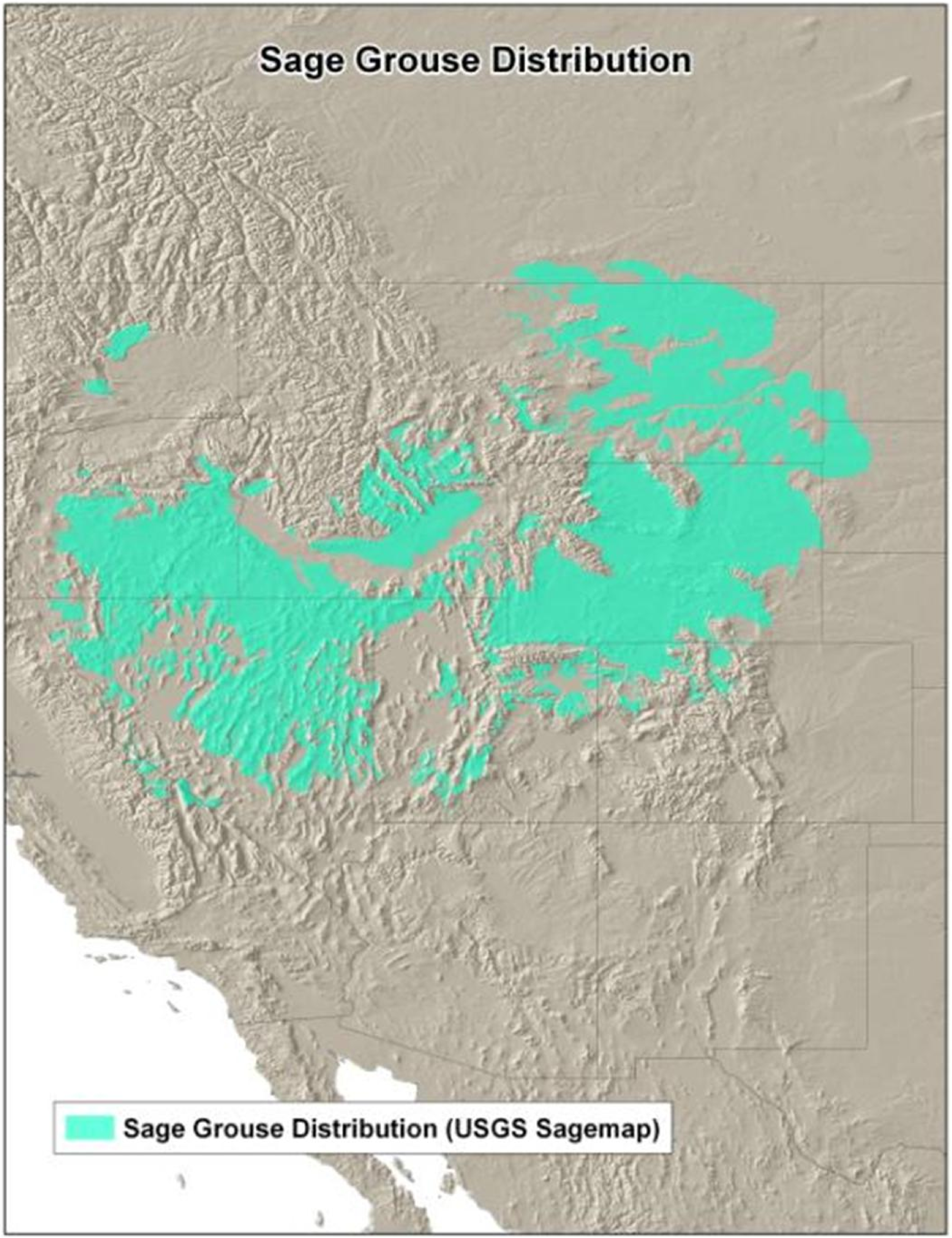
GYS
July Precipitation Anomalies
1900-1970 vs 2000-2010
114°W
112°W
110°W
108°W
50°N
48°N
46°N
44°N
42°N
40°N
N
S
W
E
GYE_Boundary
Precipitation -1 SD
Precipitation -2 SD
0 15 30 60 90
Miles

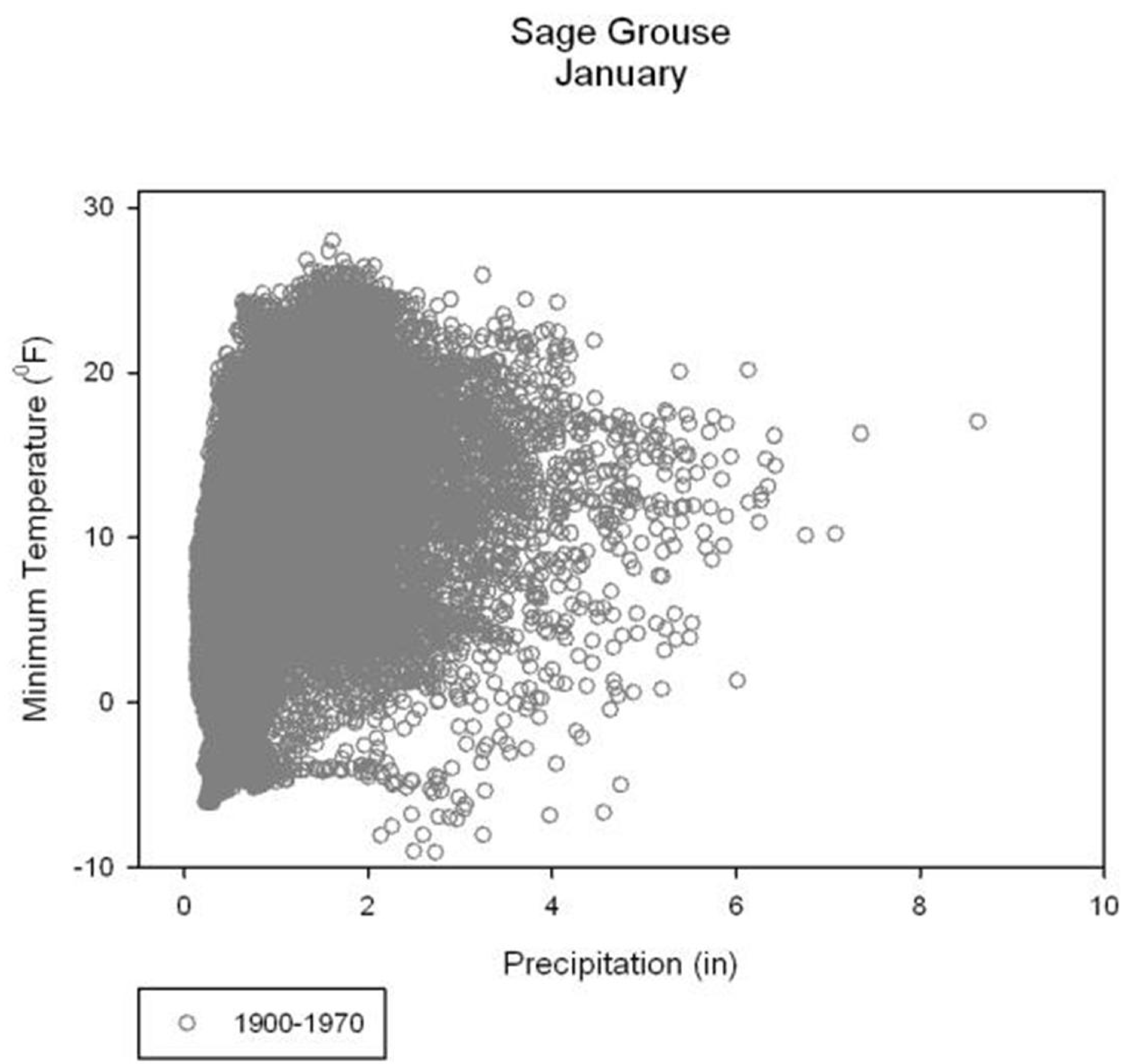


GYS
August Precipitation Anomalies
1900-1970 vs 2000-2010
114°W
112°W
110°W
108°W
50°N
48°N
46°N
44°N
42°N
40°N
N
S
W
E
GYE_Boundary
Precipitation -1 SD
Precipitation -2 SD
0 15 30 60 90
Miles

