Landscape Climate Change Vulnerability Project (LCC_VP)

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Colorado State University:

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Clingman's Dome, Great Smoky Mountain NP

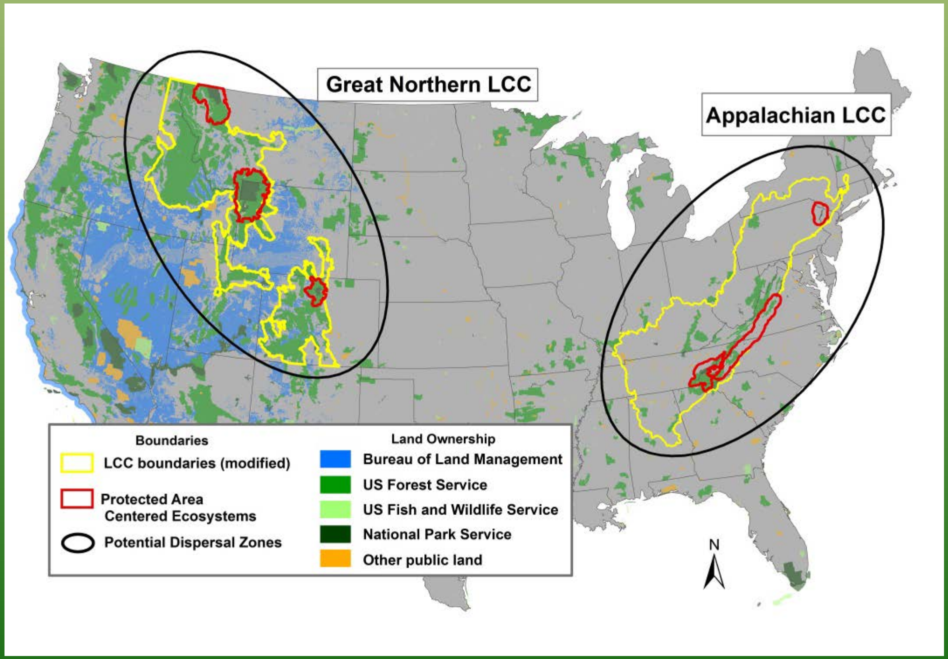
NASA Applied Sciences Program
(NNH10ZDA001N - BIOCLIM)

NPS I&M Program

Goals and Objectives

Goal

Demonstrate the four steps of a climate adaptation planning strategy in two LCCs using NASA and other data and models.



Activities for Year Two

1. **Linking with collaborators and assessing needs.**
2. **Synthesizing current knowledge to assess vulnerability.**
3. **Do new science to assess vulnerability.**
4. **Lay foundation to inform decision support and policy**

Link with Collaborators and Assess Needs

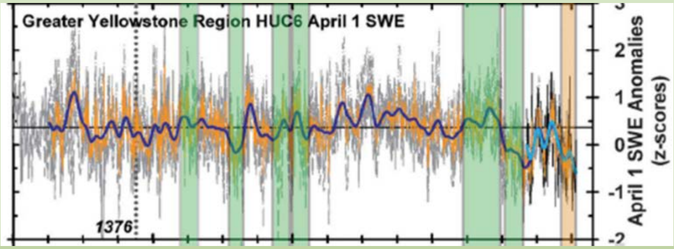
Organization	*Key Collaborators*	*Date*	*Needs We Can Address*
Greater Yellowstone Coord Comm Whitebark Pine Subcomm.	Virginia Kelly, Karl Buermeyer, Dan Reinhart, Nancy Bokino, Kristin Legg	April 2012	Effectiveness of “GYCC WBP Strategy” under future climate
Grand Teton NP Yellowstone NP JD Rockefeller Pky	Sue Consolo Murphy, Dave Hallac, Virginia Kelly, Kristen Legg, Kelly McClosky, Kathy Mellander, Dan Reinhart	July 2012	Multiple
Rocky Mountain NP	Ben Bobowski, Judy Visty, Jeff Connor, John Mack, Larry Gamble, Jim Cheatham, Mary-Kay Watry, Nate Williamson	Nov 2012	Climate, land use, ecosystem interactions Limber pine Collaborative management among agencies
Yellowstone NP	Dave Hallac, Ann Rodman, P.J. White, Roy Renkin,	Nov 2012 Jan 2013	Whitebark pine – grizzly bears Grassland phenology YNP climate change program direction: Monitoring, Vulnerable resources, Management options
Great Smoky Mt NP Shenandoah NP App. Highlands I&M	Jim Renfro, Jeff Troutman, Tom Remaley, Jim Schaberl, Paul Super, Jeb Wofford	Nov 2012	Vegetation comm (6 across elevation range) PACE methods Land use legacy in parks
Delaware Watergap	Rich Evans, Mathew Marshall, Leslie Moorlock	Nov 2012	Hemlock vegetation community Land use / hydrology

