Climate Change in the Greater Yellowstone Area: 1900-Present and Forecast to 2100

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LCC-VP
LANDSCAPE CLIMATE CHANGE VULNERABILITY PROJECT

DEVELOPING A CLIMATE CHANGE ADAPTATION STRATEGY CONSERVATION TARGETS WORKSHOP

Grand Teton, Yellowstone, and John D. Rockefeller Parkway

July 30, 2012 Old Faithful Snowlodge

NASA

Great Northern LANDSCAPE CONSERVATION COOPERATIVE

IMR Resources and Science

GRYN

MONTANA STATE UNIVERSITY
Mountains & Minds

It Seems Like Climate is Changing…

How much has it changed in the past century?

How much might it change in the next 100 years?

Topics

- Past to present (1900-2010)
  - Magnitude of Change and Trends
    - Temperature
    - Temperature
    - Precipitation
    - Drought index
    - Snowpack
  - Spatial Variation in Rates of change
  - Comparison With Other National Parks
  - Summary

- Future (2040 and 2080)
  - Magnitude of Change
    - Temperature
    - Precipitation
    - Snowpack
    - Drought index
  - Spatial Variation in Rates of change

- Climate Impacts
  - Streams and Trout
  - Vegetation Communities
  - Grasslands and Ungulates

- Take Home Messages

References

Coops, N.C., Waring, R.H., 2011. A process-based approach to estimate lodgepole pine (Pinus contorta Dougl.) distribution in the Pacific Northwest under climate change. Climat. Change, doi:10.1007/s10584-010-9861-2.

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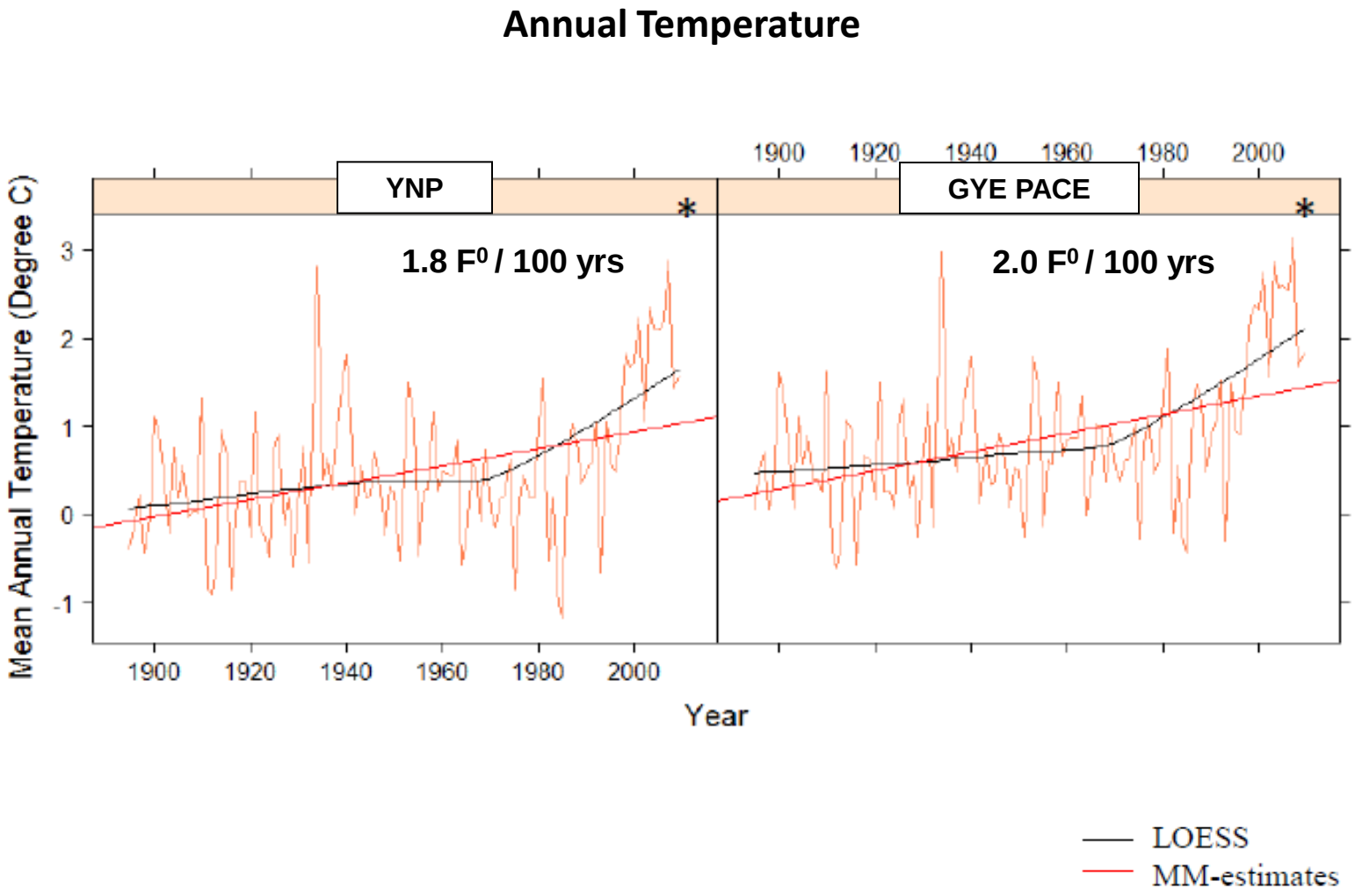
Past to Present: Trends and Magnitude



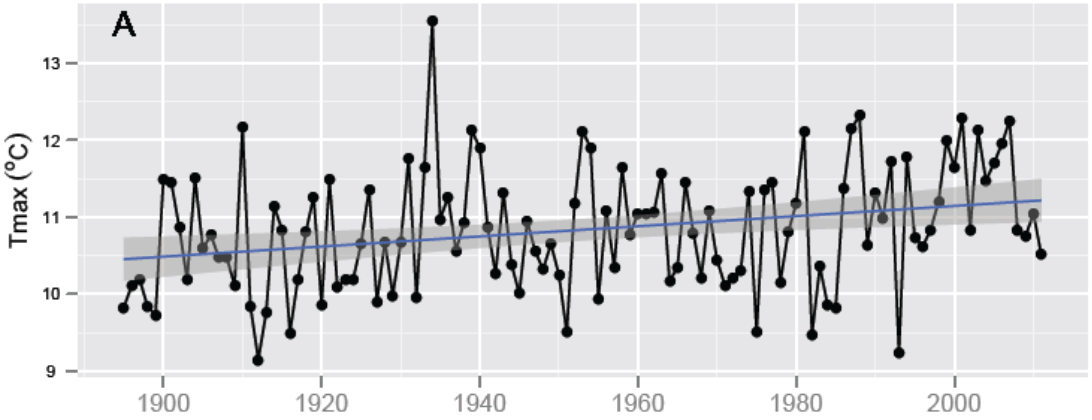
Data: PRISM (Daly 2002)

Hass 2010

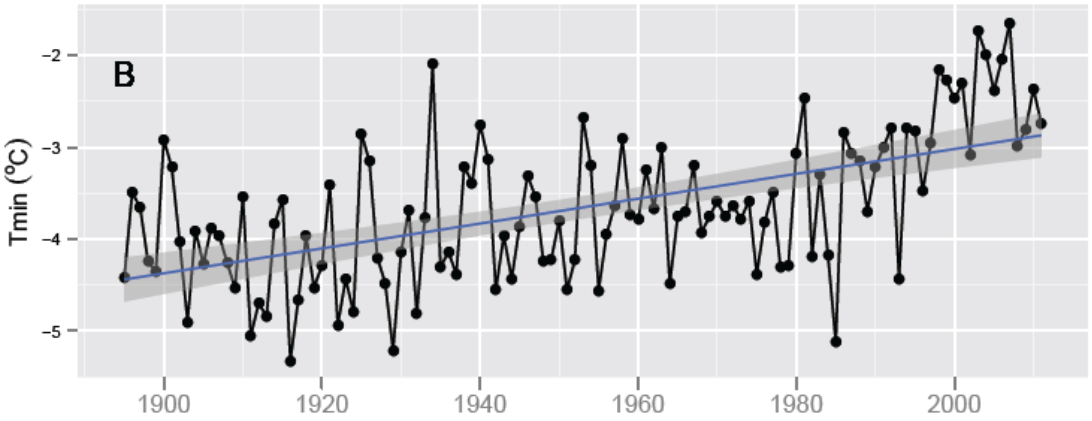
Past to Present: Trends and Magnitude

Maximum and Minimum Annual Temperature

GYE PACE



1.3 F⁰ / 100 yrs



2.3 F⁰ / 100 yrs

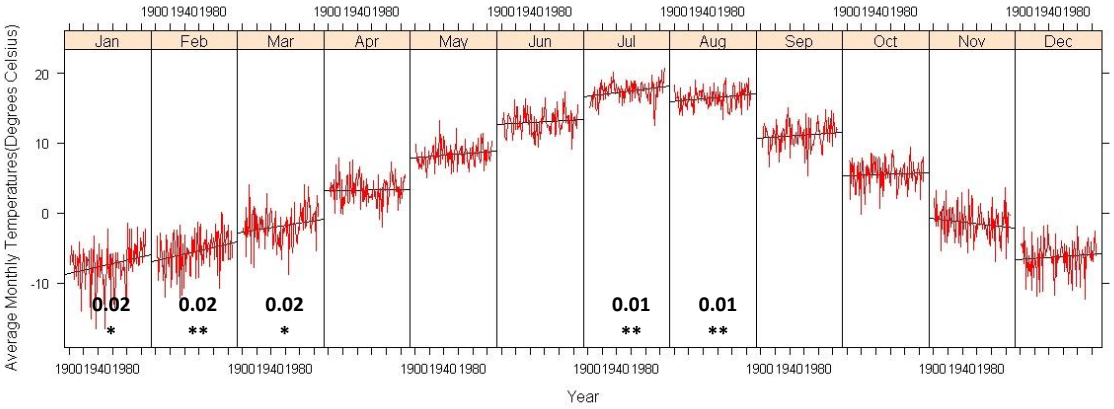
Data: PRISM (Daly 2002)