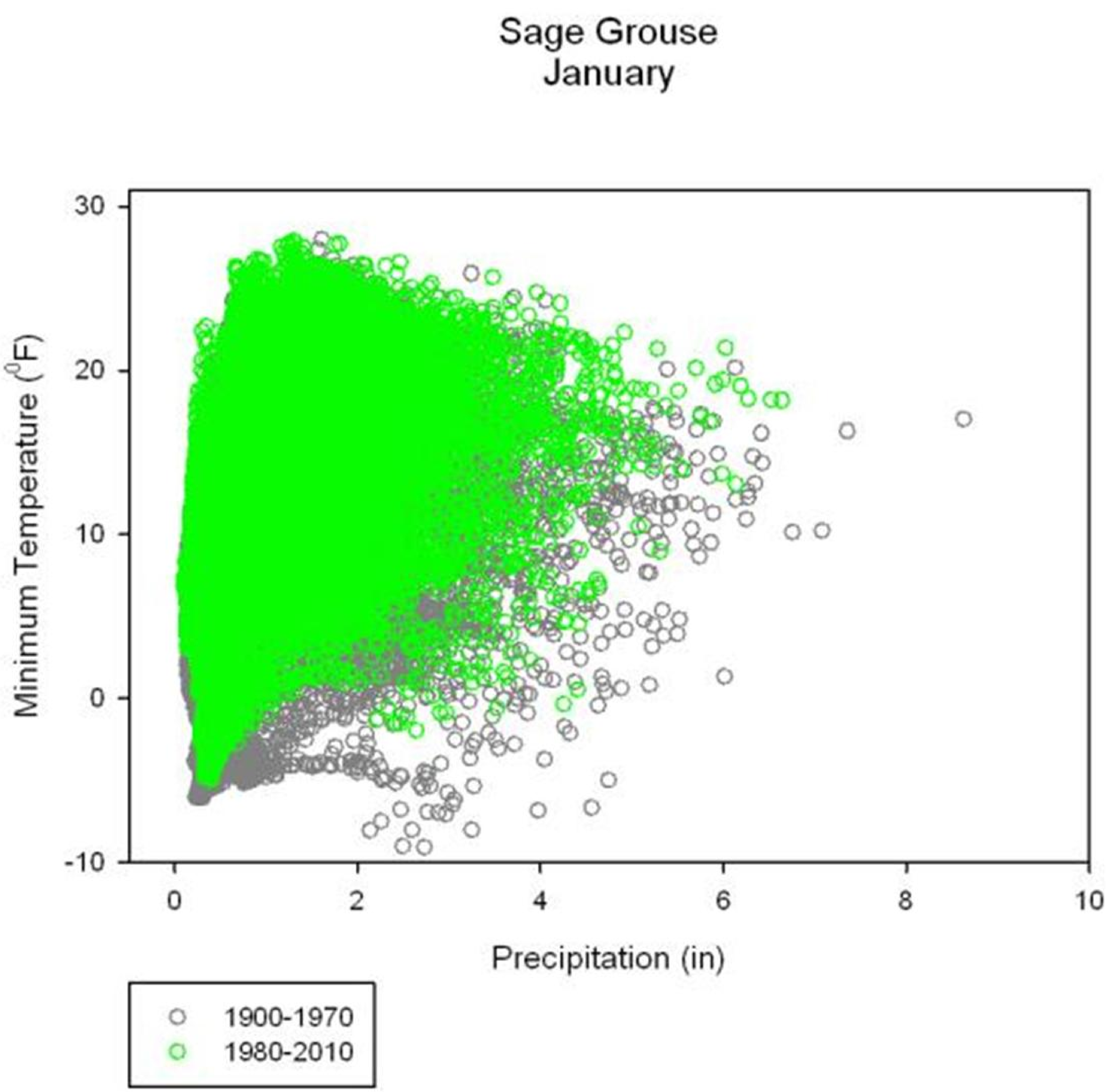
Sage Grouse

Recent Climate Space Trends

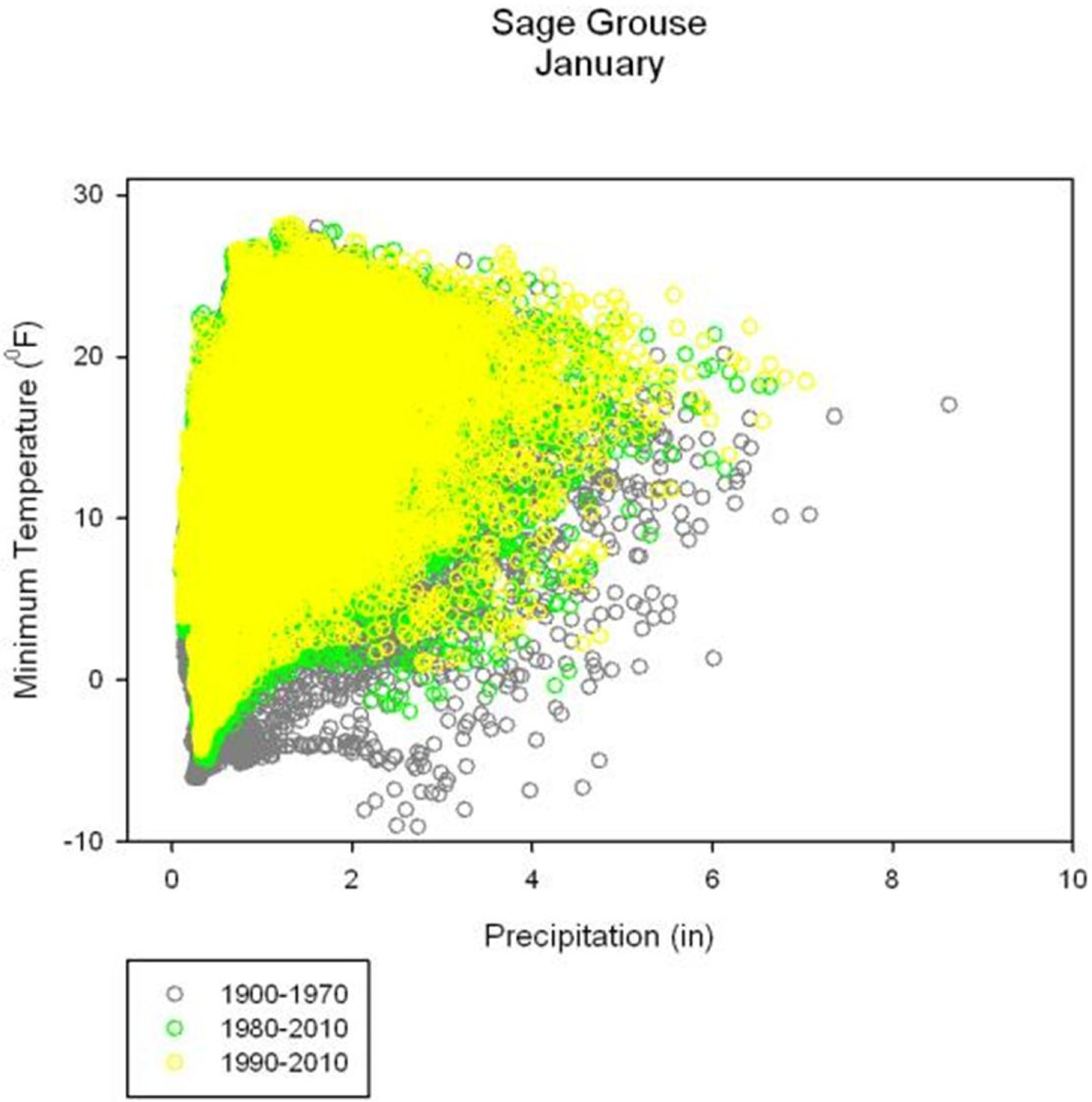

Sage Grouse Distribution
Sage Grouse Distribution (USGS Sagemap)



Sage Grouse
January
30
20
10
0
-10
Minimum Temperature (⁰F)
0
2
4
6
8
10
Precipitation (in)
1900-1970

