Climate Change Trends for Planning at Fort Union Trading Post National Historic Site, North Dakota

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Historical Trends

From 1901 to 2002, mean annual temperature increased across North America (Figure 1; Gonzalez et al. 2010) and showed a statistically significant increase in the area that includes Fort Union Trading Post National Historic Site (NHS) (Figure 2, Table 1). From 1901 to 2002, precipitation increased across most of North America (Figure 3; Gonzalez et al. 2010), although it showed no statistically significant trend in the Fort Union area (Figure 4, Table 1). Analyses of causal factors attribute 20th century warming and precipitation changes to greenhouse gas emissions from vehicles, power plants, deforestation, and other human activities (Intergovernmental Panel on Climate Change (IPCC) 2007, Bonfils et al. 2008).

Future Projections

The Intergovernmental Panel on Climate Change (IPCC) has coordinated research groups to project possible future climates under defined greenhouse gas emissions scenarios (IPCC 2007). The three main IPCC greenhouse gas emissions scenarios are B1 (lower emissions), A1B (medium emissions), and A2 (higher emissions). Actual global emissions are on a path above IPCC emissions scenario A2 (Friedlingstein et al. 2010).

For the three main IPCC emissions scenarios, projected 21st century temperature in the Fort Union area could increase three to four times the amount of historical 20th century warming (Figure 5, Table 1, Mitchell and Jones 2005, Gonzalez et al. 2010). General circulation models (GCMs) of the atmosphere project increased annual precipitation in the Fort Union area under all three emissions scenarios (Figure 6, Table 1), with 13 out of 18 GCMs projecting increases in precipitation (Figure 7; historical average from Mitchell and Jones 2005, Hijmans et al. 2005; projections from IPCC 2007, Tabor and Williams 2010, Conservation International; analysis by P. Gonzalez).

Projections indicate potential changes in the frequency of extreme temperature and precipitation

events. Modeling under emissions scenario A2 projects 20 to 24 fewer days with minimum temperature < 0ºC, up to three more consecutive days with a maximum temperature > 35º C, and up to 2 more days with rainfall > 2.5 cm between the periods 1980-2000 and 2041-2070 (Kunkel et al. in review).

Table 1. Historical and projected climate (mean ± standard deviation (SD)) trends for the area that includes Fort Union Trading Post NHS (Mitchell and Jones 2005, IPCC 2007, Gonzalez et al. 2010). Historical climate and climate projections for IPCC emissions scenarios B1 and A1B are calculated for the 50 x 50 km pixel that includes the park (Gonzalez et al. 2010). Climate under emissions scenario A2 is calculated for the 4 x 4 km pixels that include the park (data from Conservation International using method of Tabor and Williams (2010)). Note "century^{-1}" is the fractional change per century, so that 0.12 century^{-1} is an increase of 12% in a century.

	mean	SD	units
Historical (1901-2002)			
temperature - annual average	4.8	1.1	ºC
temperature - linear trend	1.2	3.7	ºC century^{-1}
precipitation - annual average	350	80	mm y^{-1}
precipitation - linear trend	0.03	0.74	century^{-1}
Projected (1990-2100)			
IPCC B1 scenario (lower emissions)			
temperature - change in annual average	3.0	1.0	ºC century^{-1}
precipitation - change in annual average	0.01	0.11	century^{-1}
IPCC A1B scenario (medium emissions)			
temperature - change in annual average	4.0	1.0	ºC century^{-1}
precipitation - change in annual average	0.02	0.11	century^{-1}
IPCC A2 scenario (higher emissions)			
temperature - change in annual average	4.5	1.0	ºC century^{-1}
precipitation - change in annual average	0.12	0.11	century^{-1}

Figure 1.