Synthesize Current Knowledge

Historical Climate Observations

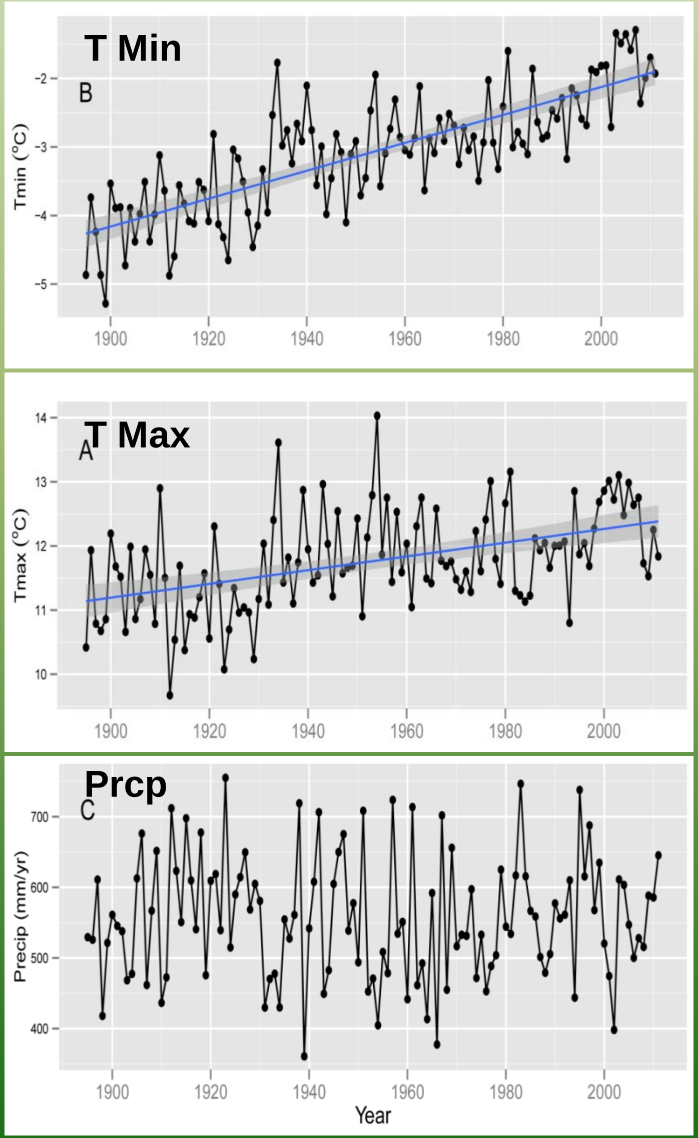
Greater Yellowstone Ecosystem

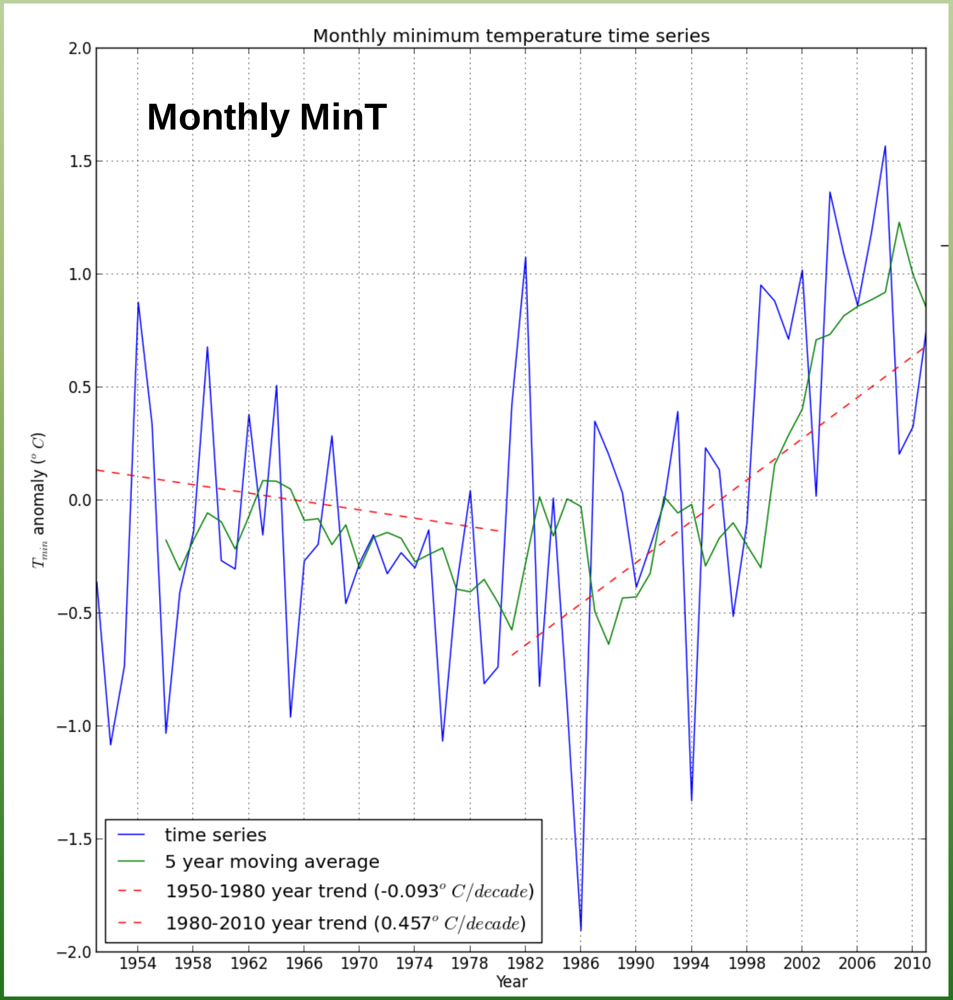
Snow water equiv.