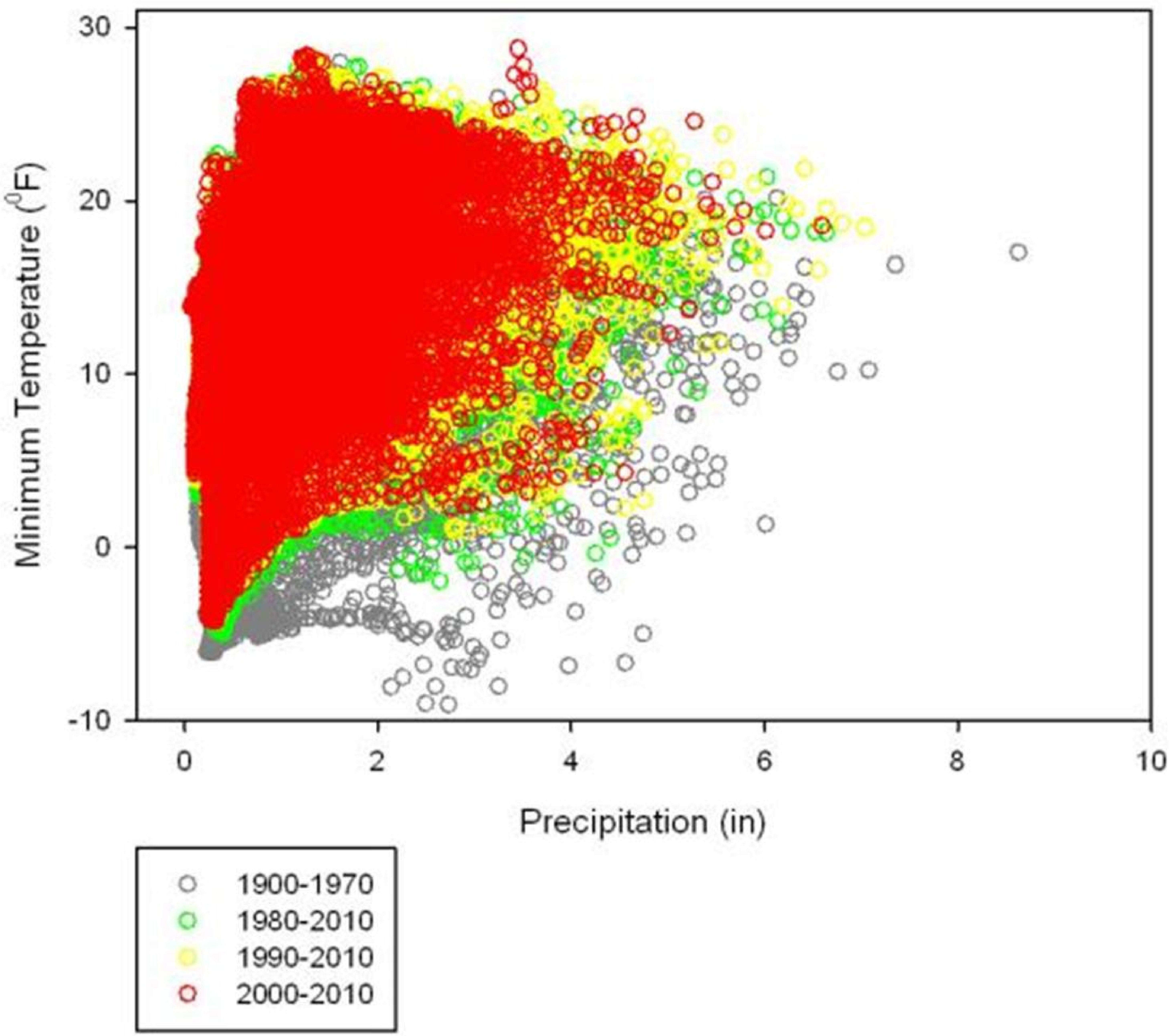


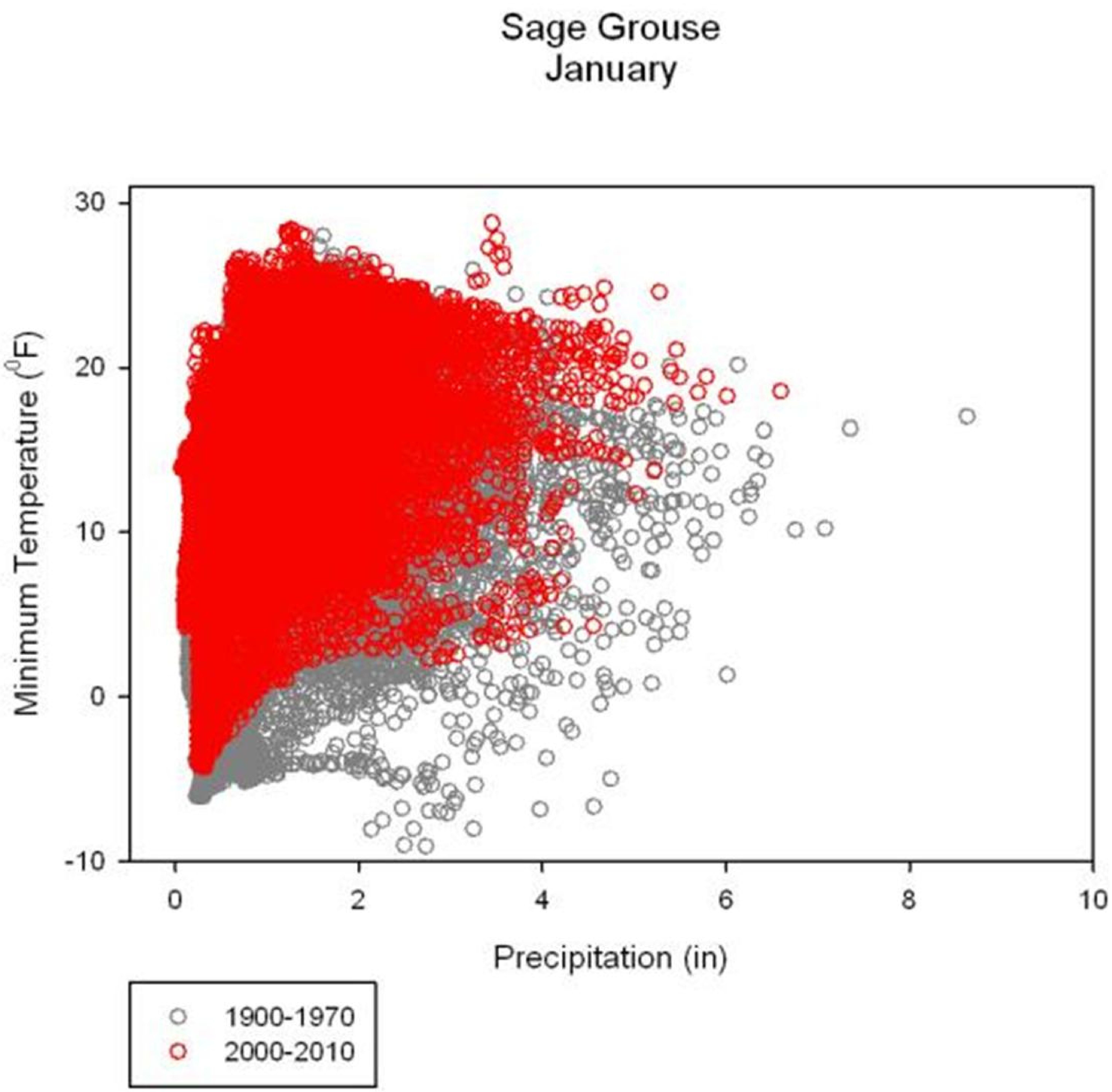
Sage Grouse
January
Minimum Temperature (⁰F)
30
20
10
0
-10
0
2
4
6
8
10
Precipitation (in)
1900-1970
1980-2010



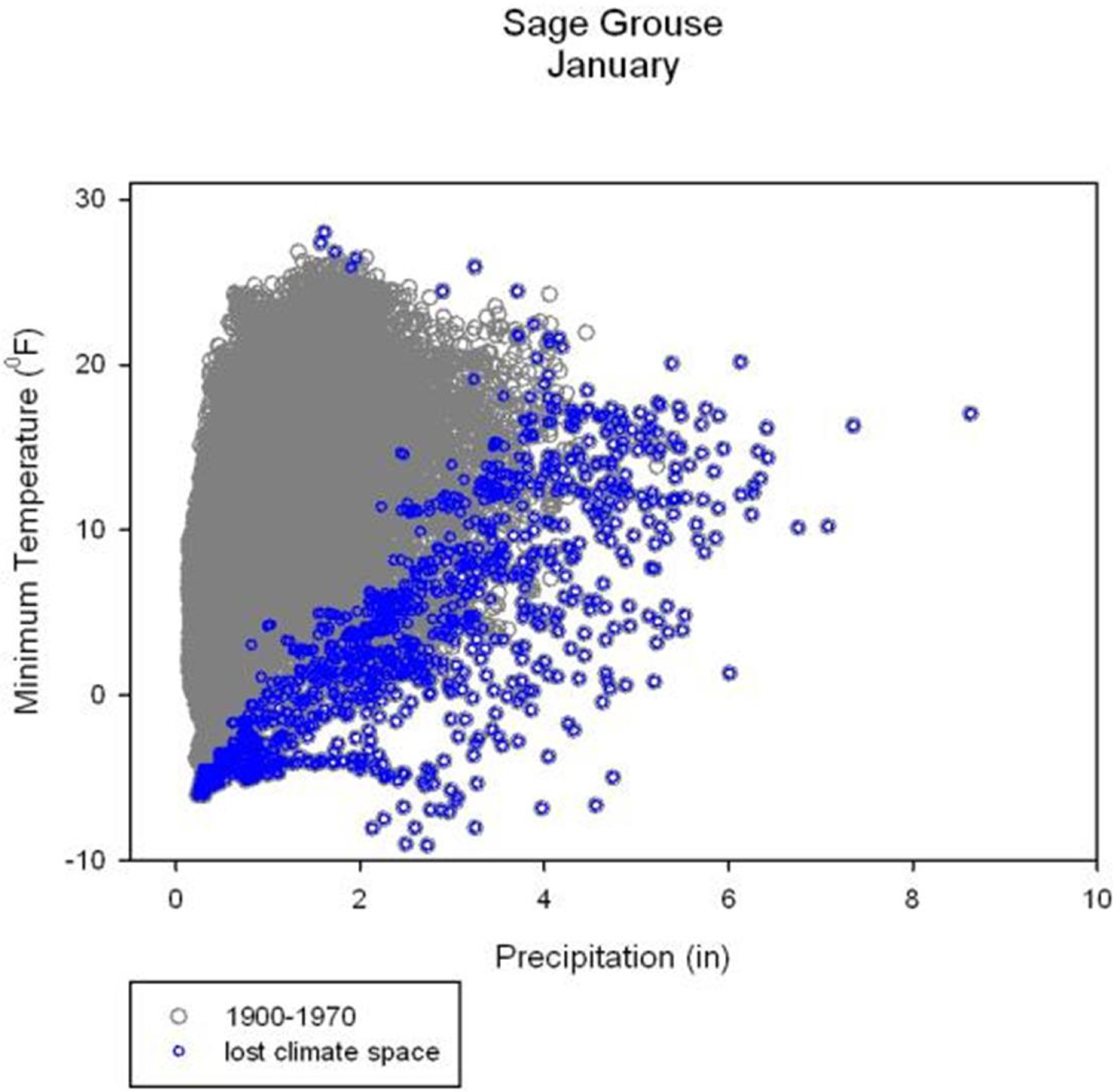
Sage Grouse
January
30
20
10
0
-10
Minimum Temperature (°F)
0
2
4
6
8
10
Precipitation (in)
1900-1970
1980-2010
1990-2010