Chang et al. in prep

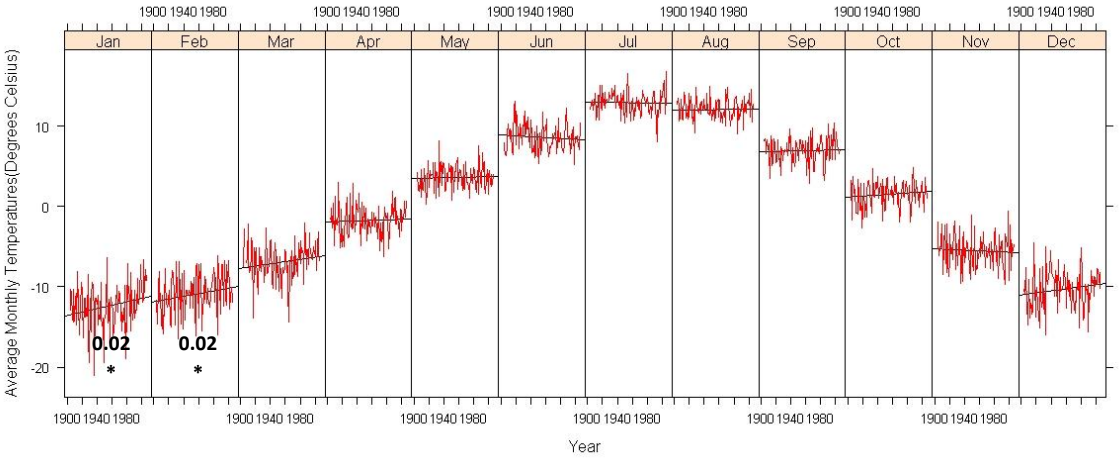
Monthly Temperature Trends
(slope, sig)

Past to Present: Trends and Magnitude

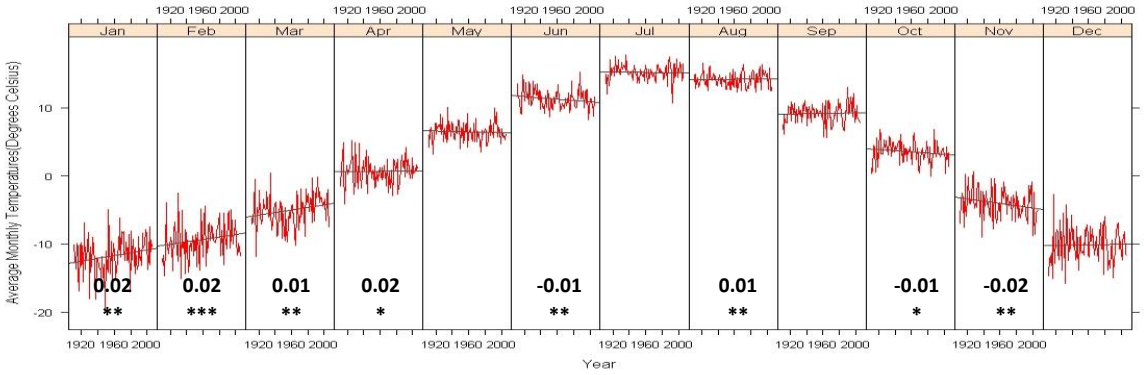
Mammoth



Yellowstone Lake



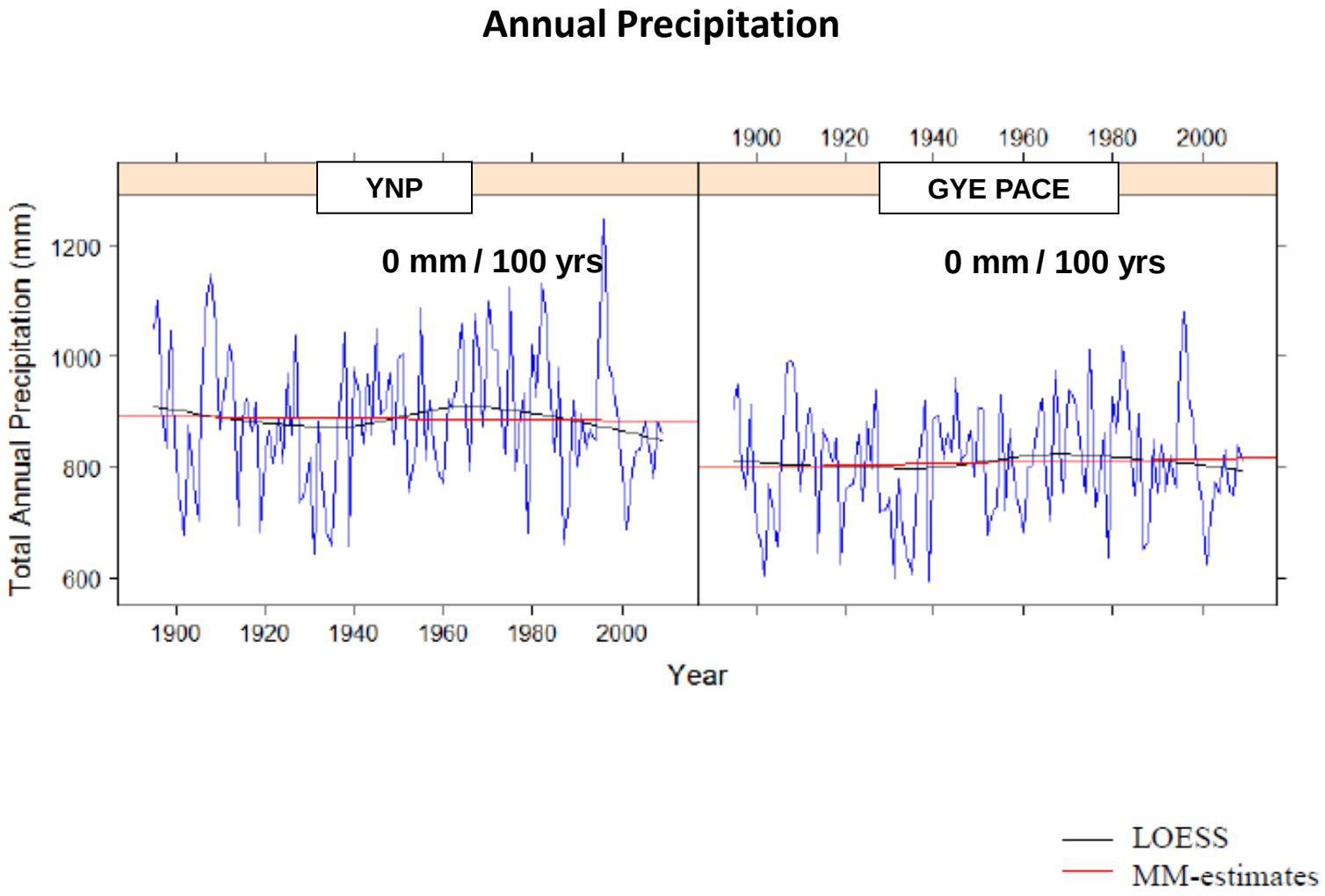
Moran



Data: Met Station (Williams et al. 2008)