Pederson et al. 2011.

Rocky Mountain National Park





John Gross, PRISM Data

Tony Chang, Met station and PRISM data

Synthesize Current Knowledge

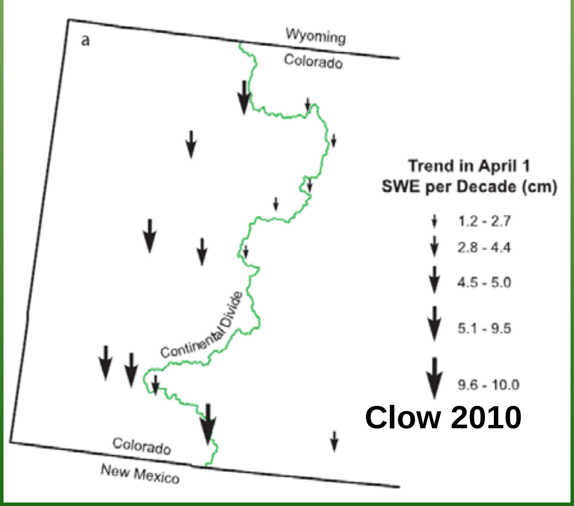
Key Climate Patterns and Ecological Consequences

John Gross

Rocky Mountain NP Climate Change Drivers

Climate Variable	Trend	Relative Change by 2050	Projections for 2050s	Confidence	Source / Comments
Temperature (change from 1960-1990; x + SD)	↑	Large	2.7 + 0.7 C (4.9 + 1.3 F) Warming greater in summer	Very likely	CMIP3 ensemble for 1 degree cell including RMNP*
Extreme high temperatures	↑	Large	1-in-20 year mean maximum temperature Likely to increases by 2-3 C (3.6 -5.4 F). 1-in-20 year maximum temperature events Likely to occur 1-in-2 to 1-in-4 years.	Likely	IPCC 2012
Mean precipitation (% change from 1960-1990; x + 1 sd)	↔	Small	1 + 7.2 %	About as likely as not	CMIP3 ensemble for 1 degree cell including RMNP*
Evaporation	↑	Moderate	Increase due to temperature; difficult to quantify	Likely	
Intense precipitation events	↑	Moderate	"Marked" increase in 24-hr precipitaton for 2040-2070 period. 50-70% increase in event maxima.	Likely	
Snowfall (April 1 SWE)	↓	Moderate	2050: -15 to -30%	Likely	
Streamflow	↔	Small	No change to slight decrease	About as likely as not	
Drought	↑	Moderate	Difficult to quantify. Likely result of higher temperatures, increased evaporation, and perhaps increased variation in precipitation.	Likely	
Hail	↓	Large	Almost complete elimination of surface hail	Likely	