Sage Grouse
January



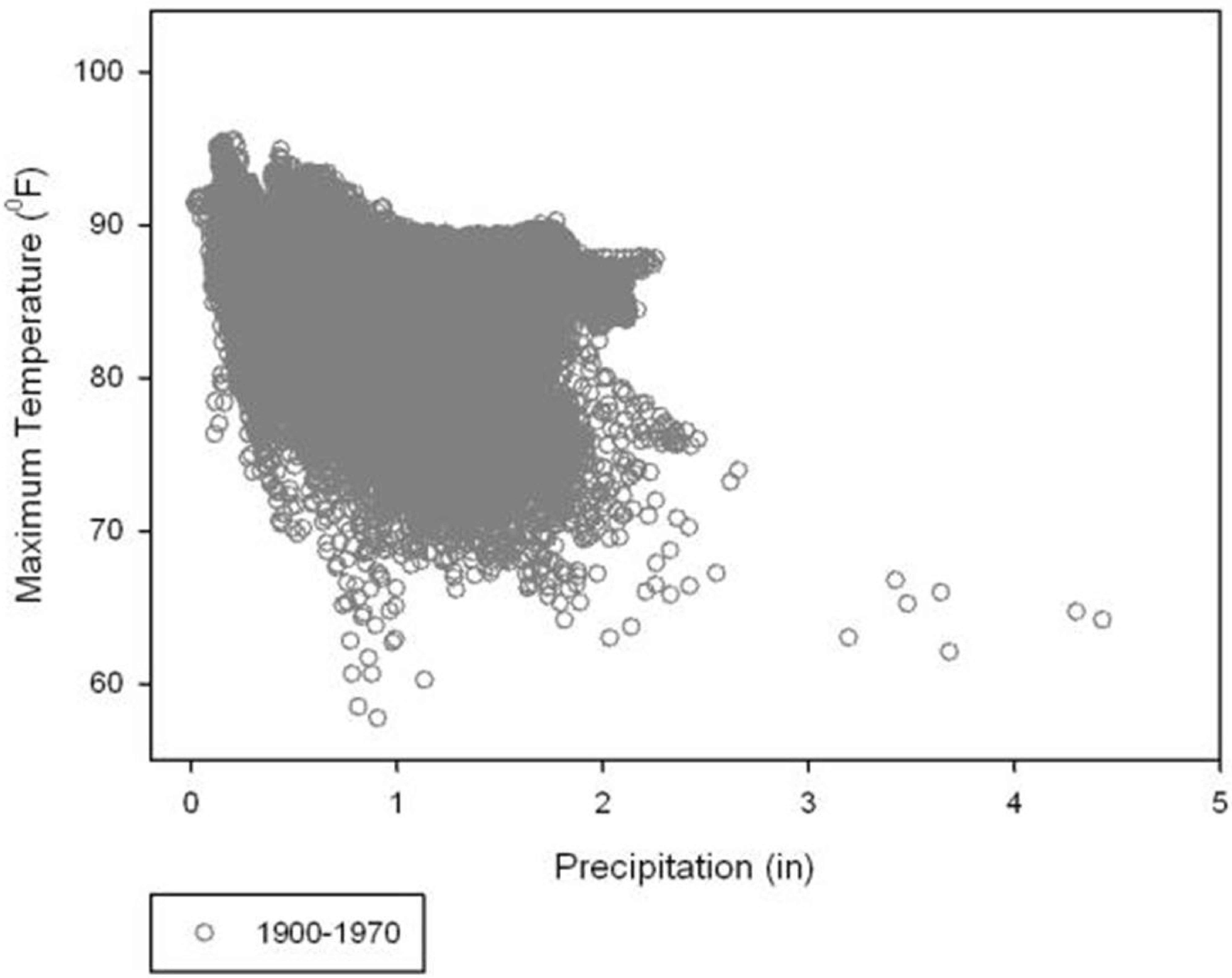


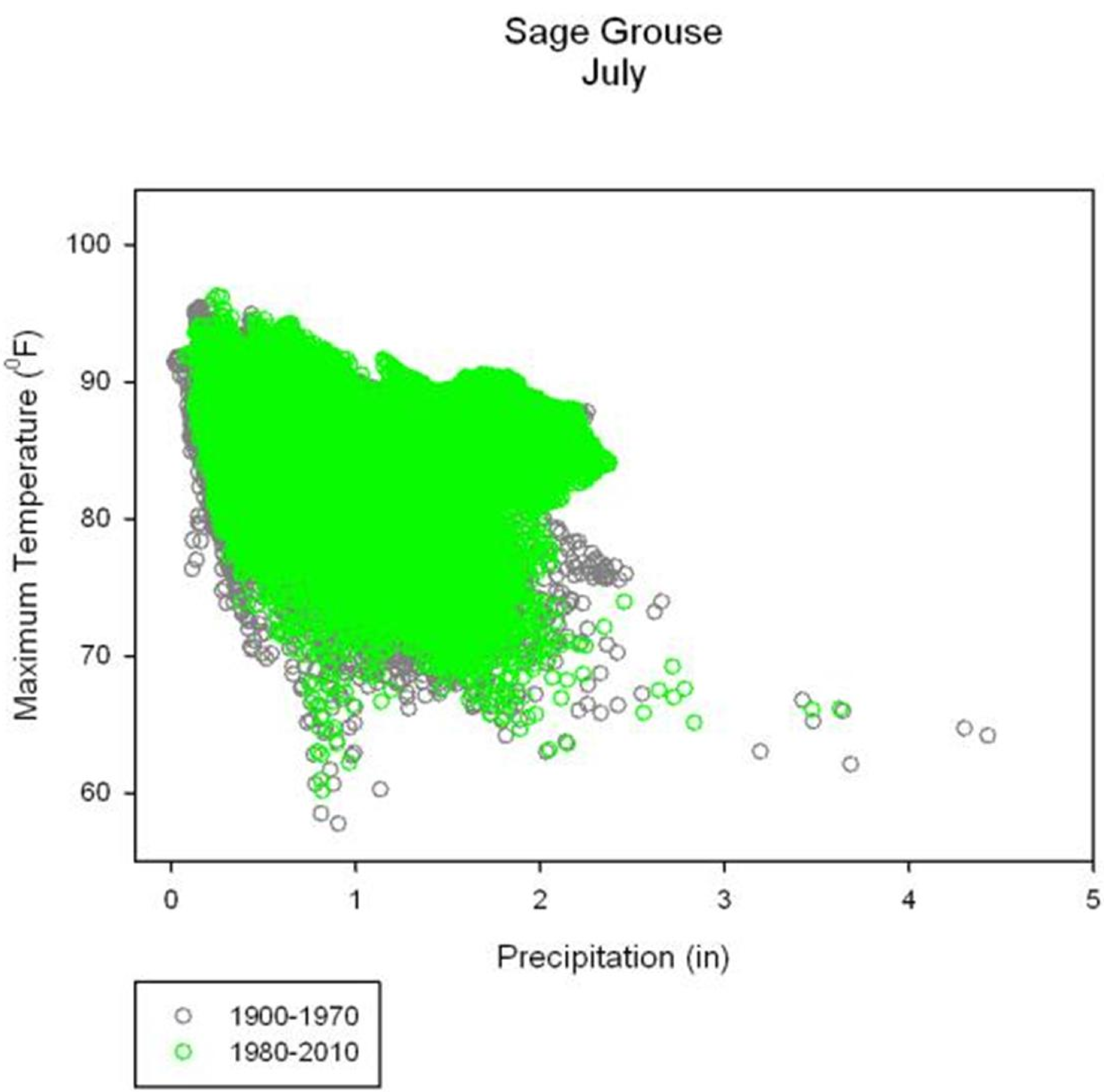
Sage Grouse
January
Minimum Temperature (0F)
Precipitation (in)
30
20
10
0
-10
0
2
4
6
8
10
1900-1970
2000-2010