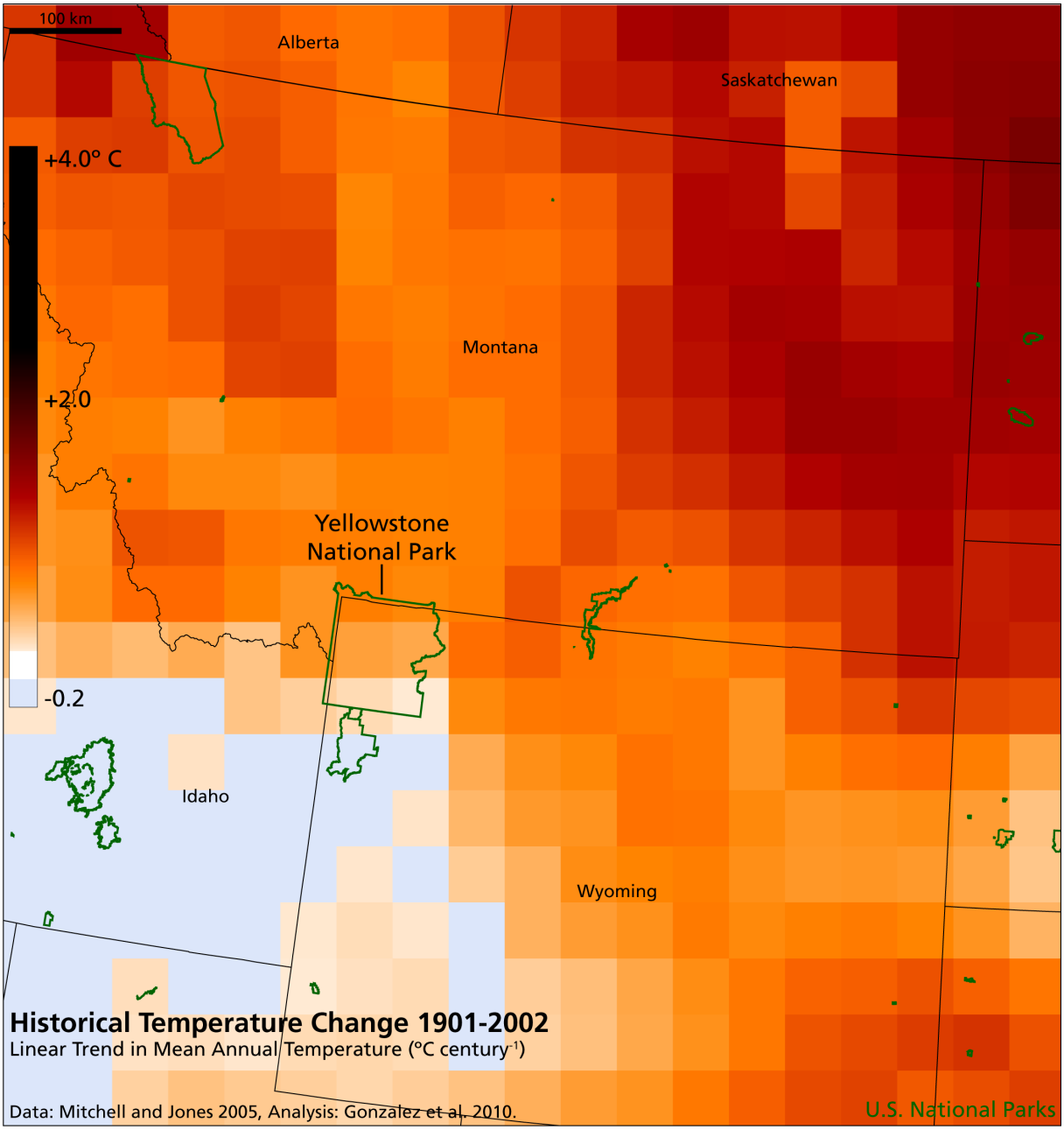
100 km
Alberta
Saskatchewan
+4.0° C
Montana
+2.0
Yellowstone
National Park
-0.2
Idaho
Wyoming
Historical Temperature Change 1901-2002
Linear Trend in Mean Annual Temperature (°C century-1)
Data: Mitchell and Jones 2005, Analysis: Gonzalez et al. 2010.
U.S. National Parks

Figure 2.