Hass 2010

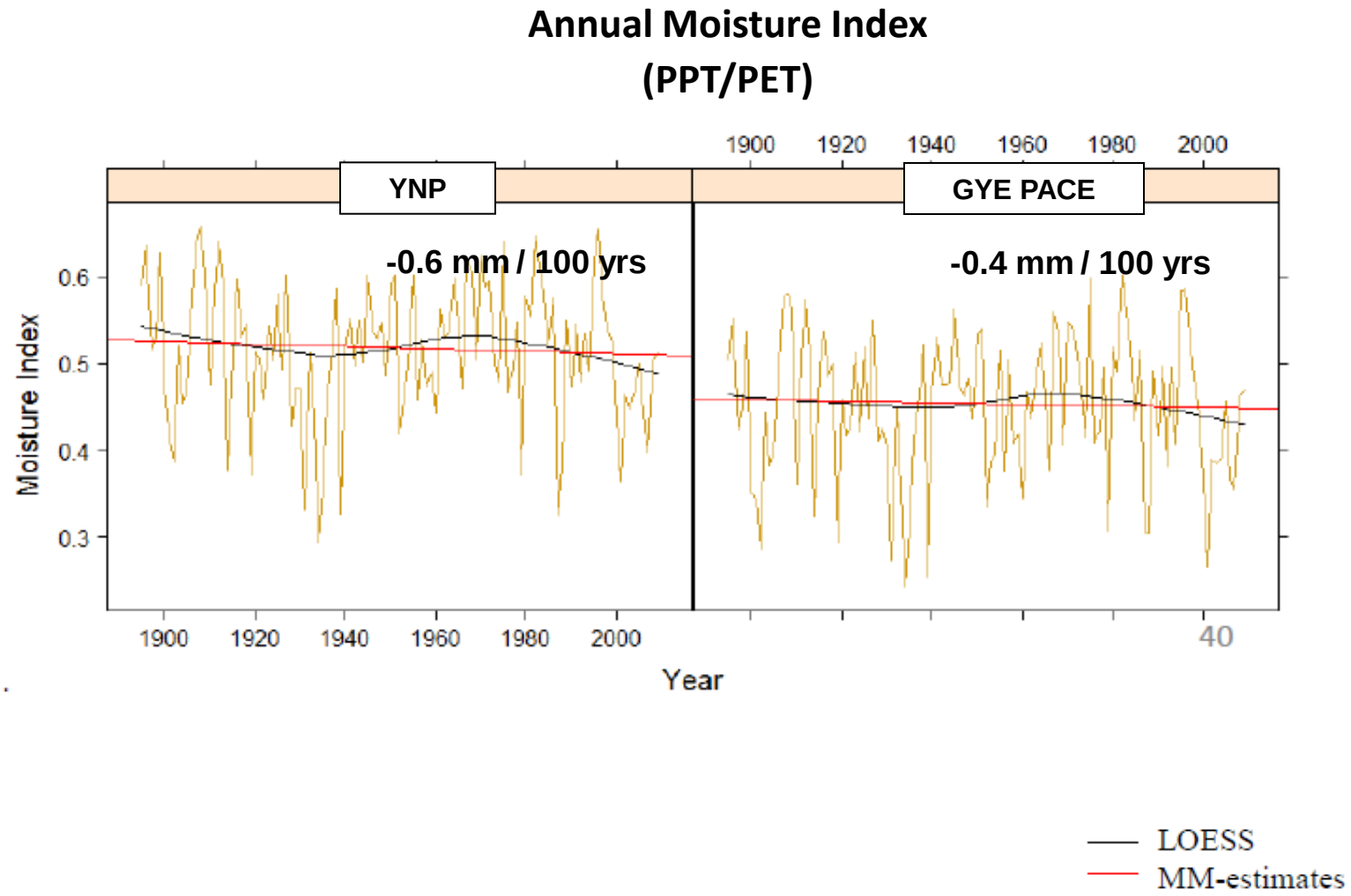
Past to Present: Trends and Magnitude



Data: PRISM (Daly 2002)

Hass 2010.

Past to Present: Trends and Magnitude



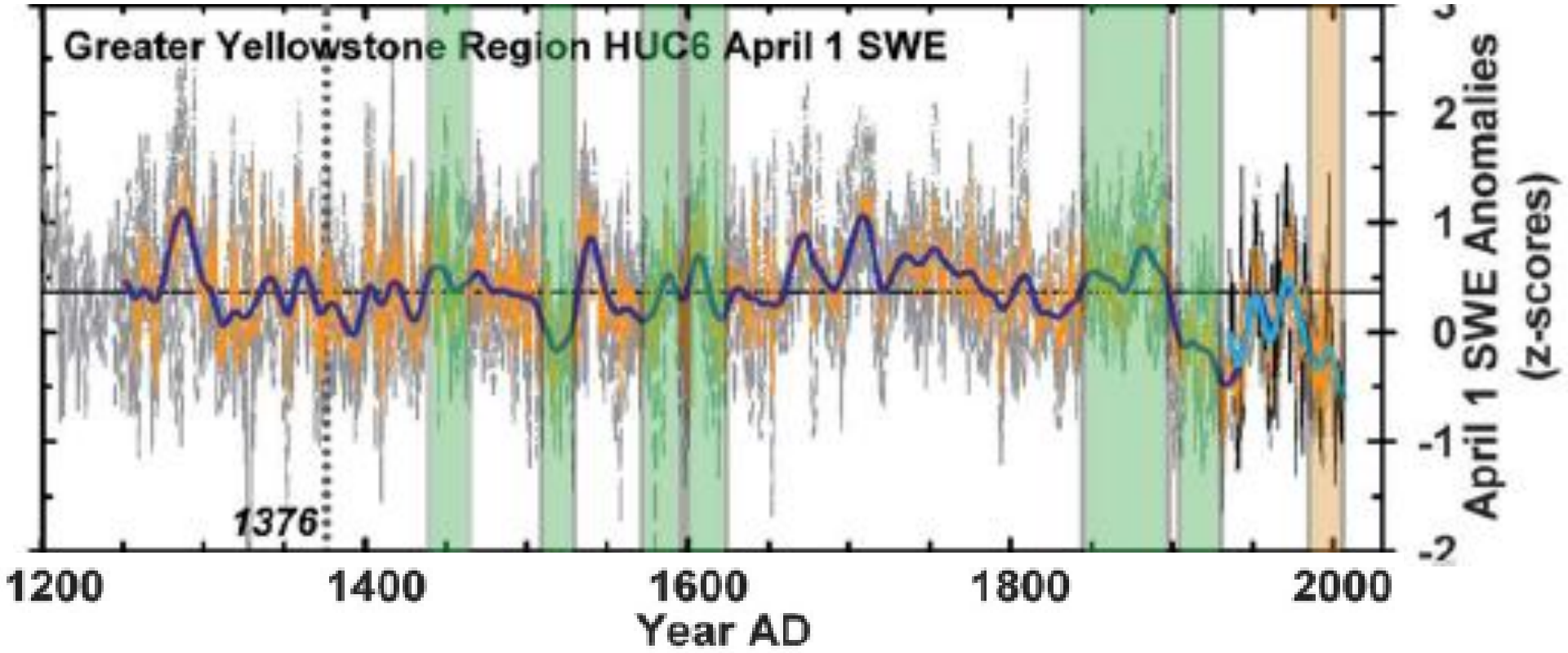
Data: PRISM (Daly 2002)

Hass 2010.

Past to Present: Trends and Decadal Variation

Snow Pack

- Dark blue line - 20-year spline of the regional SWE average
- Light blue line - 20-year spline of observed records
- Shaded intervals - decadal-scale SWE anomalies

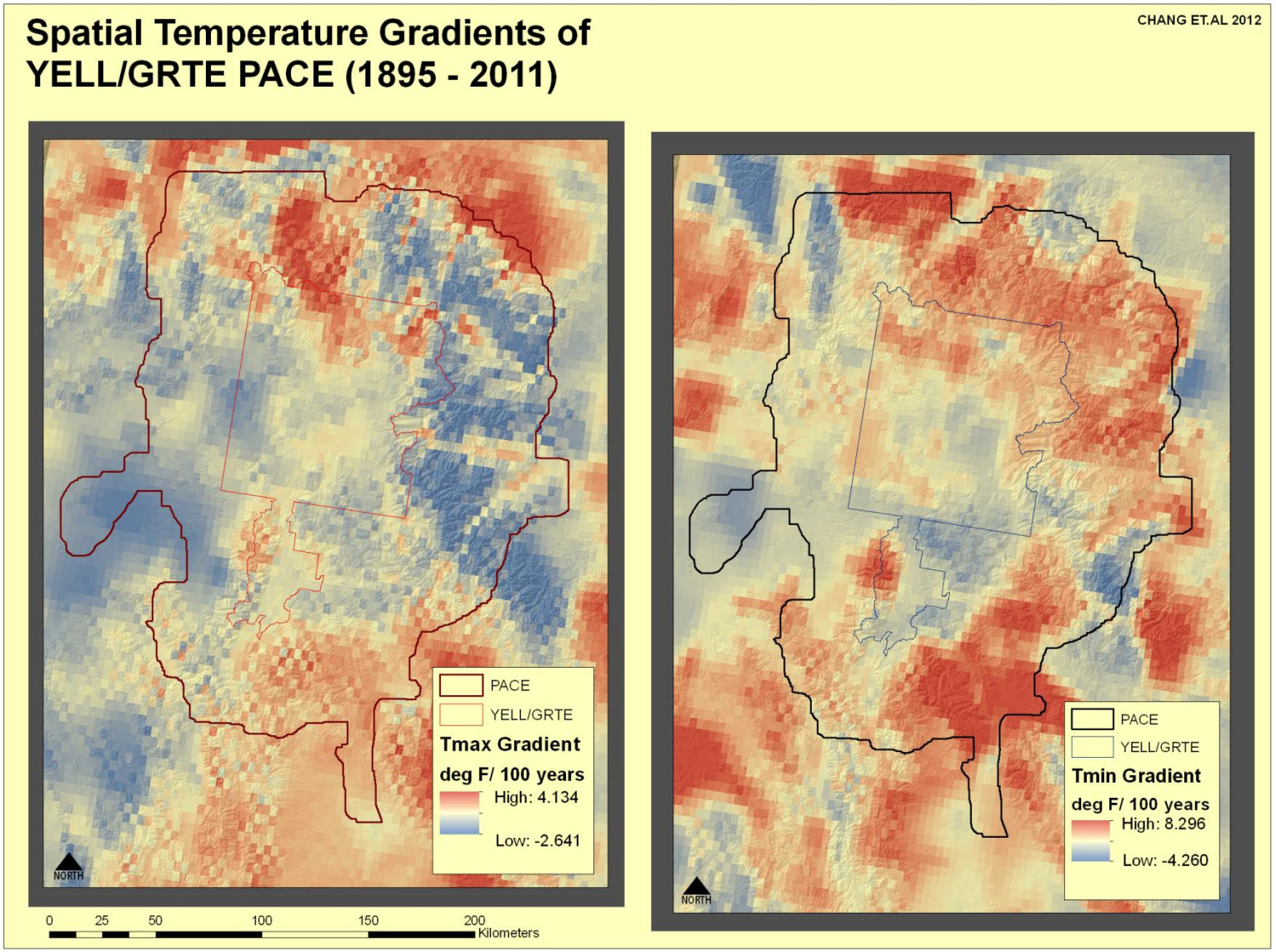


- Current SWE is ~20% lower than the long term average.
- Since 1900, spring temperatures are the primary driver of change in snowpack
- In the past 800 years, only 1300-1330 and 1511-1530) had low snowpack comparable with post 1900.
- Pronounced decadal variability due to ocean temperature effects complicates human induced warming.