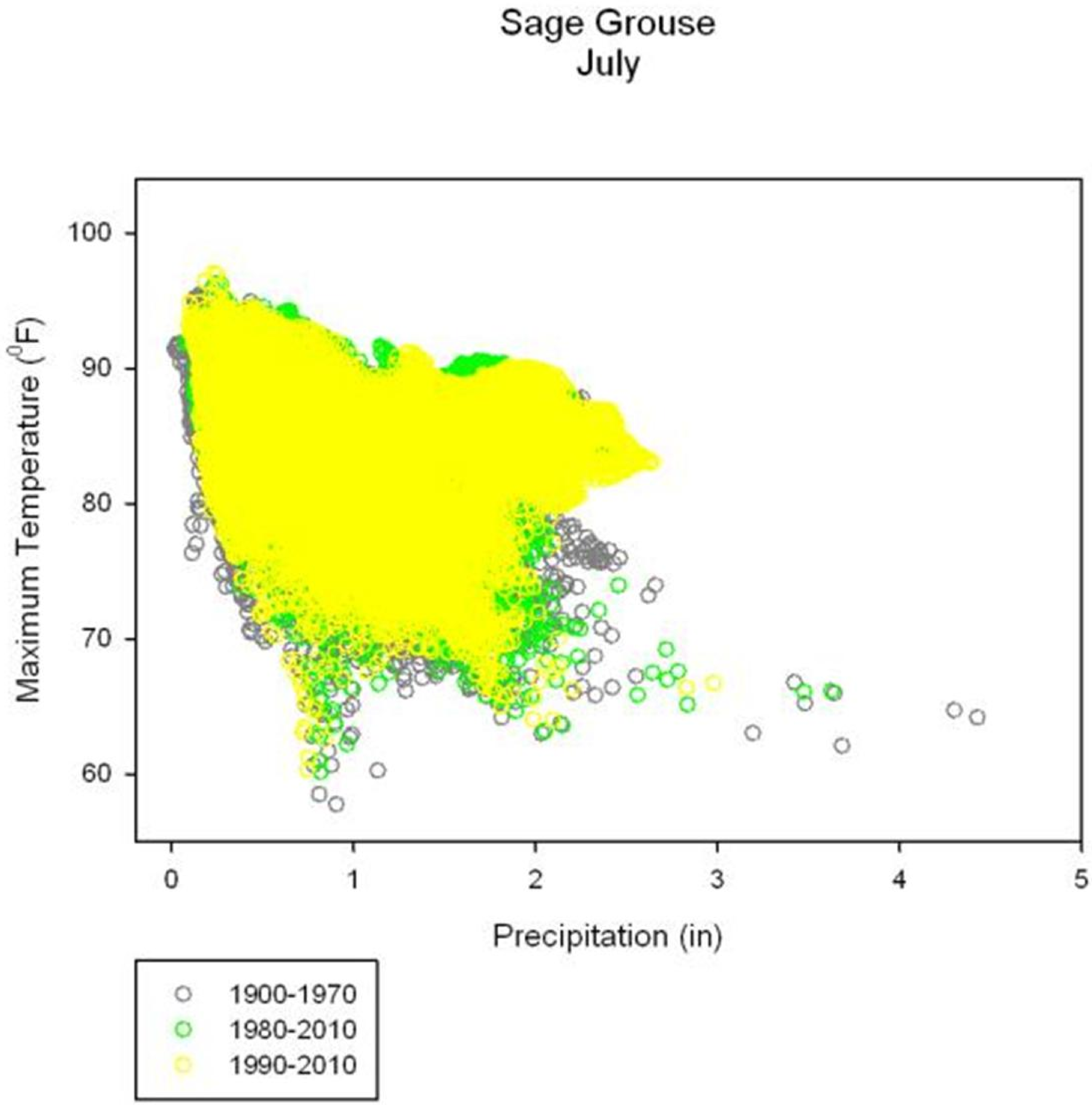


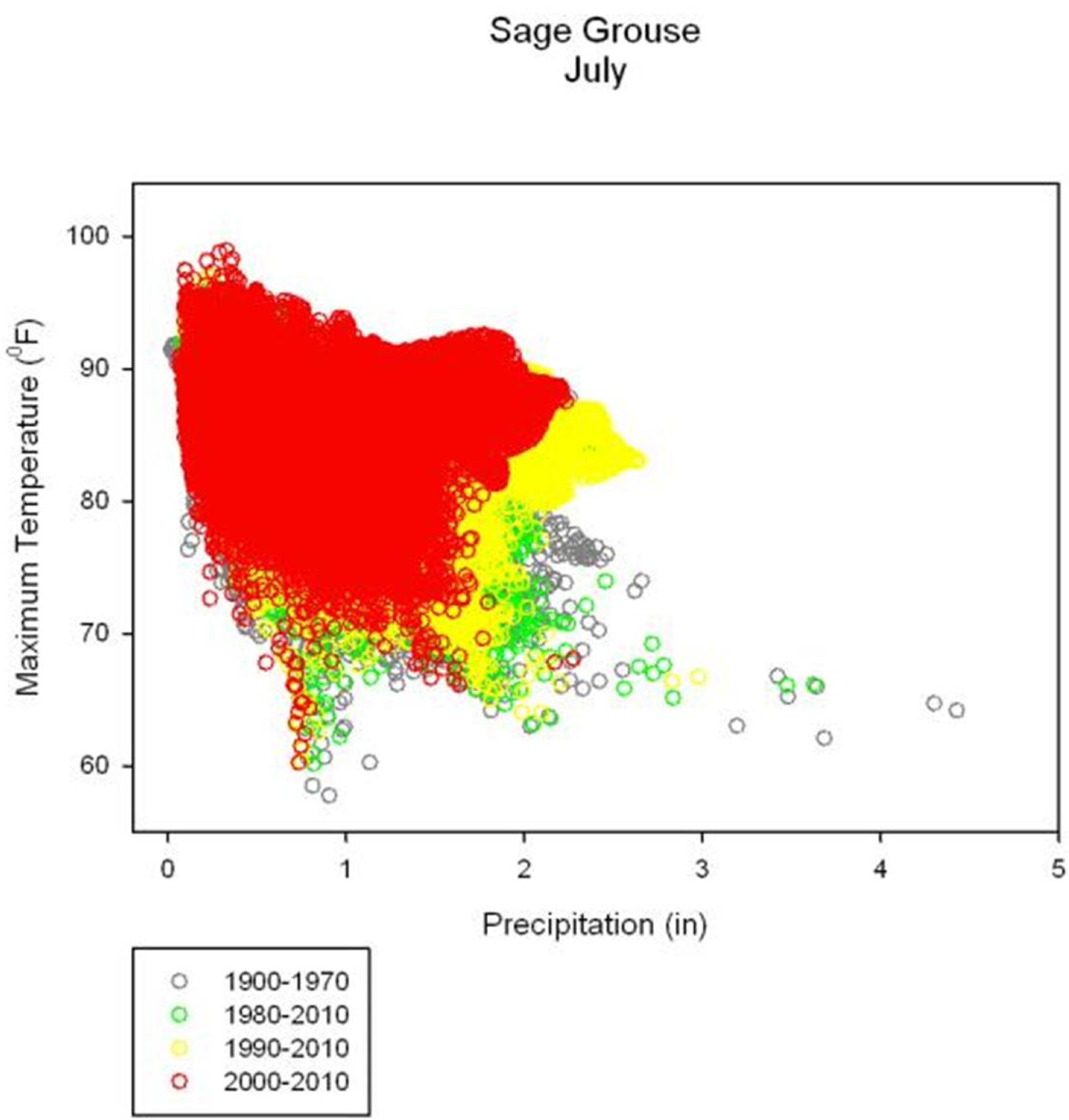
Sage Grouse
January
Minimum Temperature (°F)
30
20
10
0
-10
0
2
4
6
8
10
Precipitation (in)
1900-1970
lost climate space