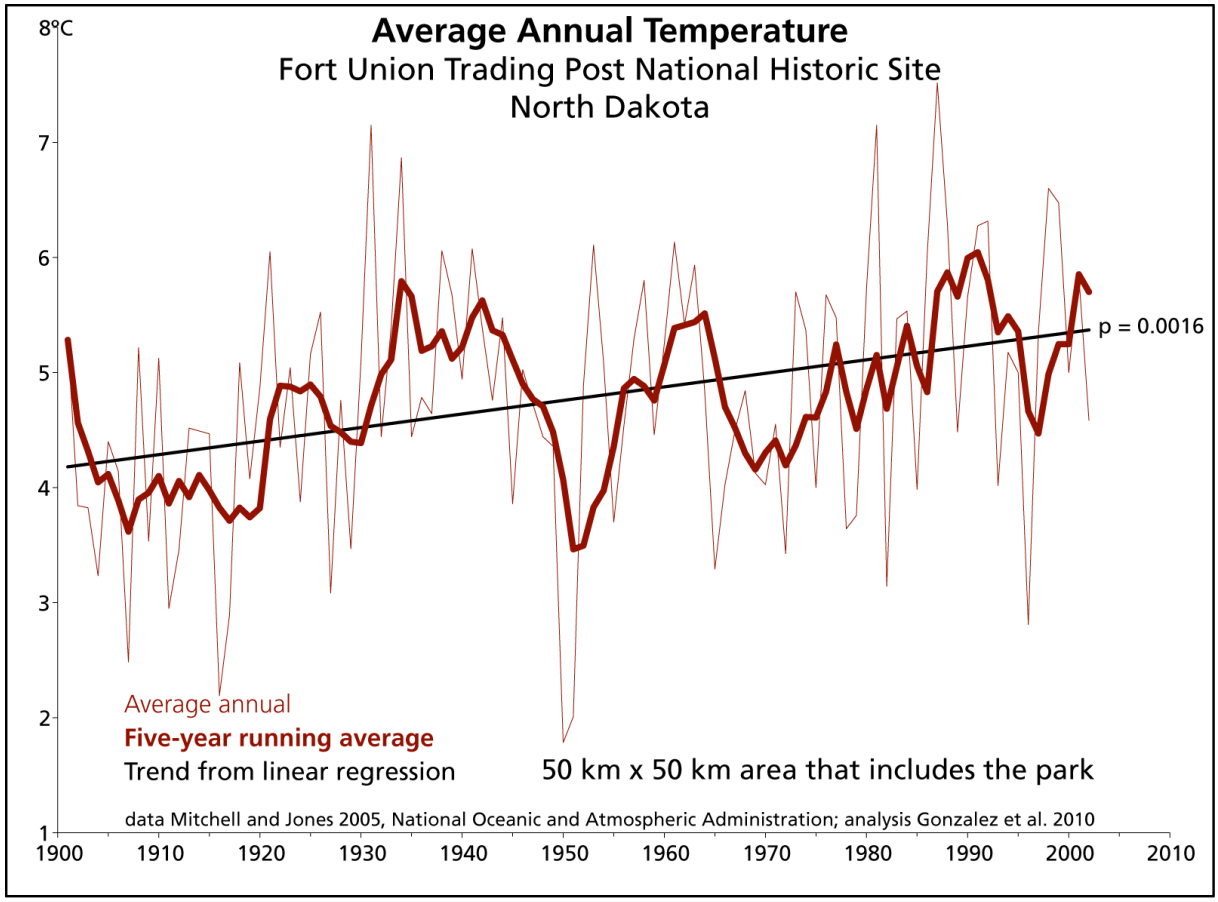
Average Annual Temperature
Fort Union Trading Post National Historic Site
North Dakota
8°C
7
6
5
4
3
2
1
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
p = 0.0016
Average annual
Five-year running average
Trend from linear regression
50 km x 50 km area that includes the park
data Mitchell and Jones 2005, National Oceanic and Atmospheric Administration; analysis Gonzalez et al. 2010

Figure 3.