Category	Topic	Trend	Comments
Fire	Pests and fire	↑	Controversy about the impact of bark beetle infestatiosn on fire behavior can be partly be attributed to differences in the time since outbreak, and fuels or fire characteristics. Although many studies report that beetle outbreaks were not as important as other factors in driving fire behavior, extent, or severity, the impact of beetlekilled trees can become significant when compared with unattacked stand. Differences may depend on environmental conditions. E.g, effects may be manifested during intermediate wind speeds (Simard et al., 2011) or in moister conditions, such as earlier in the fire season (Steele and Copple, 2009)
	Wildfires	↑	Frequency, size, and duration of wildfires in the western U.S. have increased from 1970-1986 to 1987-2003. Increases are attributed to an average 78-day increase in the length of the wildfire season, increased spring-summer temperatures, and earlier spring snowmelt (Westerling et al. 2006). In lower-elevation montane forests of the Colorado Front Range, large fires are commonly preceded by wetter than average springs two to four years in advance that presumably increase fine fuel loads (Veblen et al. 2000). Wet antecedent conditions decrease as a contributing factor at higher elevations in the montane zone (Sherriff and Veblen 2008) and are considered unimportant in the subalpine zone where fuels are abundant (Sibold et al. 2006). Increases in non-native, annual grass invasions, may alter fire dynamics. If fires and other stand-replacing disturbances occur more frequently, the resulting landscape pattern may limit the size of future fires and total area burned (Collins et al. 2009). In Lodgepole pine forests of NW Colorado and S Wyoming, increases in drought, caused by climate change led to increases in wildfire; pine beetle infestations were found to be insignificant (Kulakowski & Jarvis 2011)
Human health	Disease	↑	Climate change may favor zoonotic disease transmission to humans through altered distributions of pathogens and disease vectors, increased populations of reservoir or host species, and increased prevalence of diseases within host and reservoir species. Disease likely to increase in scope and/or incidence in the region include hantavirus pulmonary syndrome, plague and West Nile virus. (Epstein 2001, Confalonieri et al. 2007) (Summarized by Loehman 2009) The IPCC states with very high confidence that climate change will increase the risk and geographic spread of vector-borne infectious diseases, including Lyme disease, and changes in precipitation will increase water-borne disease (Field et al. 2007).
	Human Health	↓	Effects of climate change on human health include increased incidence of heat stress and heat stroke, respiratory distress from pollutants released during wildfires, cardiorespiratory morbidity and mortality associated with ground level ozone, and injury and death from floods, storms, fires and droughts (Epstein 2001, Confalonieri et al. 2007).D26
Infrastructure	Facilities, Cultural Resources, Roads, Trails	↓	Increasing frequency and intensity of severe storms and floods may pose threats to historic structures, roads and trails, archeological sites, administrative facilities and other park resources and infrastructure. Increased summer temperatures may lead to increased utility in parks in the summer, and potentially, decreases in the winter. (Loehman 2009)The NPS has expressed concerns that several sections of the Trail Ridge road could buckle, subside or crack from melting ice within permafrost, although the presence of mountain permafrost in the park has yet to be validated (Janke, Williams and Evans 2011).