Sage Grouse
July

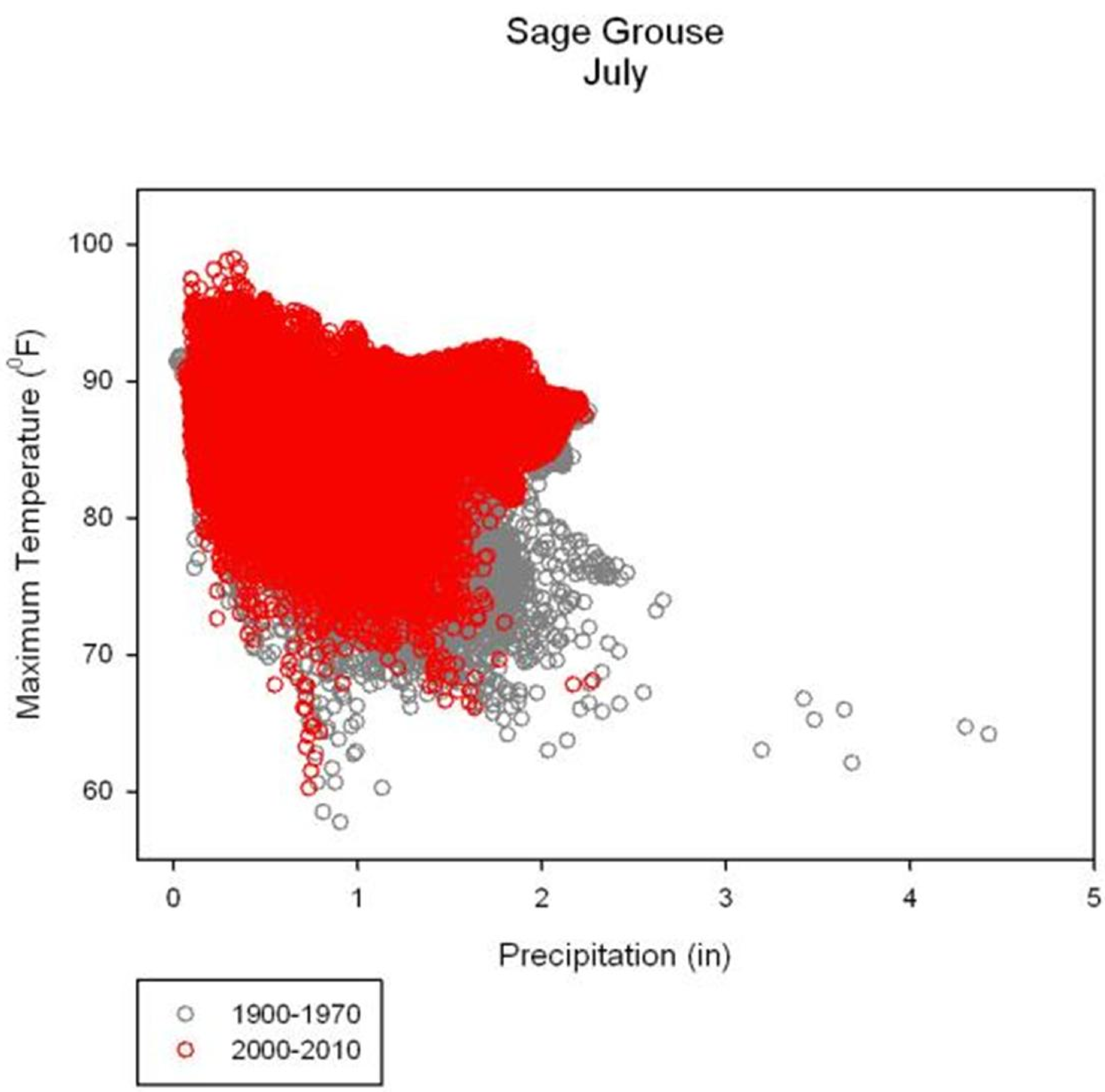



Sage Grouse
July
100
90
80
70
60
Maximum Temperature (⁰F)
0
1
2
3
4
5
Precipitation (in)
1900-1970
1980-2010

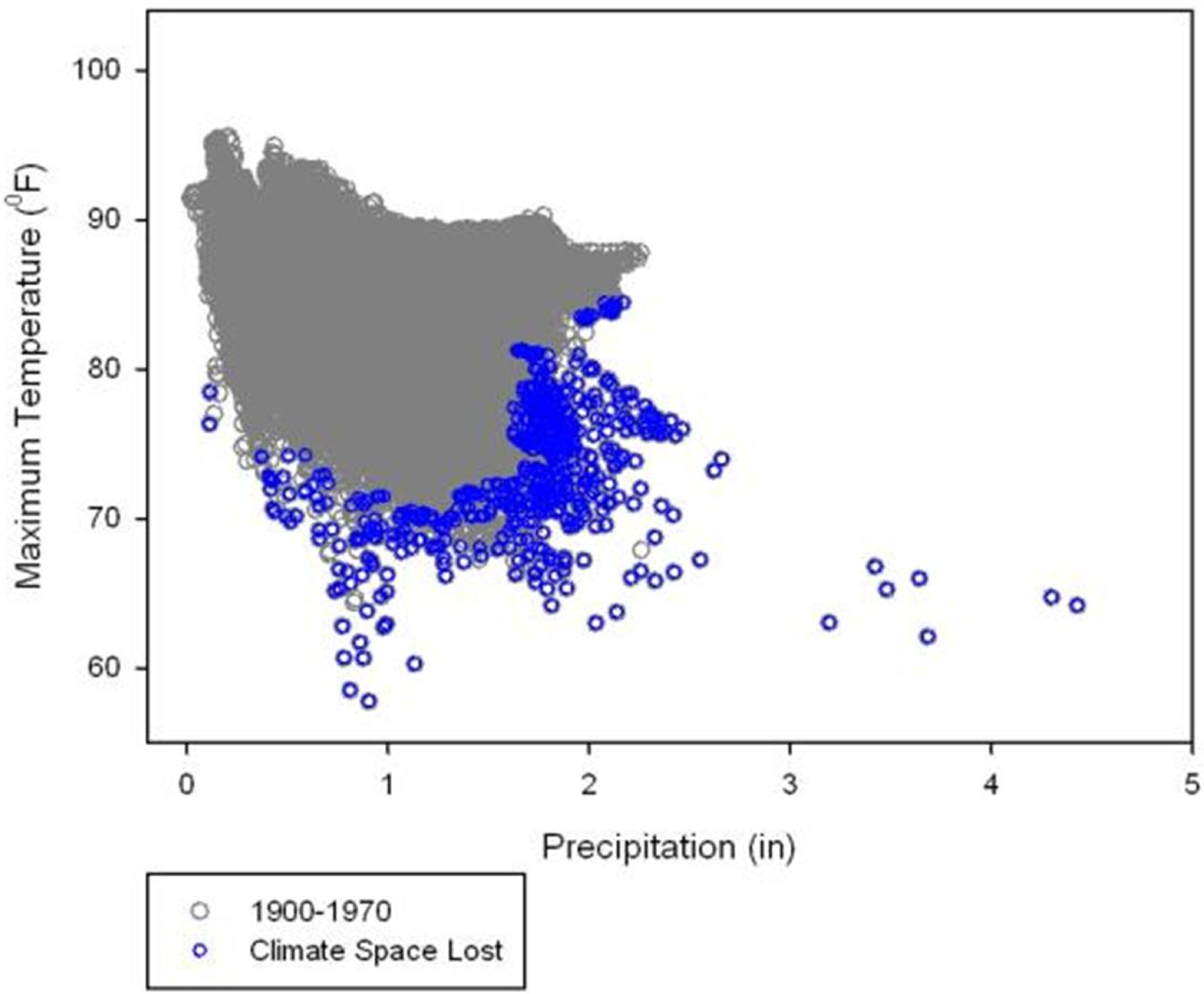

Sage Grouse
July
Maximum Temperature (°F)
100
90
80
70
60
0
1
2
3
4
5
Precipitation (in)
1900-1970
1980-2010
1990-2010