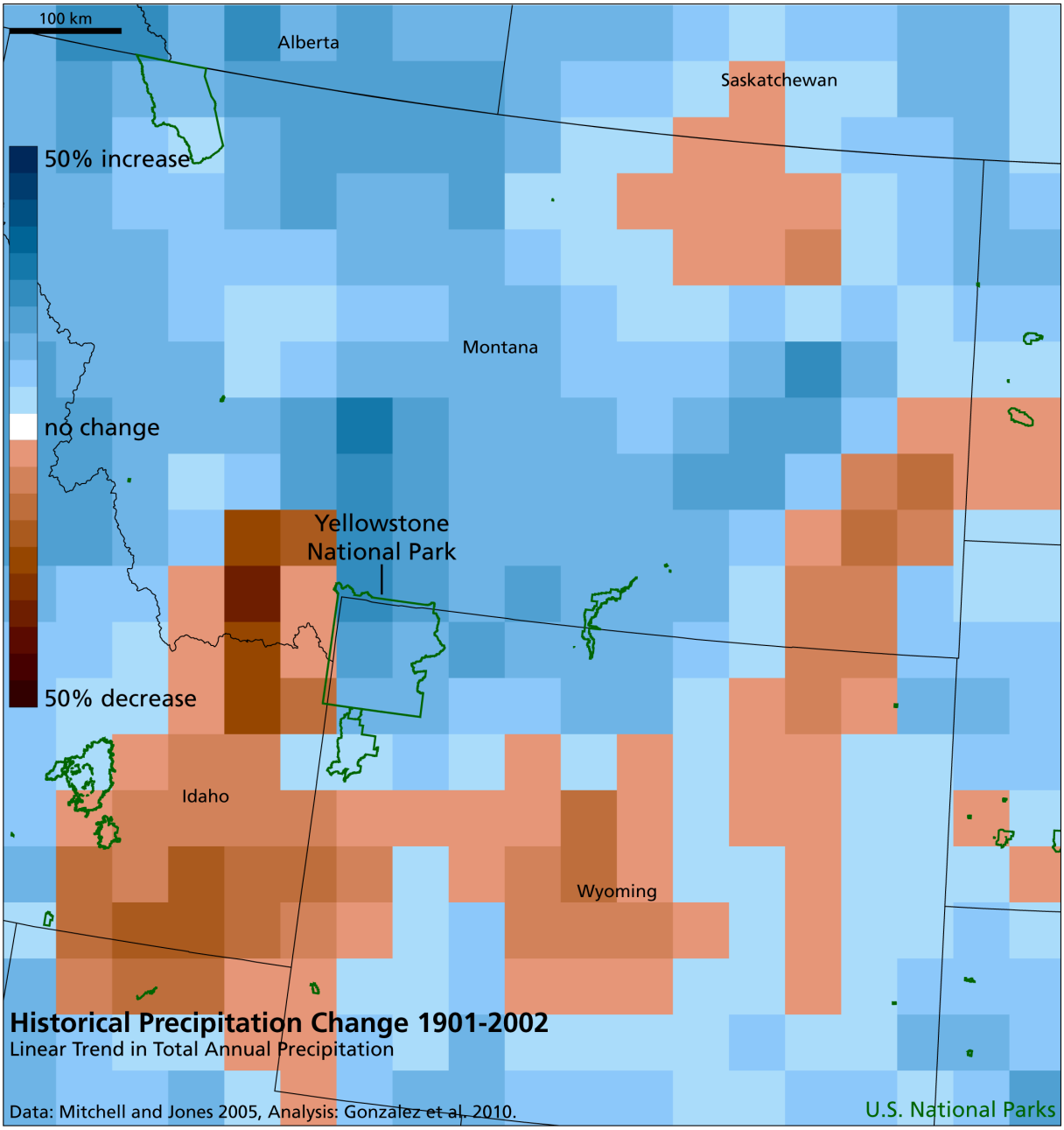
100 km
Alberta
Saskatchewan
50% increase
Montana
no change
Yellowstone
National Park
50% decrease
Idaho
Wyoming
Historical Precipitation Change 1901-2002
Linear Trend in Total Annual Precipitation
Data: Mitchell and Jones 2005, Analysis: Gonzalez et al. 2010.
U.S. National Parks

Figure 4.