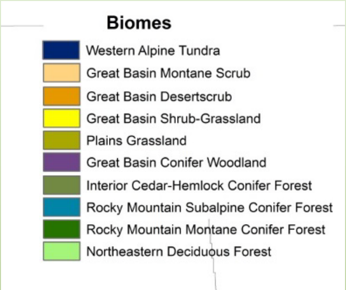


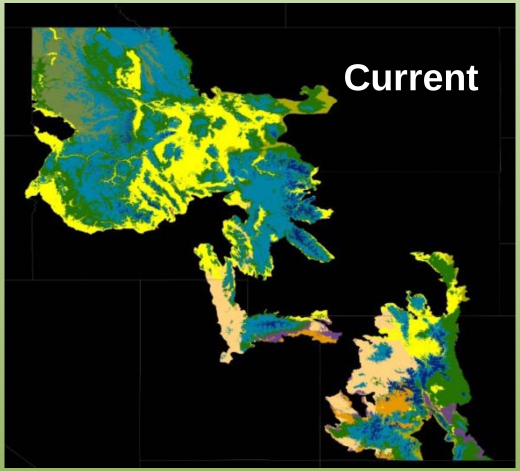
Clow 2010

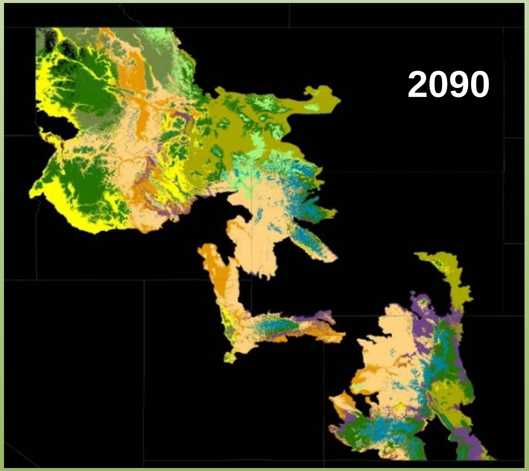
Linda Phillips

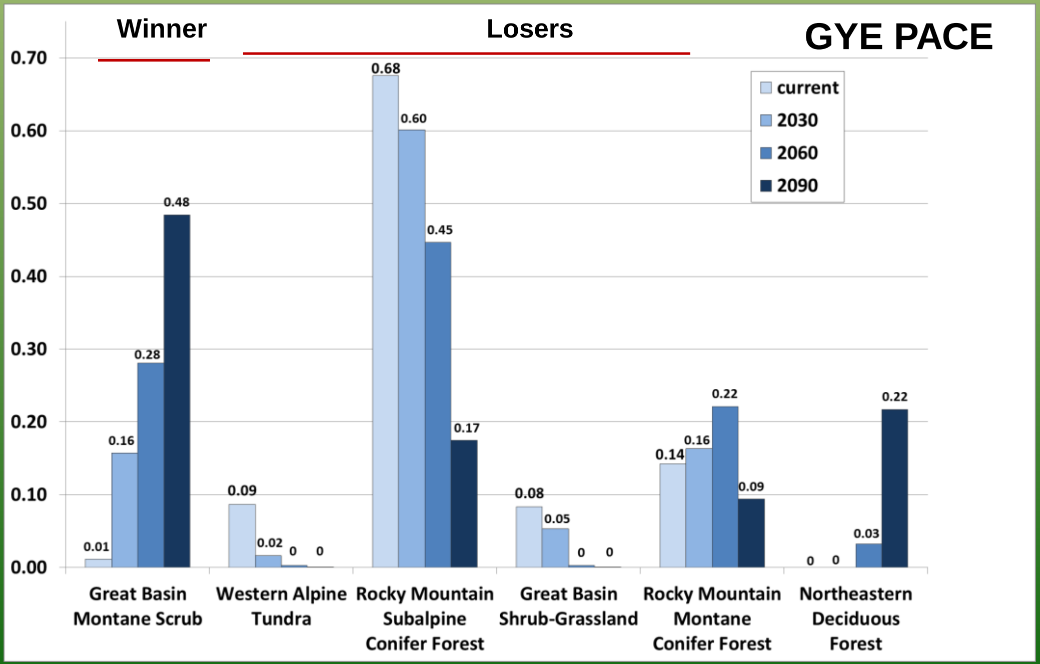
Synthesize Current Knowledge

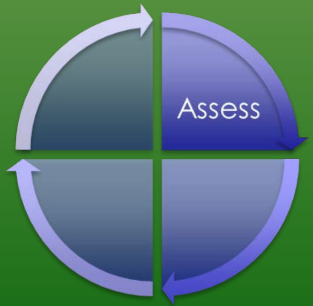
Great Northern LCC - Projected Biome Shift