Data: SNOWTEL obs and tree ring reconstructions

Pederson et al. 2011.

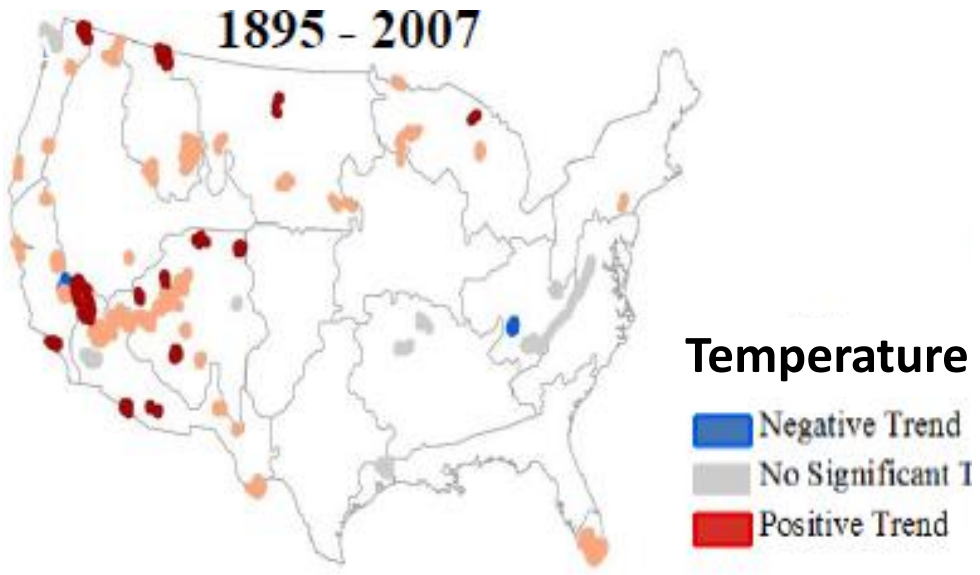
Past to Present: Spatial Variation

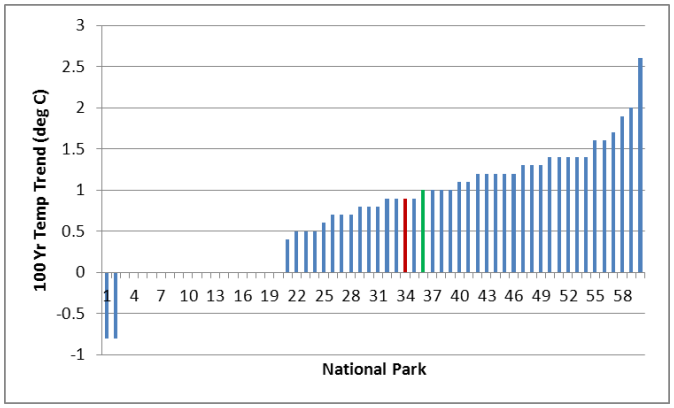


Data: PRISM (Daly 2002)

Chang et al. in prep

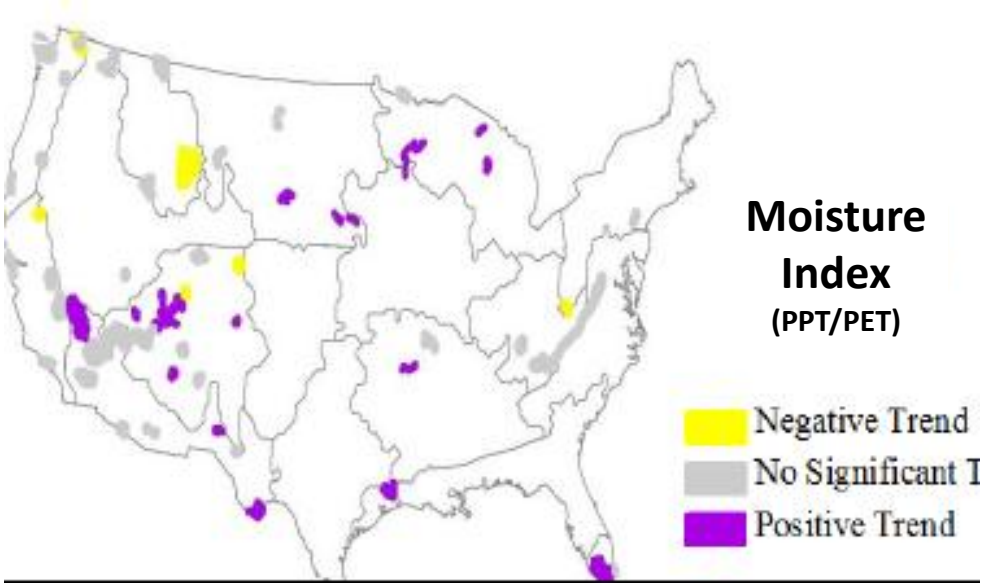
Past to Present: Comparison with other PACEs

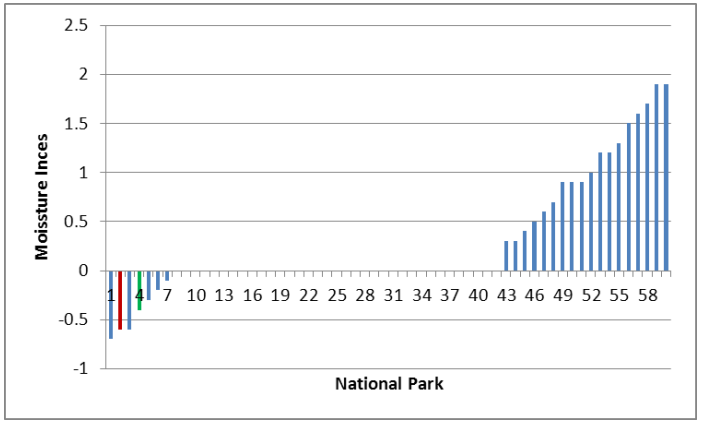




YELL

GRTE





Data: PRISM (Daly 2002)

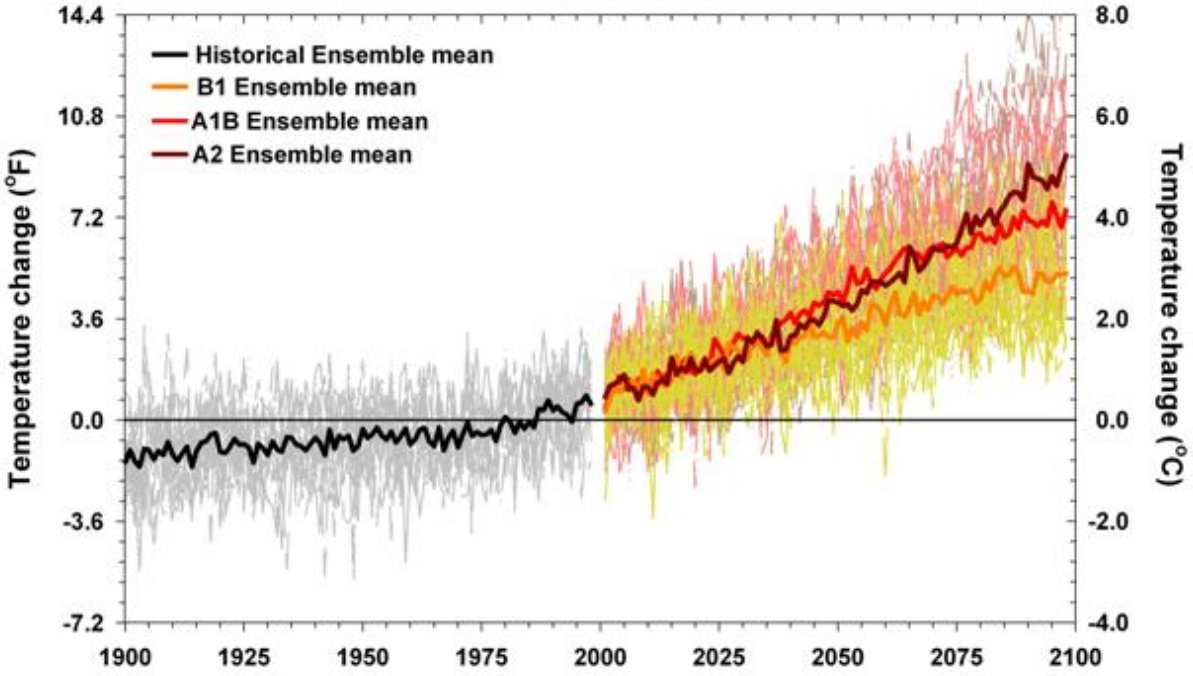
Hass 2010

Past to Present: Summary

- **Average annual temp has increased ca 1.8 F^0 in the last 100 years, a level typical for the US.**
- **The warming is most pronounced in winter and spring.**
- **PPT has not changed sig.**
- **Moisture index has declined due to increased ET associated with the warming, this drying trend is nearly the largest among 60 US parks.**
- **SWE is as low now as anytime in the last 800 yrs, largely due to warmer spring temps (ca 20% below the 500-yr average)**
- **100-yr trends must be interpreted with caution due to "natural" 10-50 yr oscillations.**
- **Spatial variation in climate change past to present is high, which poses challenges for management.**