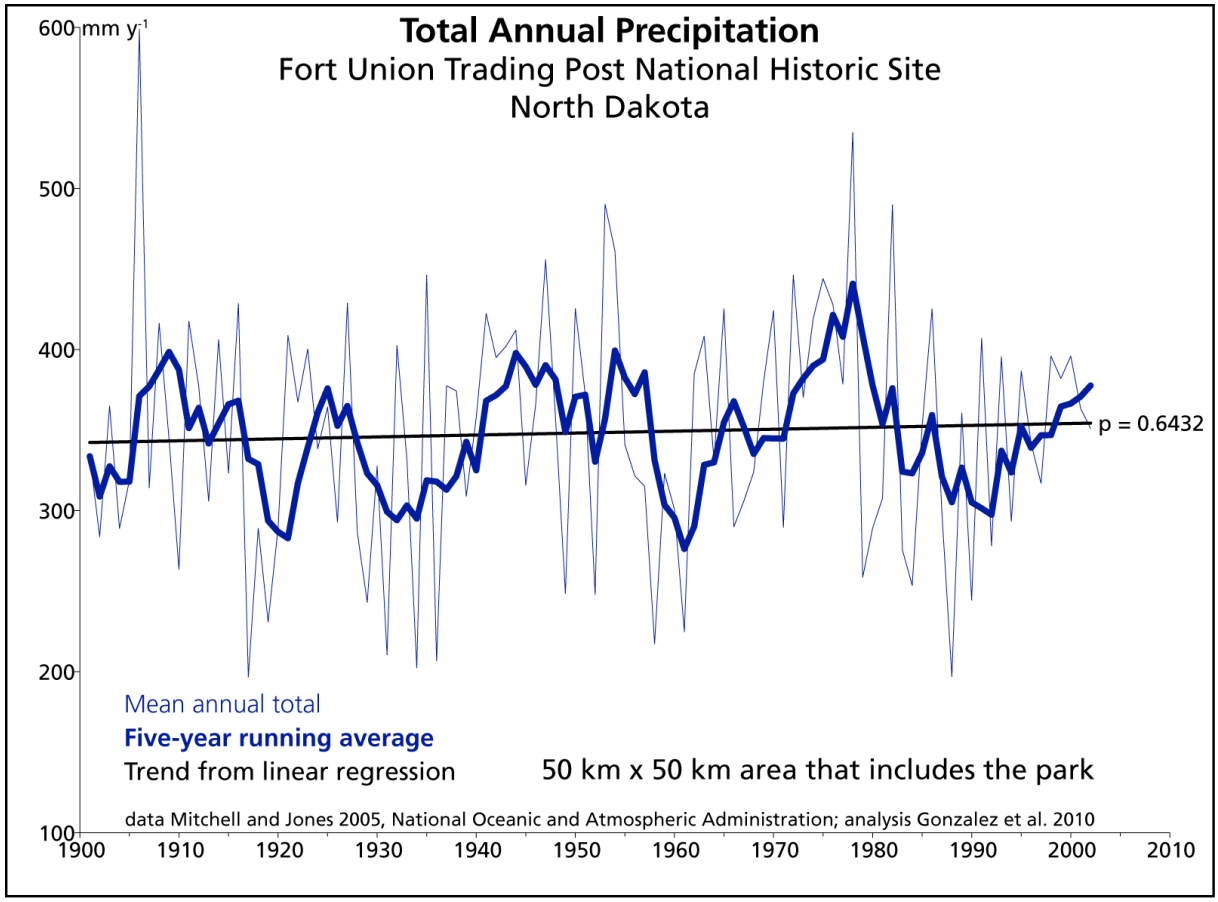
Total Annual Precipitation
Fort Union Trading Post National Historic Site
North Dakota
mm y-1
600
500
400
300
200
100
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
p = 0.6432
Mean annual total
Five-year running average
Trend from linear regression
50 km x 50 km area that includes the park
data Mitchell and Jones 2005, National Oceanic and Atmospheric Administration; analysis Gonzalez et al. 2010

Figure 5.