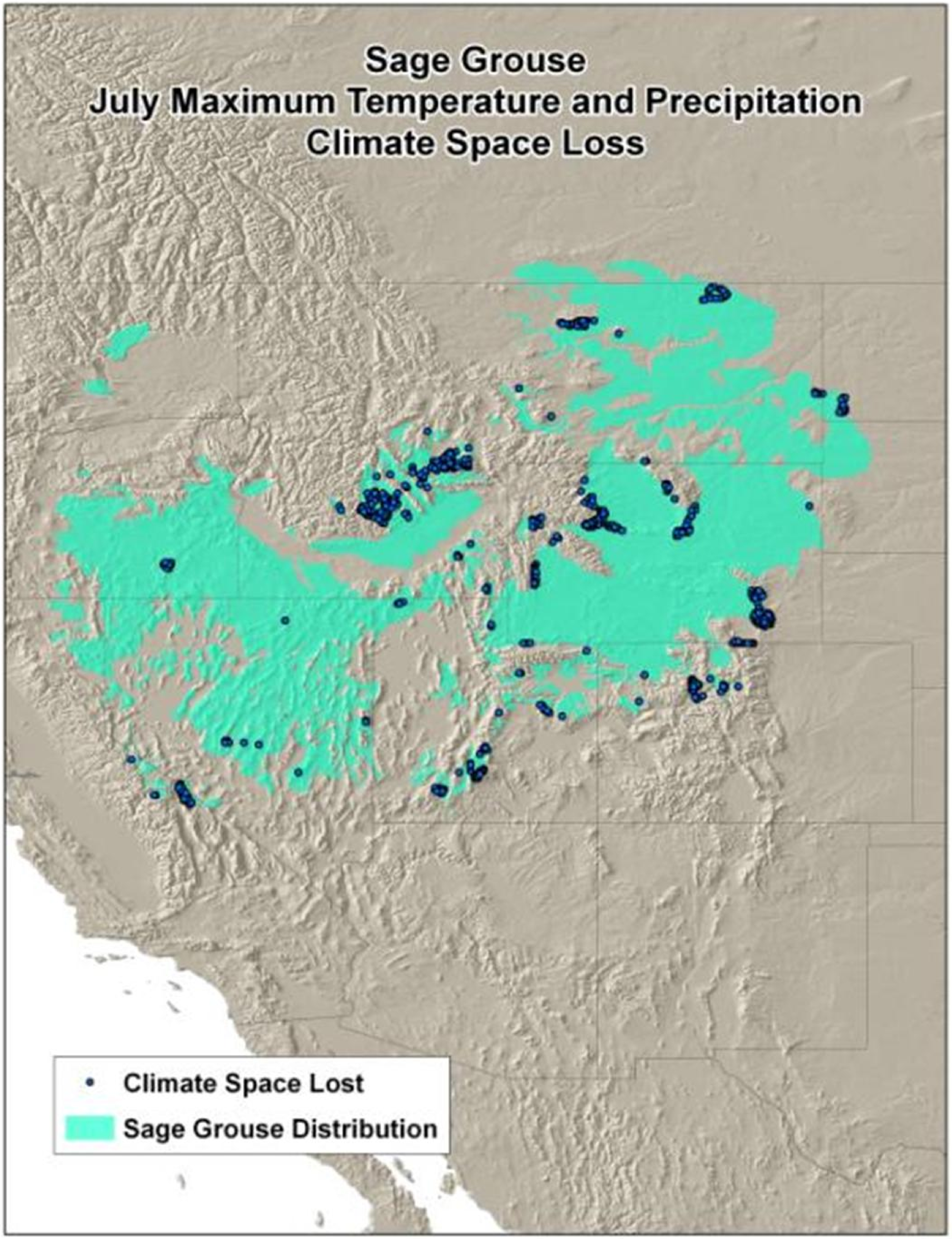


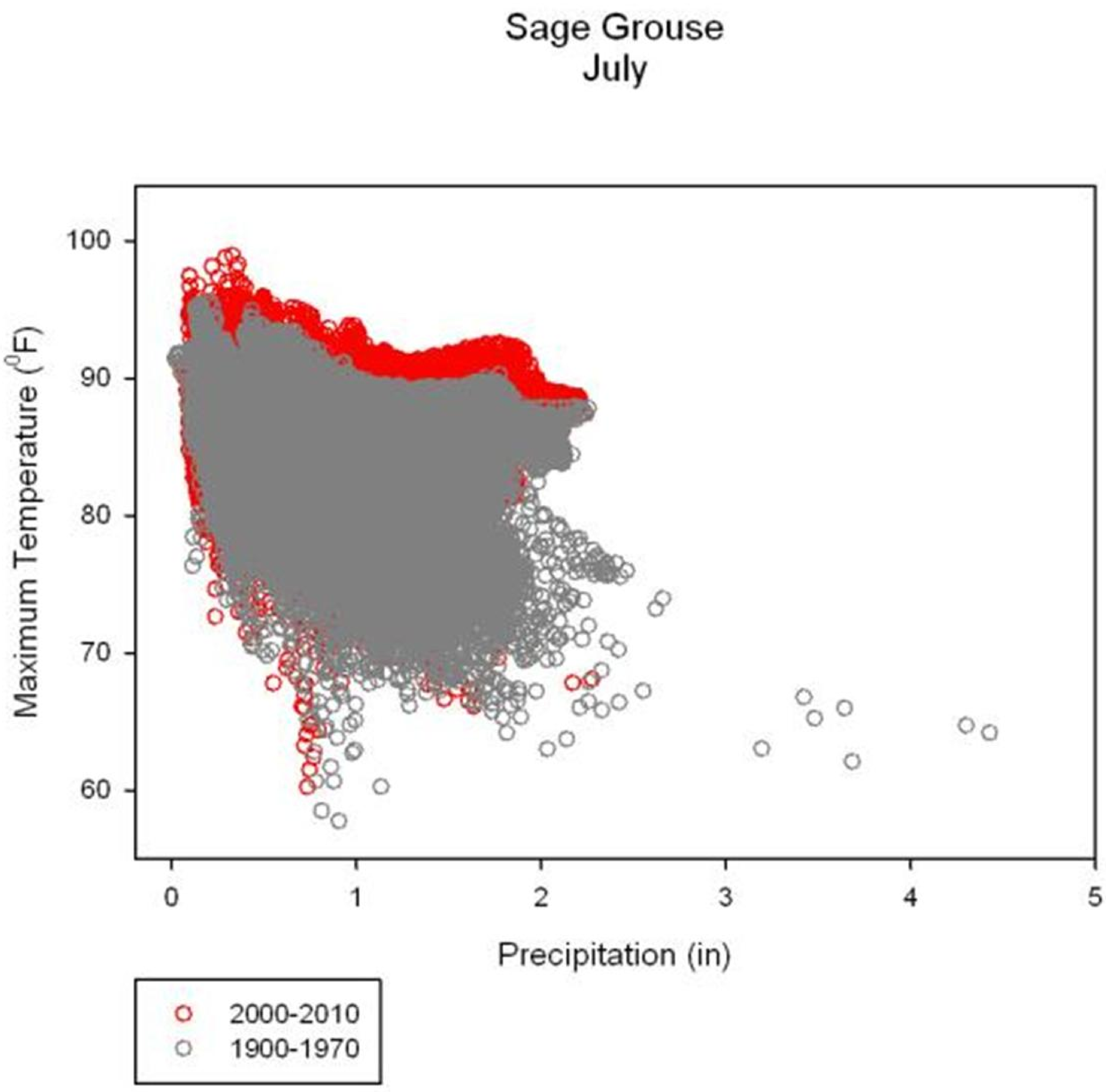
Sage Grouse
July
Maximum Temperature (^{0}F)
100
90
80
70
60
0
1
2
3
4
5
Precipitation (in)
1900-1970
1980-2010
1990-2010
2000-2010


Sage Grouse
July
Maximum Temperature (⁰F)
100
90
80
70
60
Precipitation (in)
0
1
2
3
4
5
1900-1970
2000-2010