Northern Rockies

Projected Future



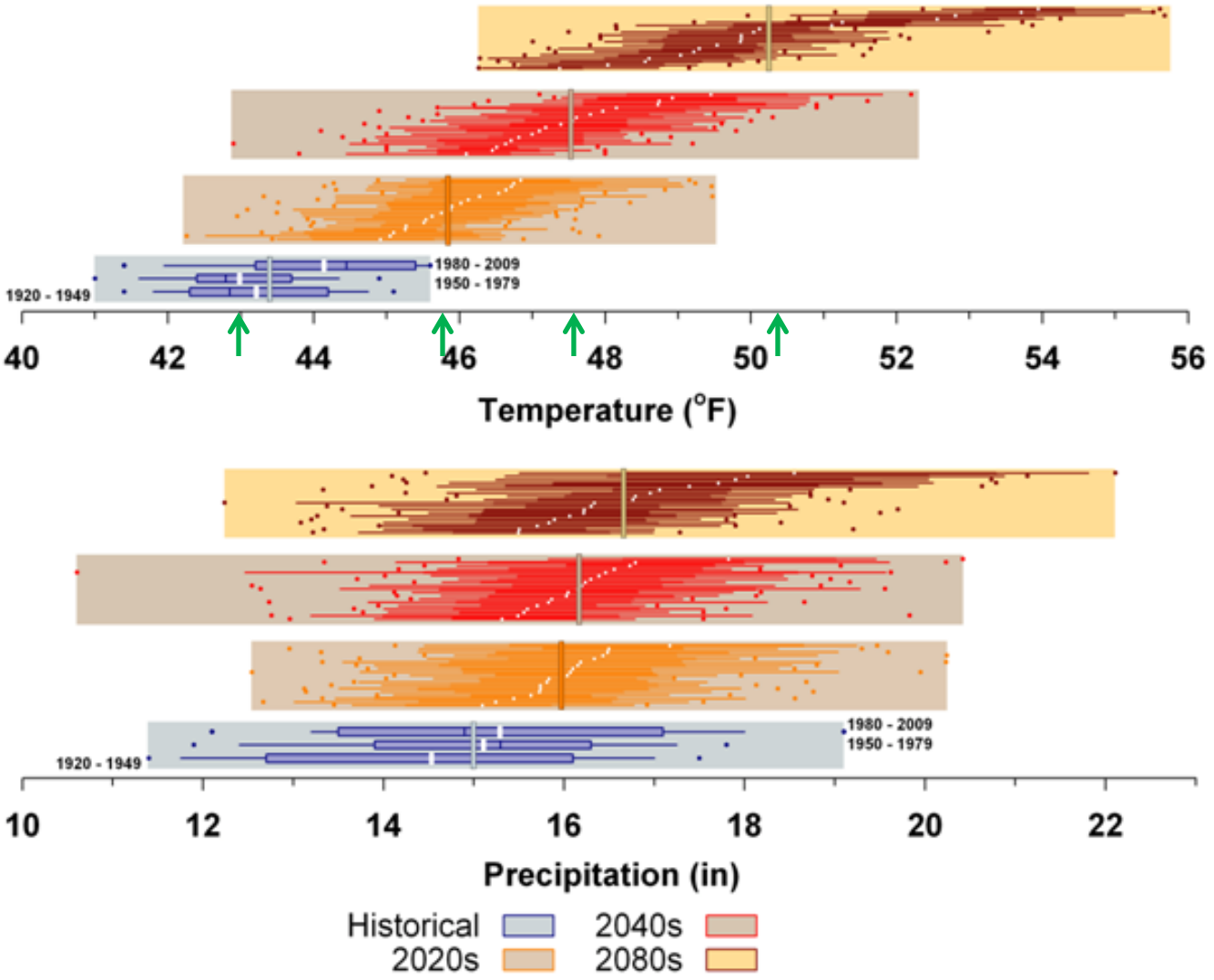
	Temperature change (° F)		Precipitation change (%)	
	B1 (low)	A1B (med.)	B1 (low)	A1B(med)
2020s	+2.1 (+1.2 to +3.9)	+2.3 (+1.3 to +3.3)	+3 (-27 to +29)	+3 (-14 to +25)
2040s	+3.0 (+1.5 to +5.5)	+3.9 (+2.5 to +5.9)	+1 (-18 to +20)	+7 (-2 to +34)
2080s	+4.8 (+3.2 to +7.9)	+6.7 (+3.8 to + 10.4)	+8 (-8 to +27)	+10 (-12 to +36)

(relative to 1970 -1999)

UW Climate Impacts Group

Northern Rockies

Projected Future

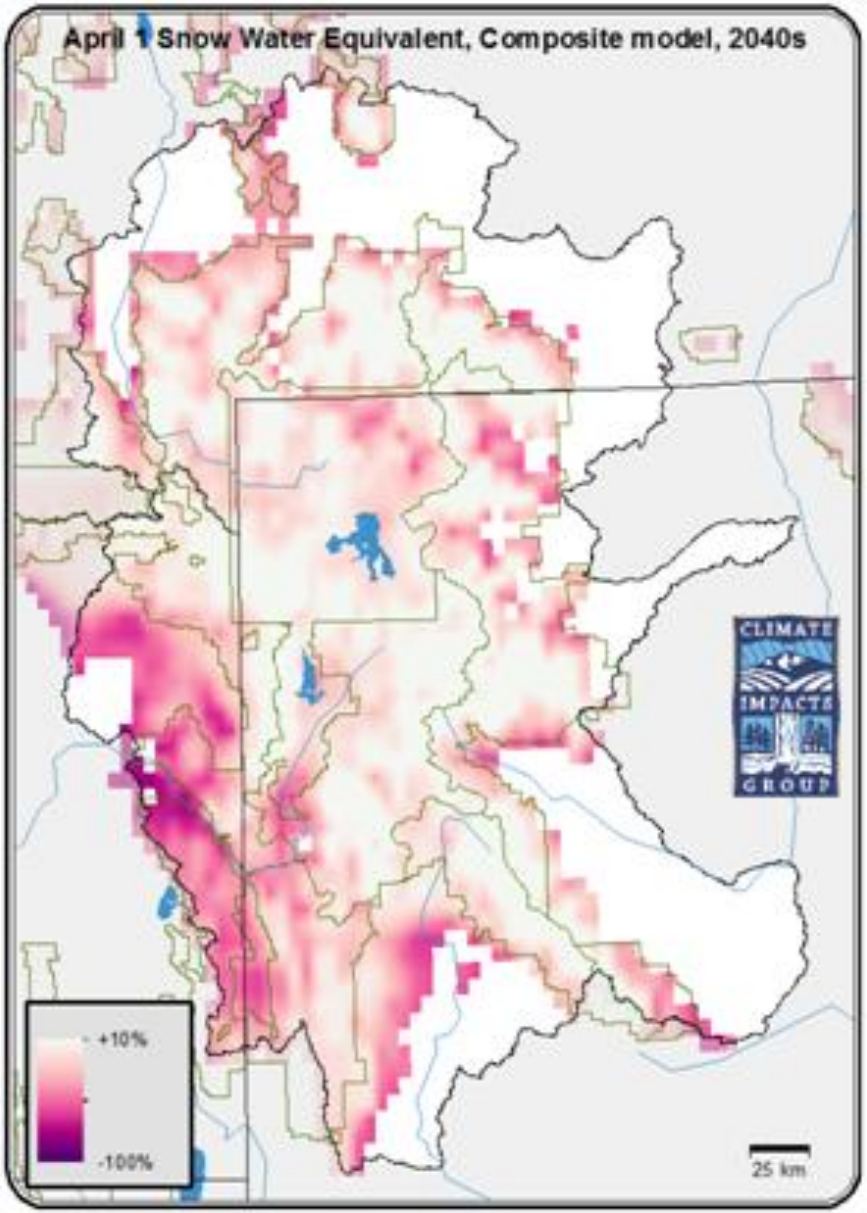


UW Climate Impacts Group

Projected Future

Snowpack

The average across 10 models is a decline in April 1 SWE of -34% averaged over the GYA in the 2040s.