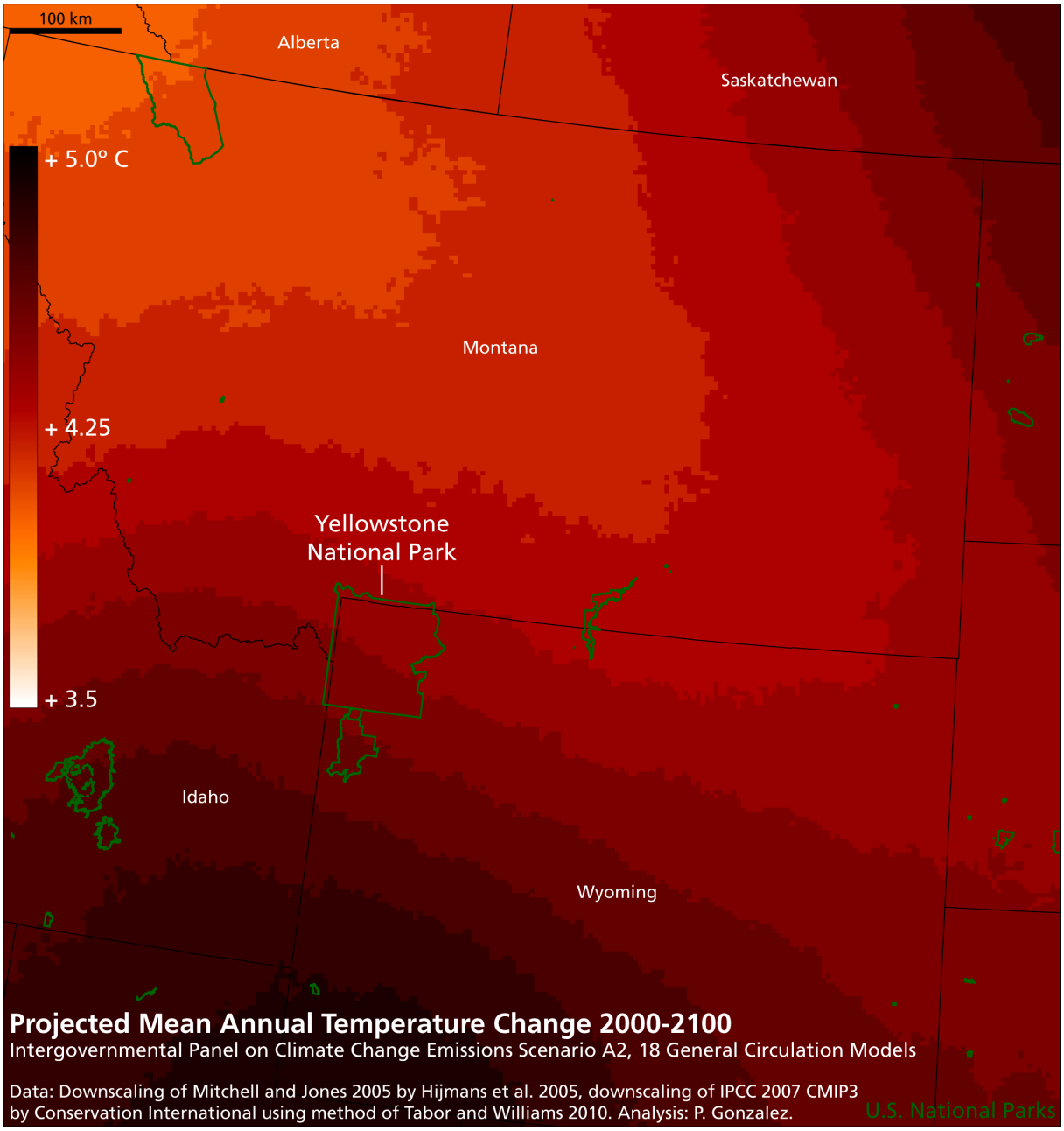
100 km
Alberta
Saskatchewan
+ 5.0° C
Montana
+ 4.25
Yellowstone
National Park
+ 3.5
Idaho
Wyoming
Projected Mean Annual Temperature Change 2000-2100
Intergovernmental Panel on Climate Change Emissions Scenario A2, 18 General Circulation Models
Data: Downscaling of Mitchell and Jones 2005 by Hijmans et al. 2005, downscaling of IPCC 2007 CMIP3
by Conservation International using method of Tabor and Williams 2010. Analysis: P. Gonzalez.
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Figure 6.