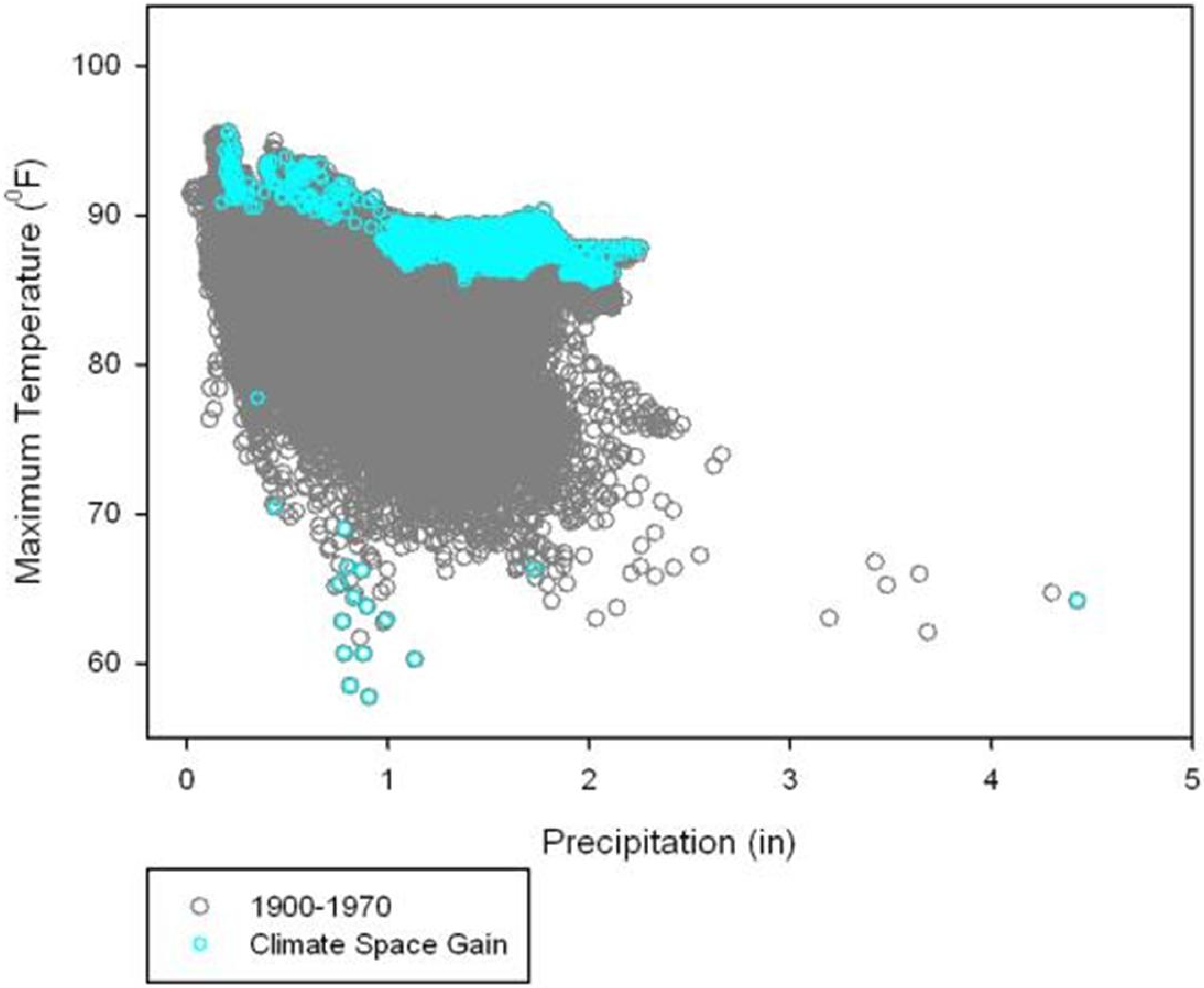
Sage Grouse
July
Climate Space Lost

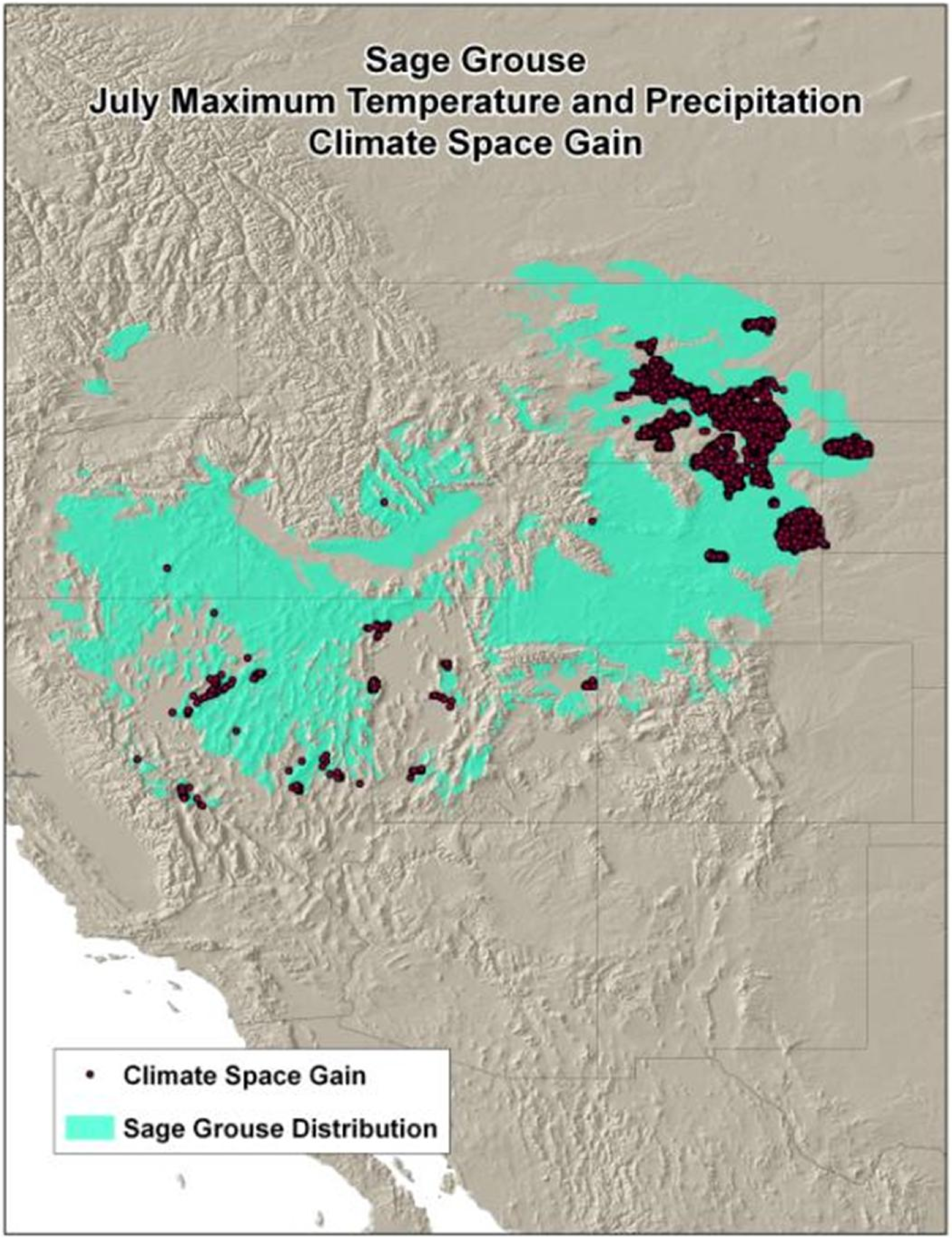


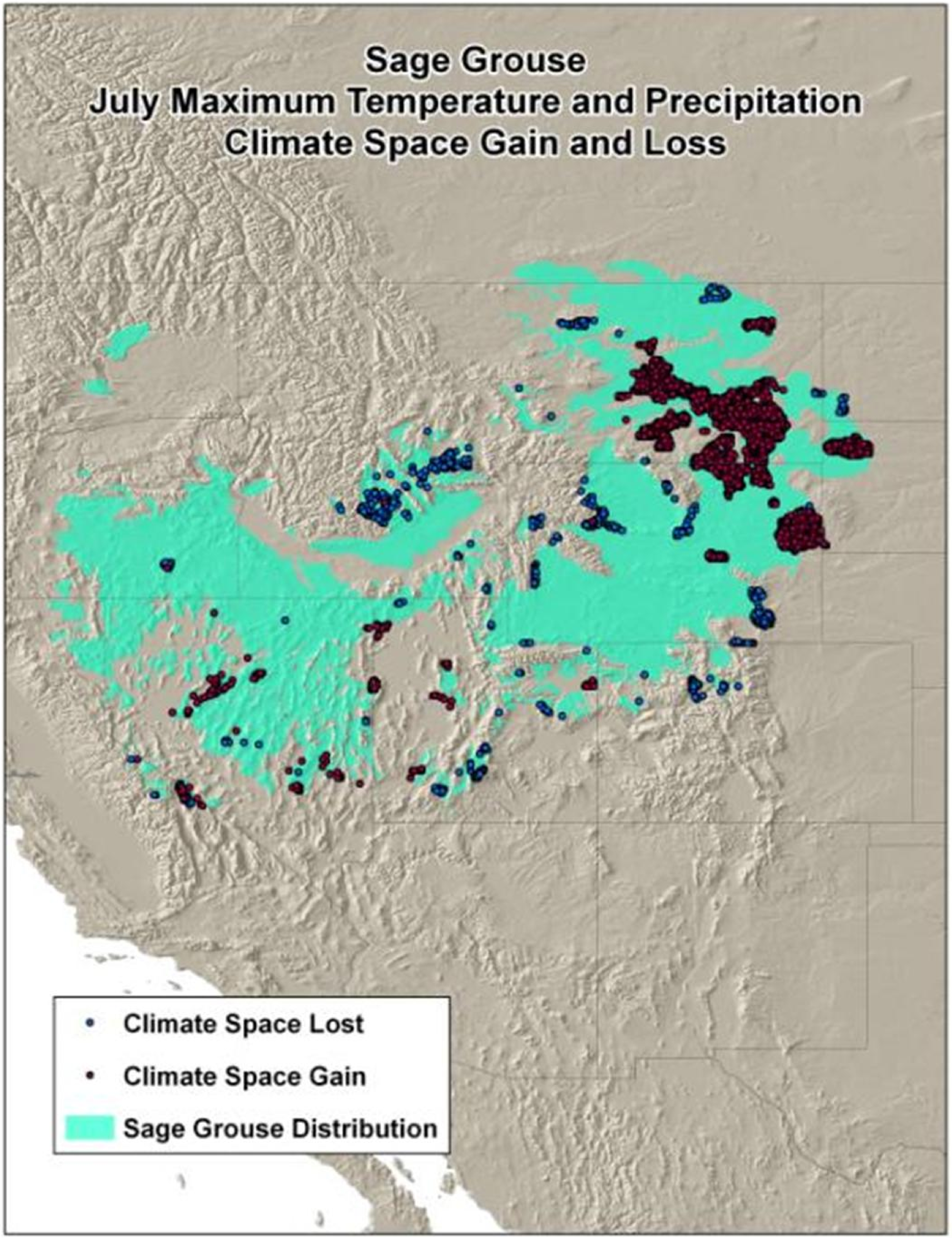

Sage Grouse
July Maximum Temperature and Precipitation
Climate Space Loss
Climate Space Lost
Sage Grouse Distribution


Sage Grouse
July
100
90
80
70
60
Maximum Temperature (^{0}F)
0
1
2
3
4
5
Precipitation (in)
2000-2010
1900-1970

Sage Grouse
July
Climate Space Gain




Sage Grouse
July Maximum Temperature and Precipitation
Climate Space Gain
Climate Space Gain
Sage Grouse Distribution


Sage Grouse
July Maximum Temperature and Precipitation
Climate Space Gain and Loss
Climate Space Lost
Climate Space Gain
Sage Grouse Distribution