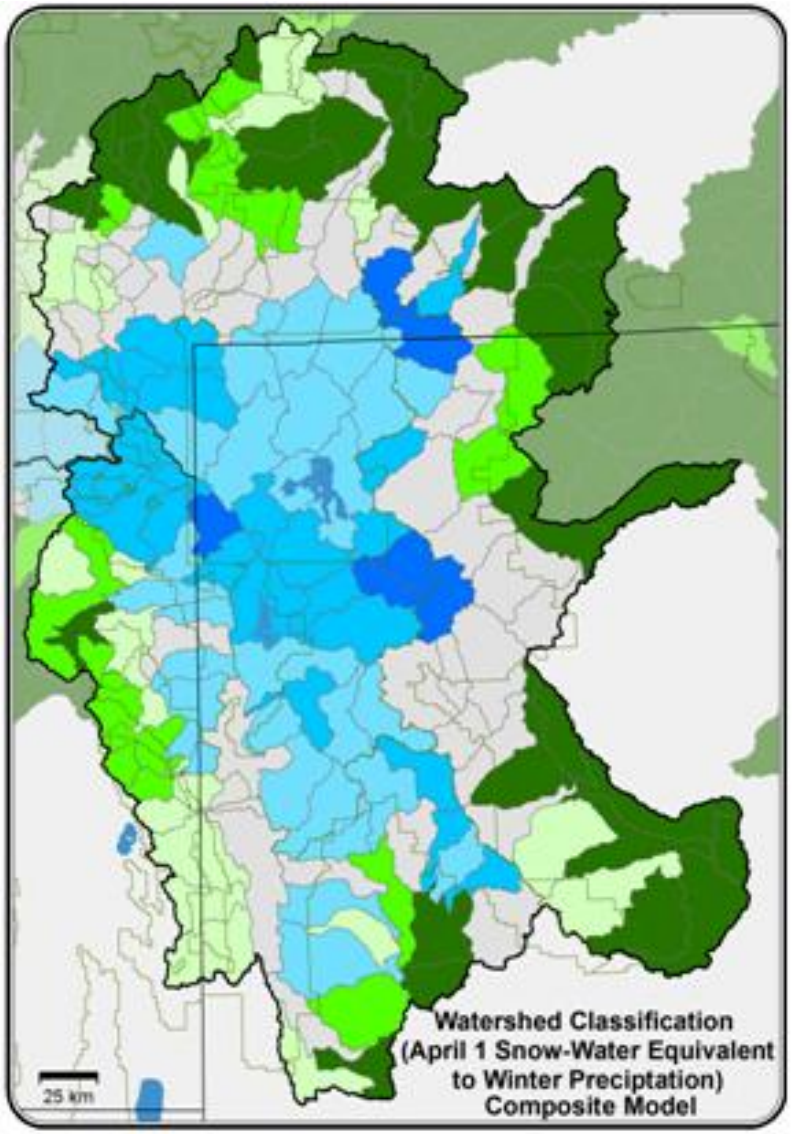


UW Climate Impacts Group

Projected Future

Snow Pack

- Some watersheds remain transitional
- Most historically transitional watersheds become rain dominant
- Most historically snow dominant watersheds become transitional.

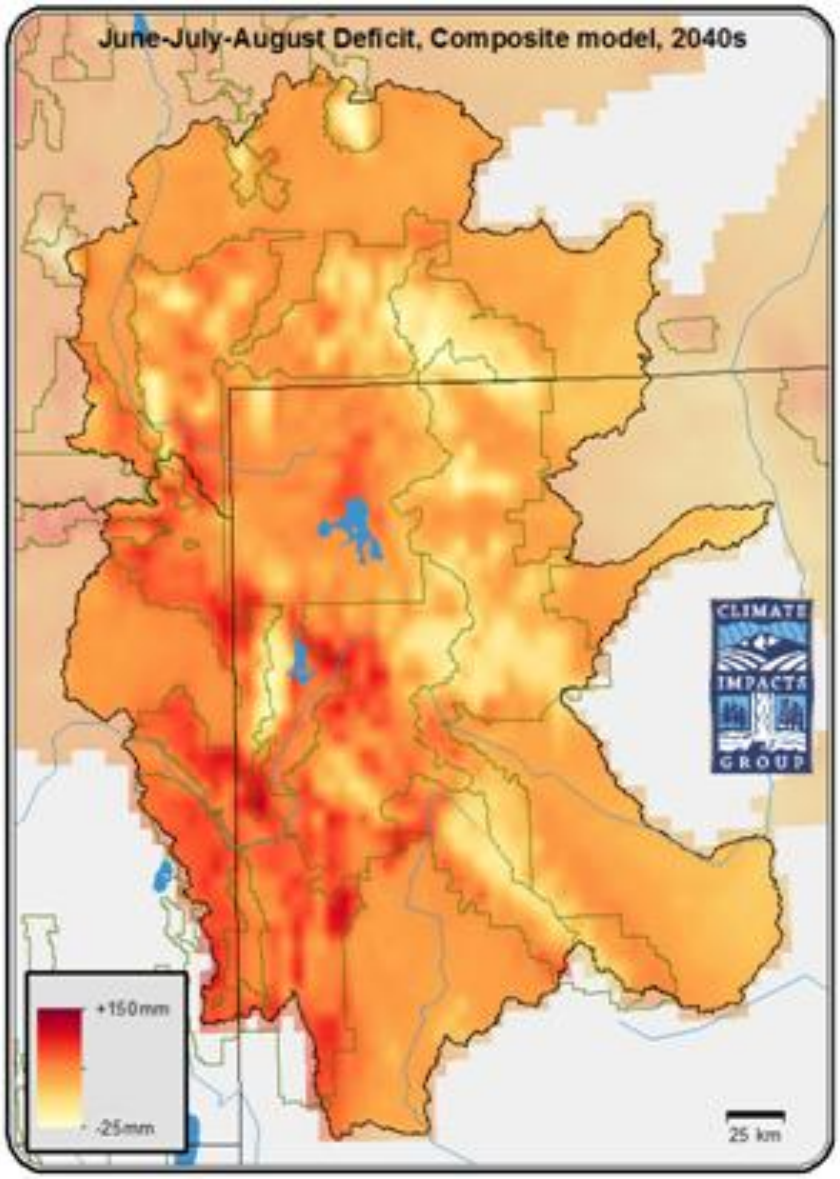


UW Climate Impacts Group

Projected Future

Water Deficit
(PET-AET)

For the 2040s, deficit increases by +31% (+30mm) averaged across he GYA.



UW Climate Impacts Group

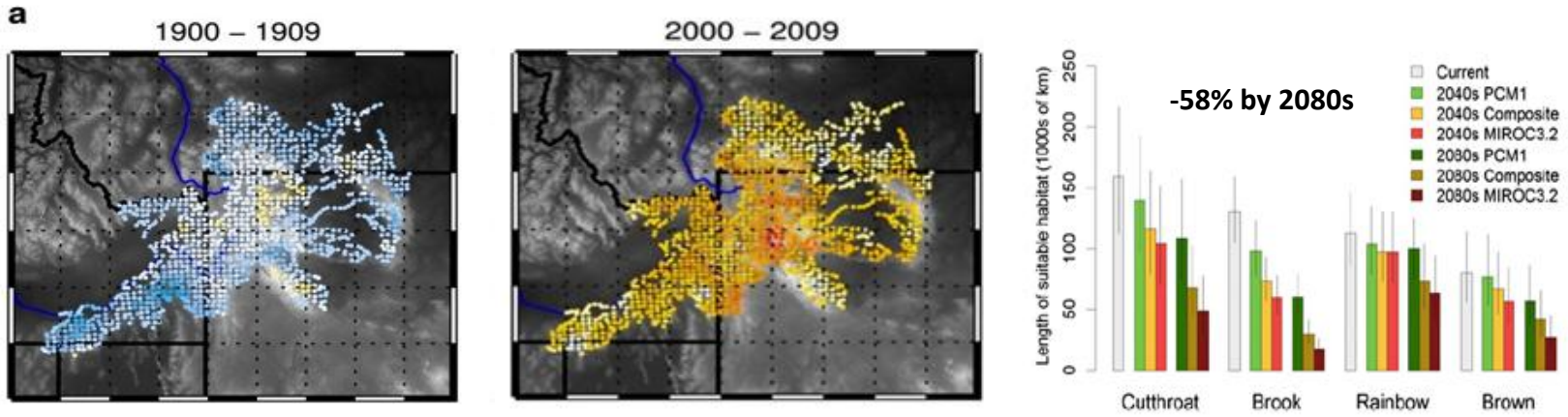
Greater Yellowstone Area Summary of Climate Change Projections 1900 to 2090

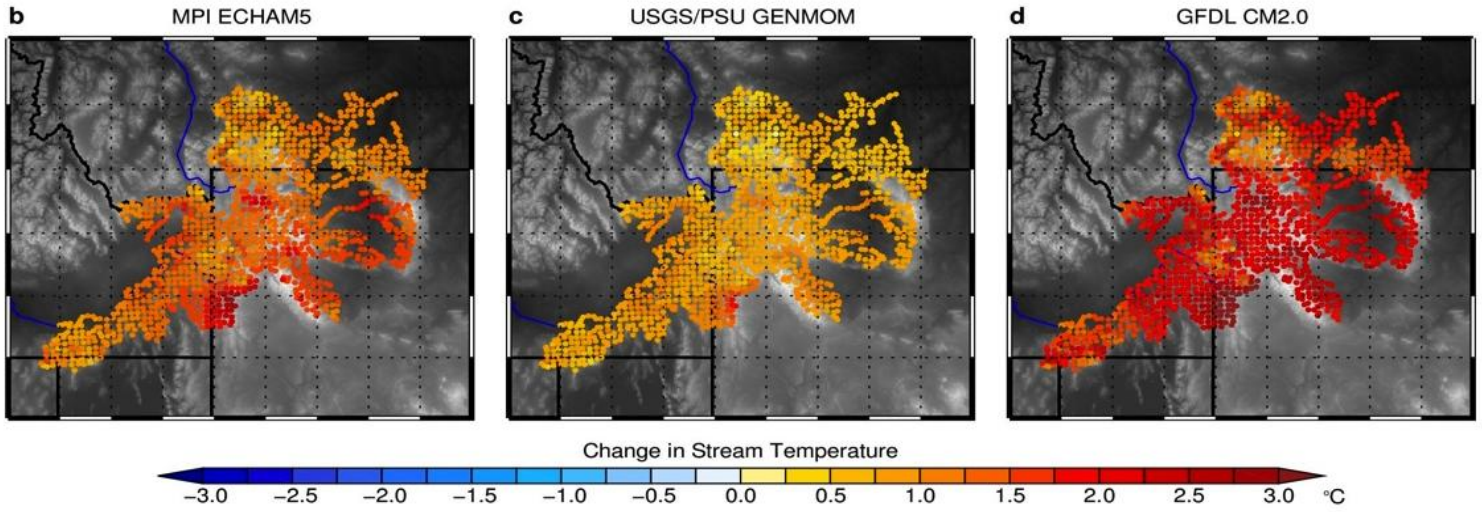
Climate Variable	Trend	Change since 1900	Projections for 2040s[1]	Projections for 2080s[1]	Source[3]
Temperature Ave ann F^0		2.0 C^0 / 100 yrs	+3.9 (+2.5 to +5.9)	+6.7 (+3.8 to +10.4)	Haas 2010 UW Climate Impacts Group
Precipitation Ave ann % rel to 1970-1999		0	+7 (-2 to +34)	+10 (-12 to +36)	Haas 2010 UW Climate Impacts Group
Moisture Index PPT/PET		-0.4 mm / 100 yrs			Haas 2010
Water Deficient PET-AET % rel to 1970-1999			+31%		UW Climate Impacts Group
Snow Pack April 1 SWE % rel to 1970-1999		~20% lower than 500-year average	-34%		Peterson et al. 2011 UW Climate Impacts Group