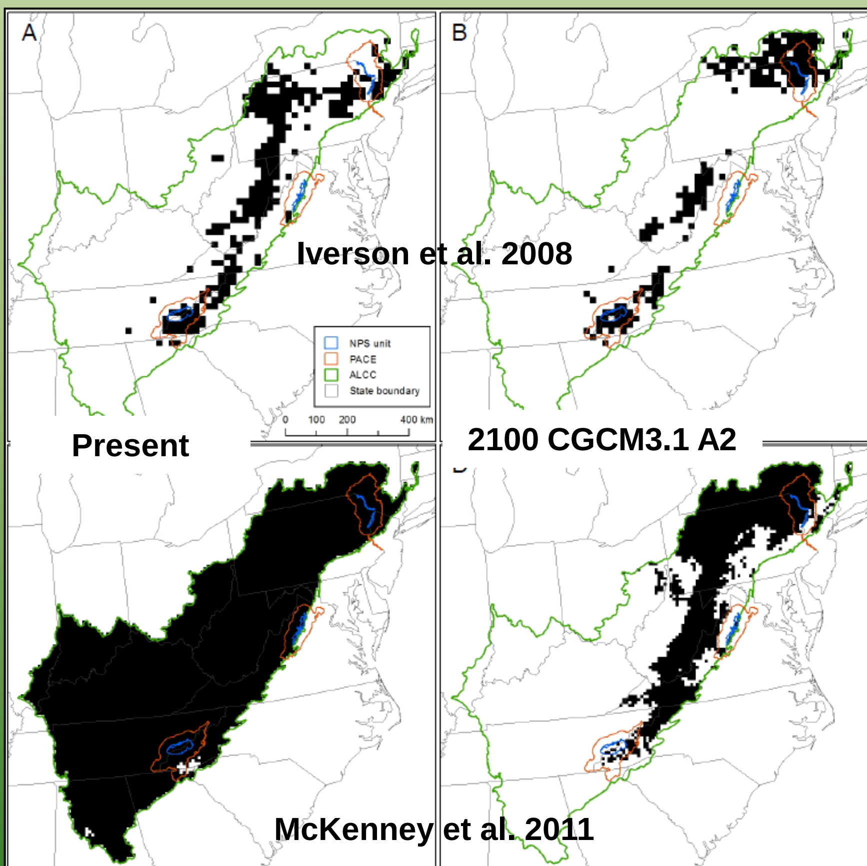
Data from Rehfeldt et al. 2012

Synthesize Current Knowledge

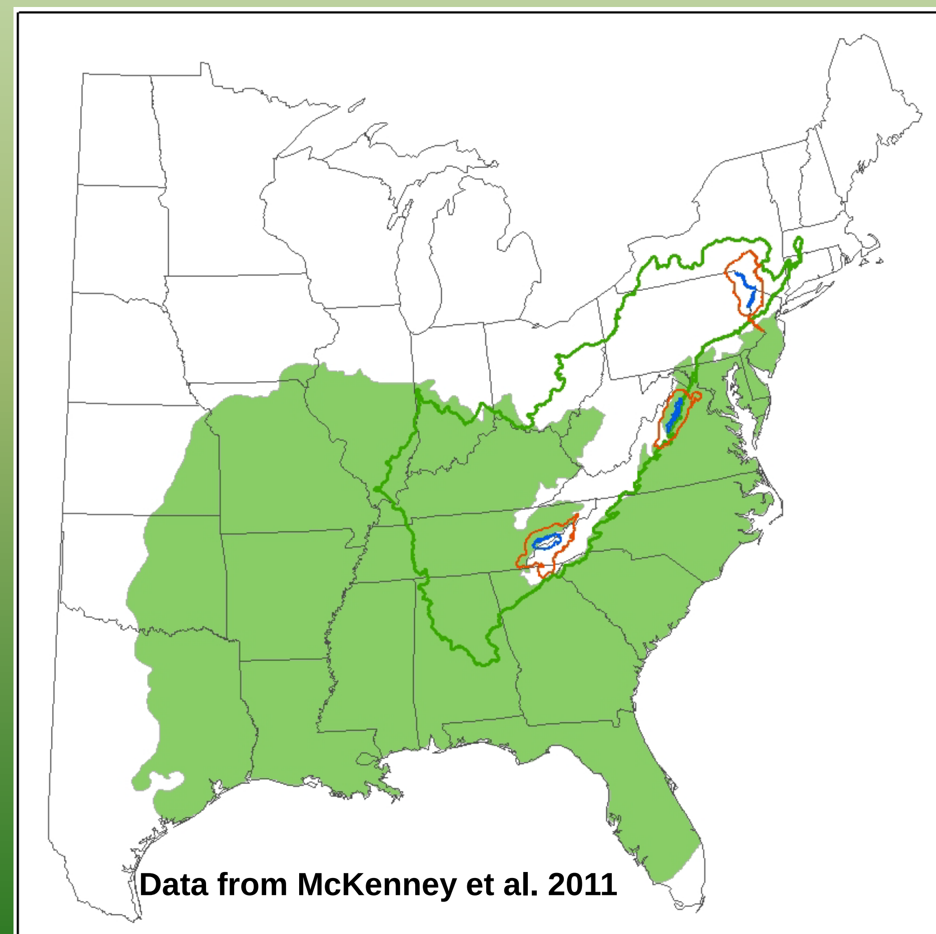
Scott Goetz et al.

Appalachian LCC

Cove Forest Modeled Distributions



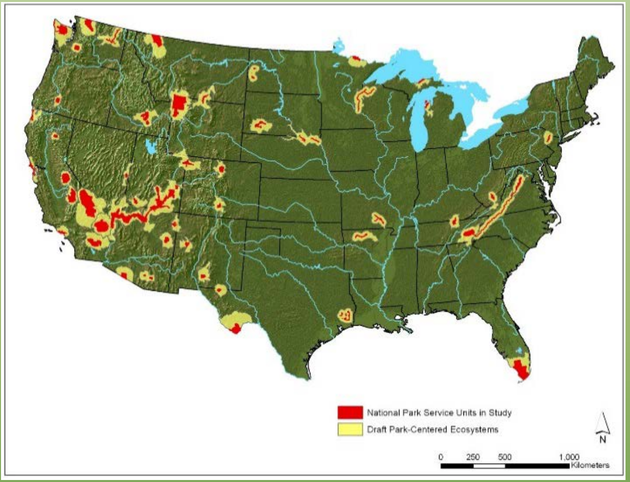
Potential Source Areas for Species Moving into ALCC



Example of Using Results for Vulnerability Assessment

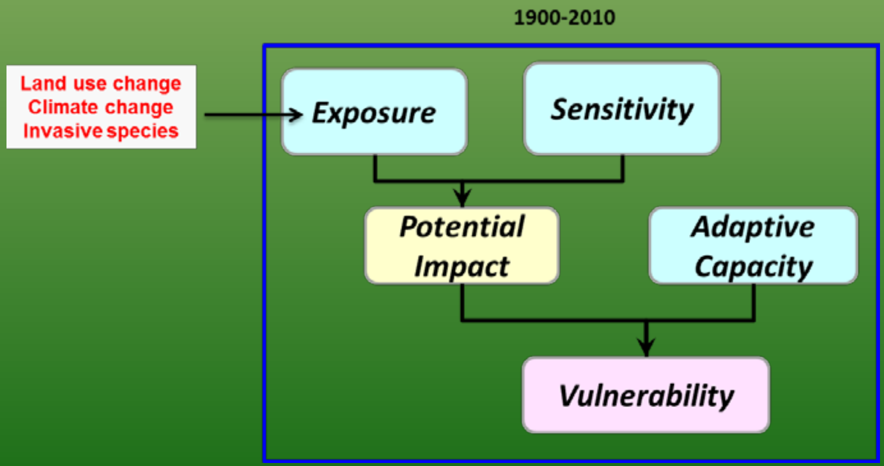
Exposure of US National Parks to Land Use and Climate Change 1900-2100
Hansen et al. In Review.