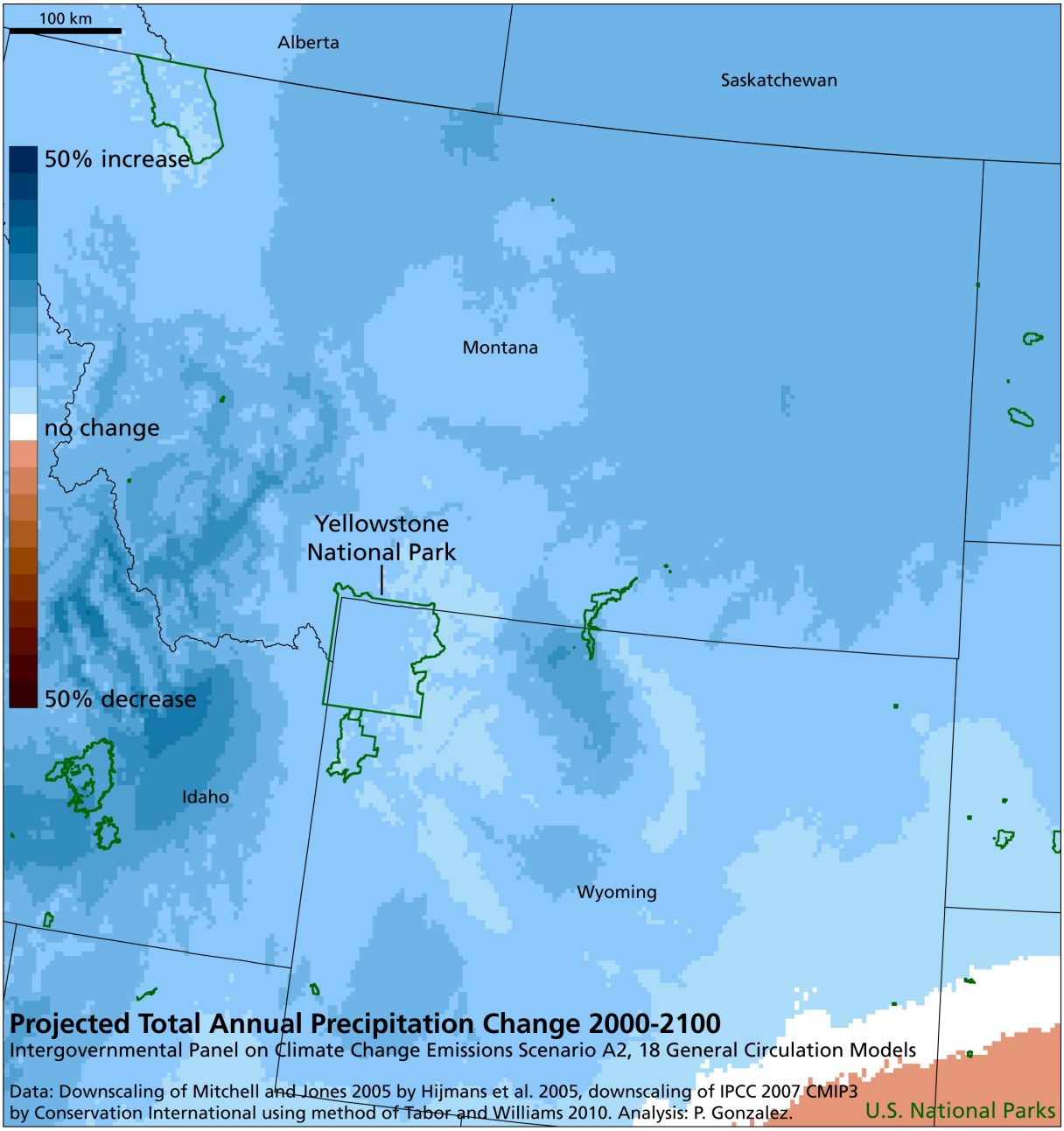
100 km
Alberta
Saskatchewan
50% increase
no change
50% decrease
Montana
Yellowstone
National Park
Idaho
Wyoming
Projected Total Annual Precipitation Change 2000-2100
Intergovernmental Panel on Climate Change Emissions Scenario A2, 18 General Circulation Models
Data: Downscaling of Mitchell and Jones 2005 by Hijmans et al. 2005, downscaling of IPCC 2007 CMIP3
by Conservation International using method of Tabor and Williams 2010. Analysis: P. Gonzalez.
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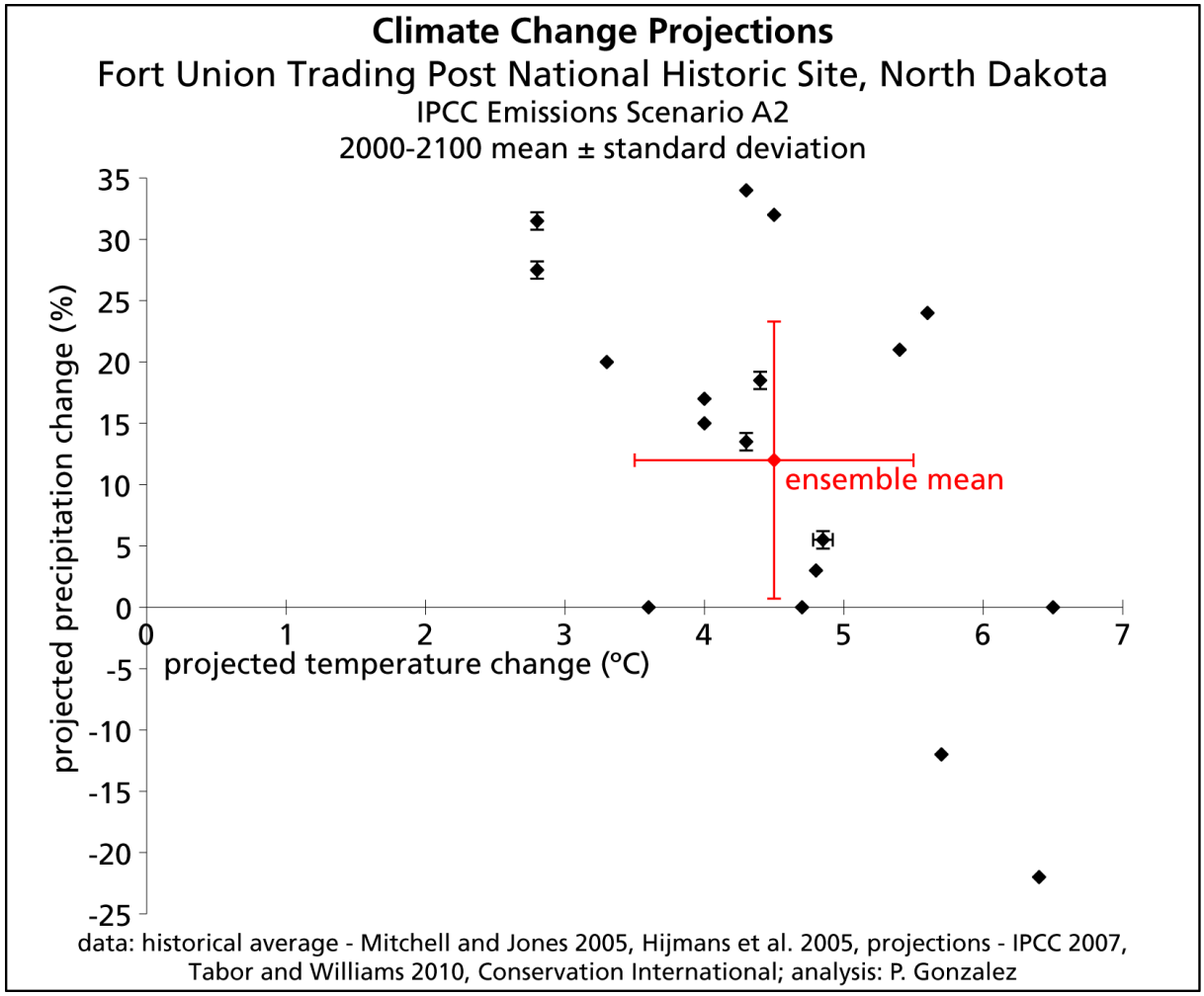
Figure 7.


Climate Change Projections
Fort Union Trading Post National Historic Site, North Dakota
IPCC Emissions Scenario A2
2000-2100 mean ± standard deviation
projected precipitation change (%)
projected temperature change (°C)
ensemble mean
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
0
1
2
3
4
5
6
7
data: historical average - Mitchell and Jones 2005, Hijmans et al. 2005, projections - IPCC 2007,
Tabor and Williams 2010, Conservation International; analysis: P. Gonzalez

References

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