Ecological Impacts

Stream Temperature and Trout Habitat

GYE





Hostetler & Alder unpublished

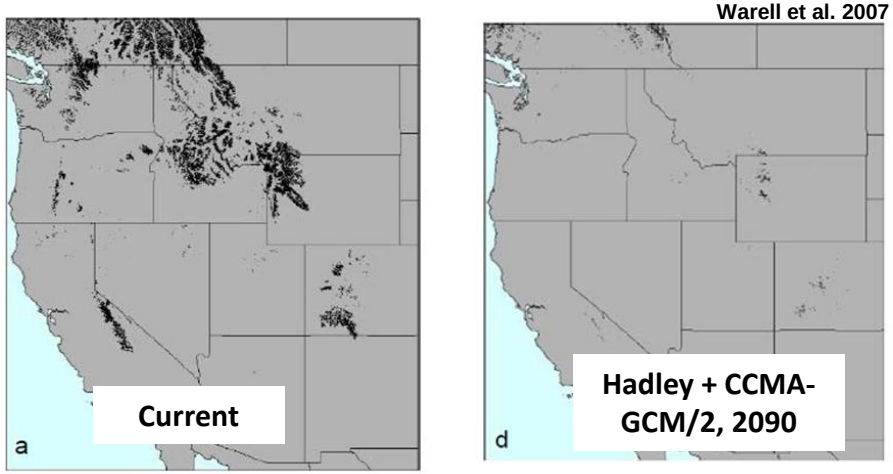
UW Climate Impacts Group

Ecological Impacts

Vegetation Types

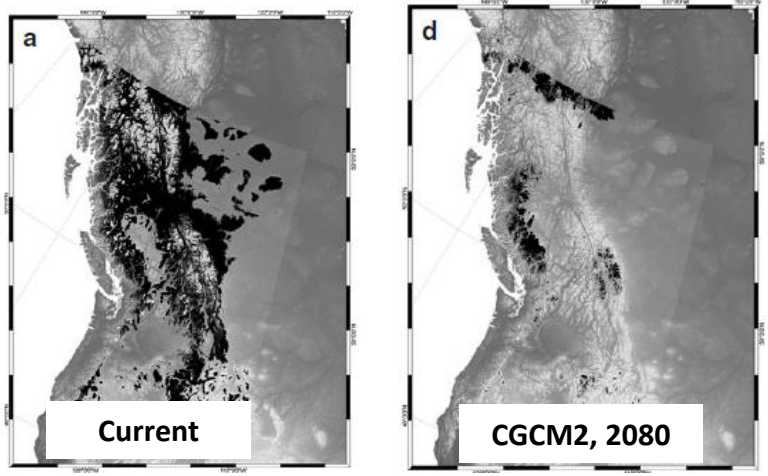
Whitebark Pine

Warell et al. 2007



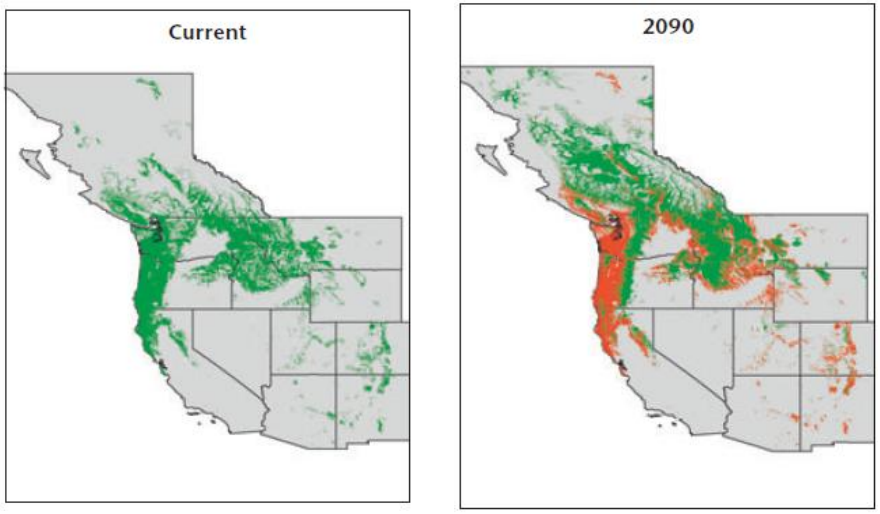
Lodgepole Pine

Coops and Waring 2011



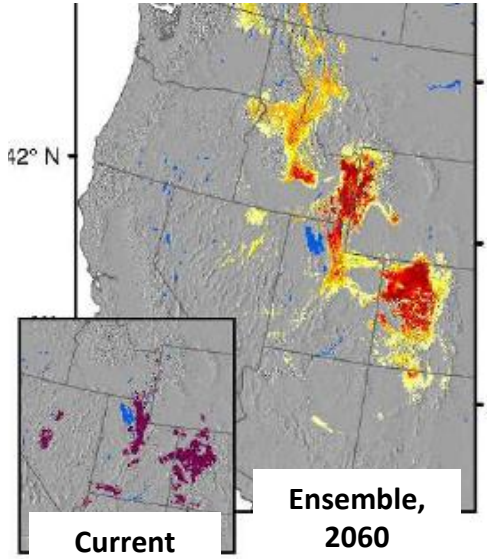
Douglas-fir

Weiskettel et al. 2012



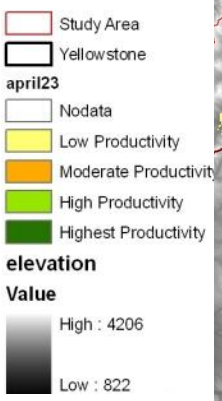
Great Basin Montane Scrub

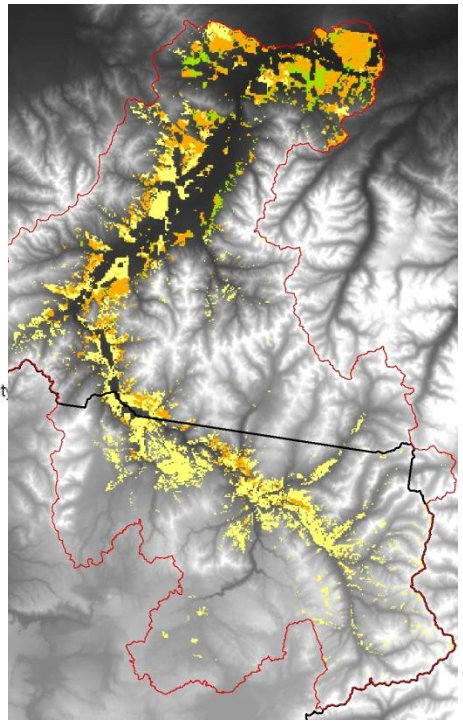
Rehfeldt et al. 2012

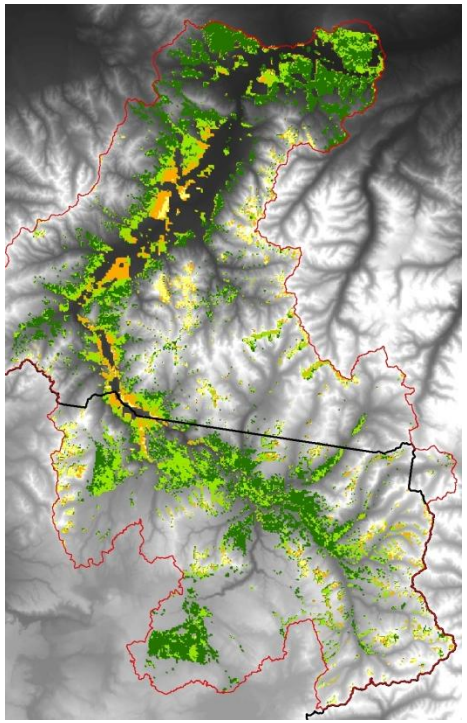


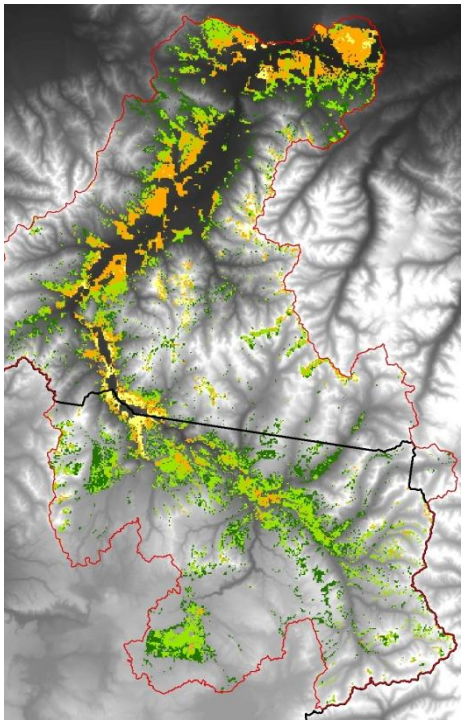
Ecological Impacts

Forage and Ungulates







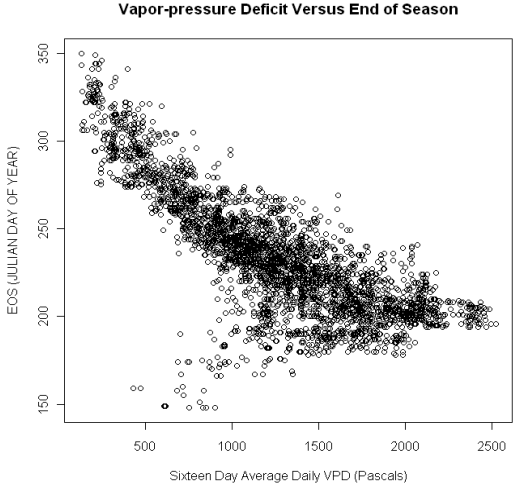


April 23, 2010

June 10, 2010

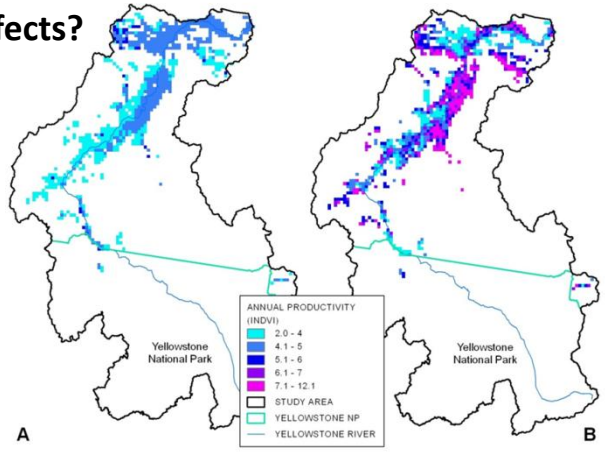
August 29, 2010

Climate Change Effects?

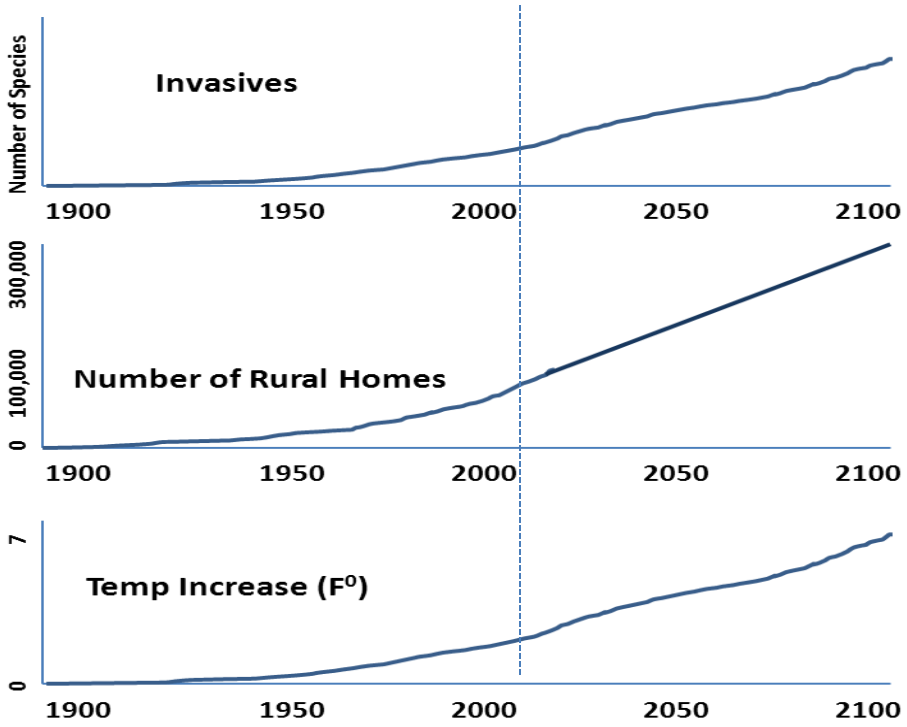


Land Use Change Effects?

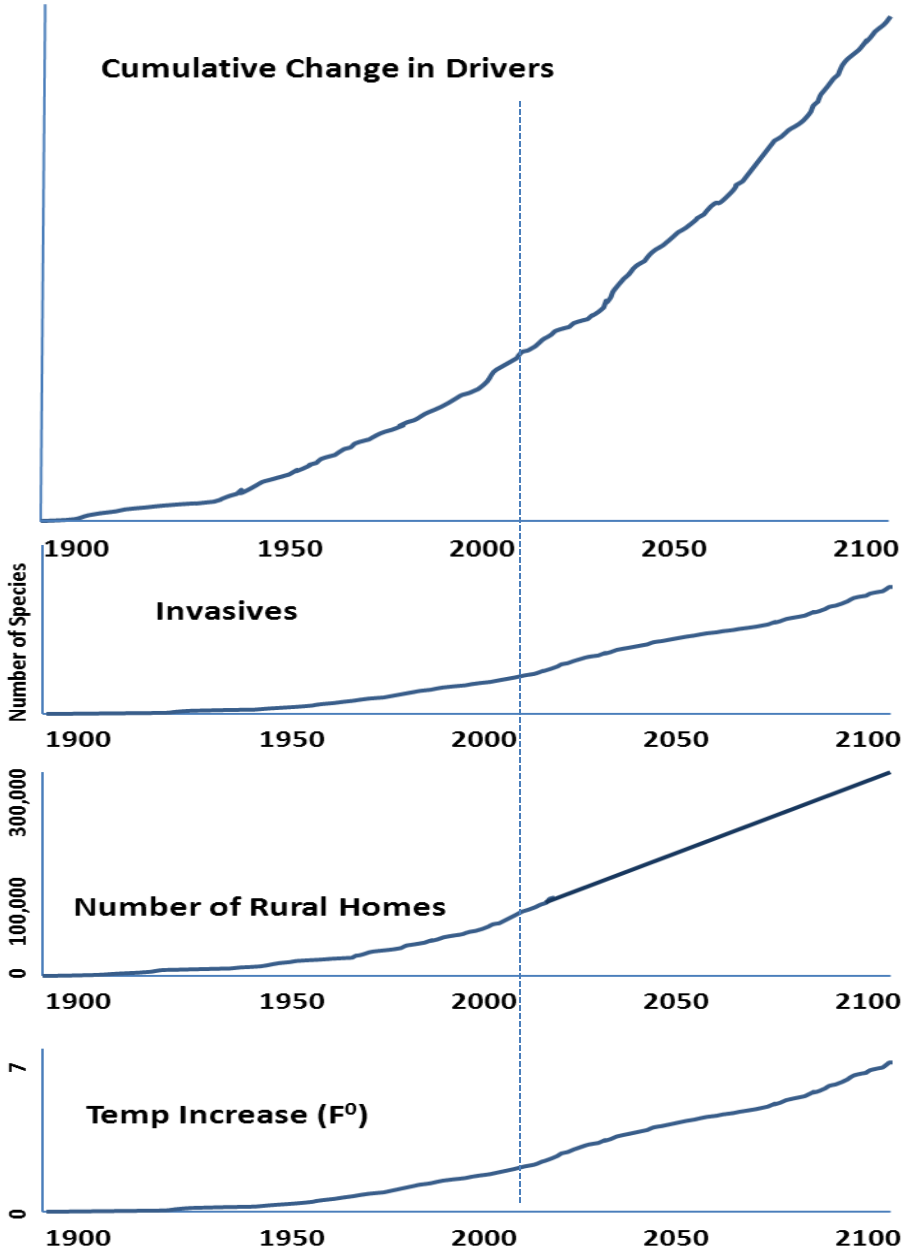
Piekielek 2012



Climate Change + Land Use Change + Invasives = ?



Climate Change + Land Use Change + Invasives = ?



Climate Change Past to Future: Take Home Messages

- **Averaging over the GYA, precipitation has changed relatively little and that is forecast to continue into the future.**
- **Temperature, snowpack, and water balance have changed substantially since 1900 and are forecast to change faster by 2040 and 2080. GYE is becoming hotter, drier, with less snow.**
- **“Natural” decadal oscillations in climate complicate understanding of human-induced climate change.**
- **Averaging over time or space hides the high amount of variability in climate change. E.g., Some locations within GYA are forecast to change very dramatically.**
- **Climate change must be considered in the context of land use change, and invasive species.**
- **The magnitude of climate change expected will have strong impacts on disturbance, vegetation, wildlife, and people.**