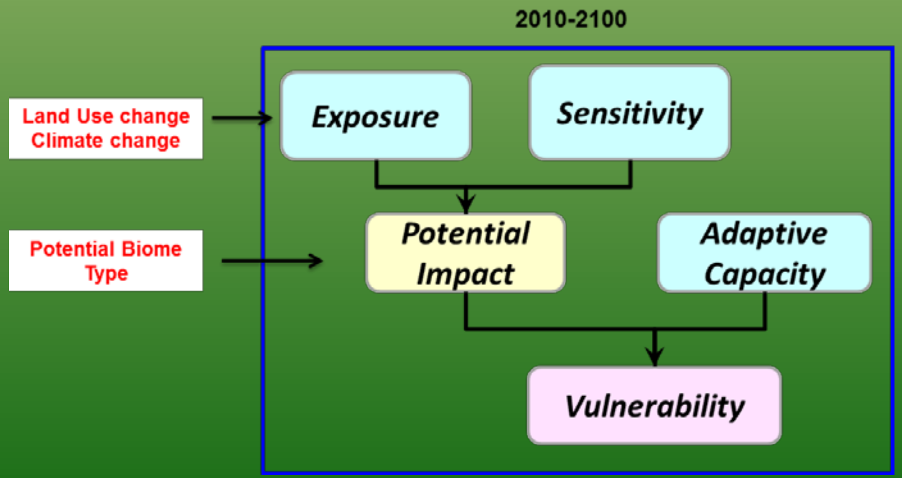
Goal: Illustrate the initial steps in an assessment of vulnerability to land use and climate change for the network of US National Parks



Objectives:

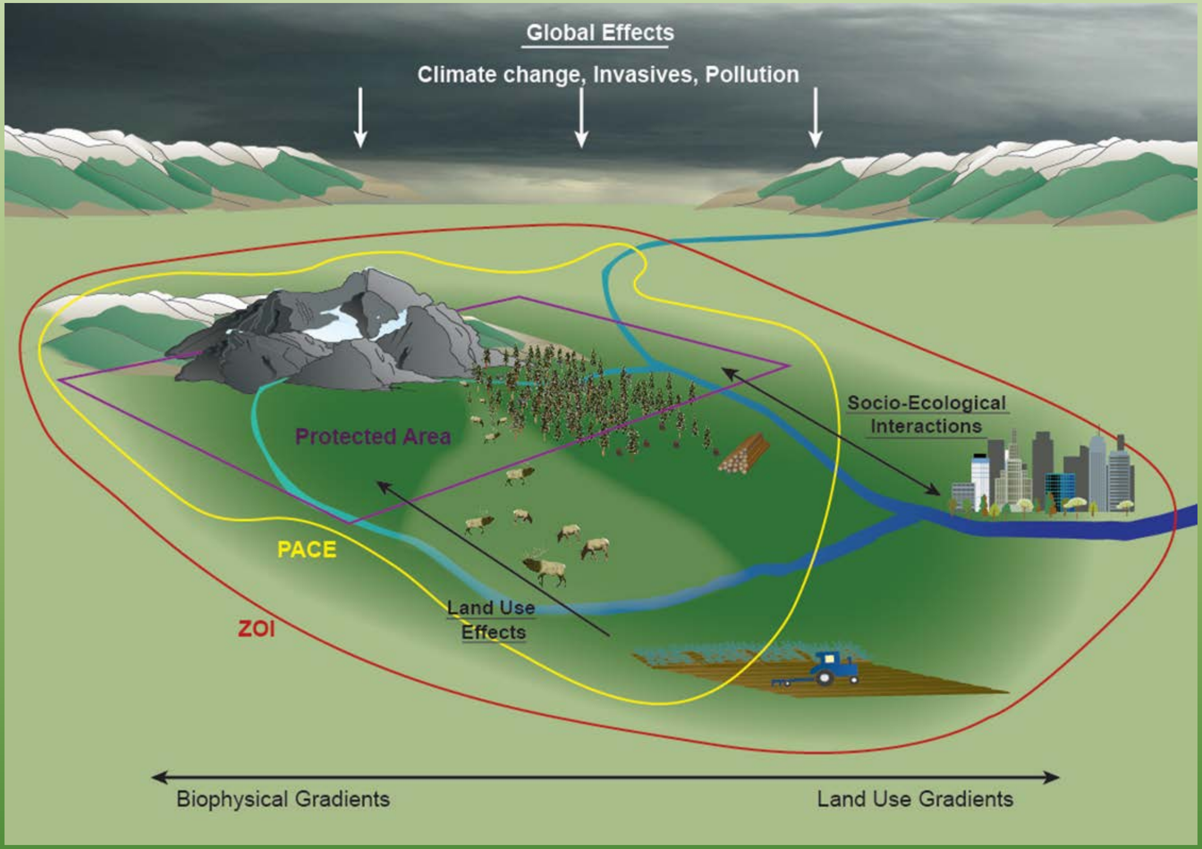
1. **Define the surrounding Protected Area Centered Ecosystem (PACE).**
2. **Quantify past exposure.**
3. **Quantify potential future exposure and potential impact.**
4. **Consider implications for management.**





Example of Using Results for Vulnerability Assessment

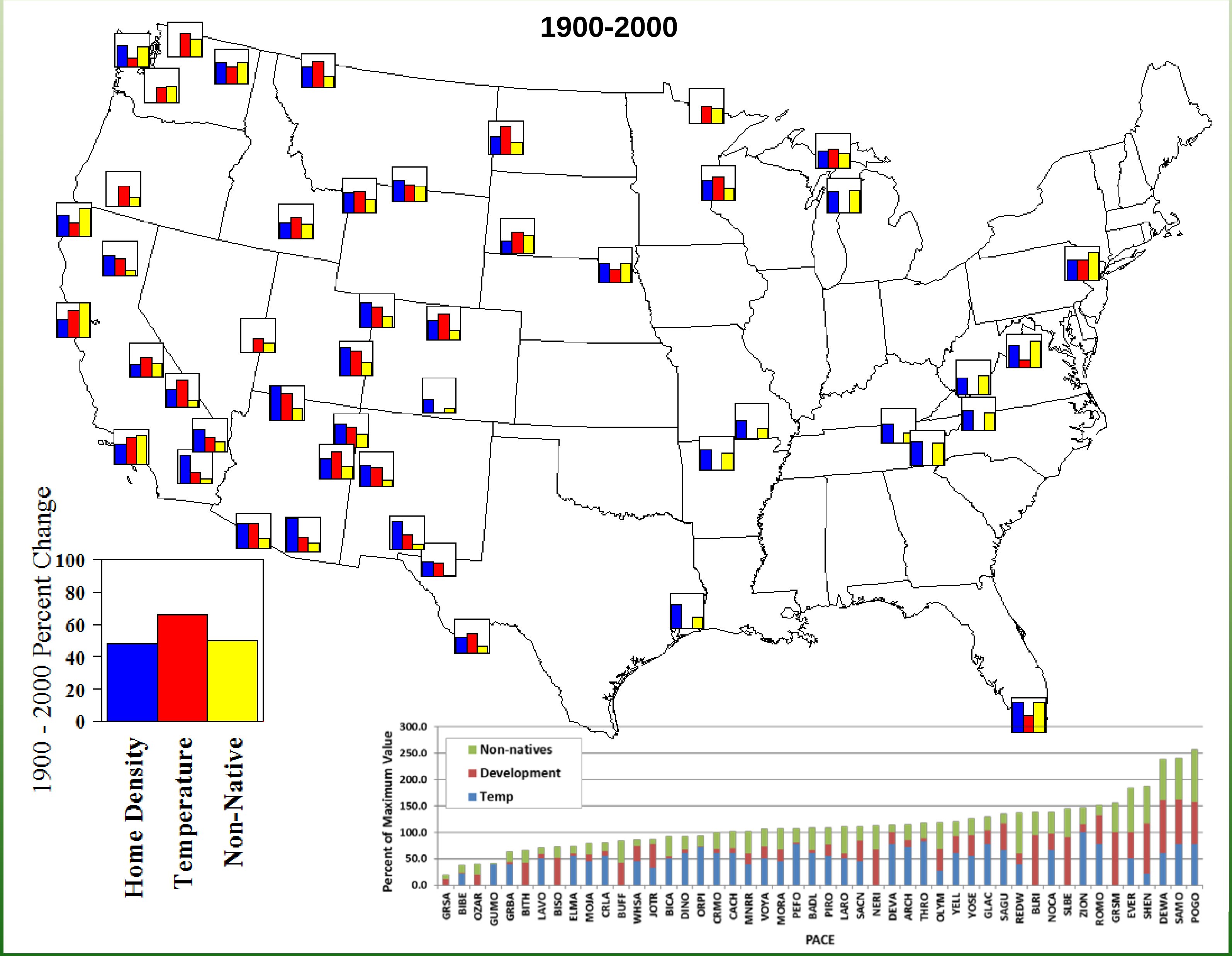
Conceptual Basis



Protected-area Centered Ecosystem (PACE) - areas wherein human activities may negatively influence ecological processes and the viability of native species within the PA.

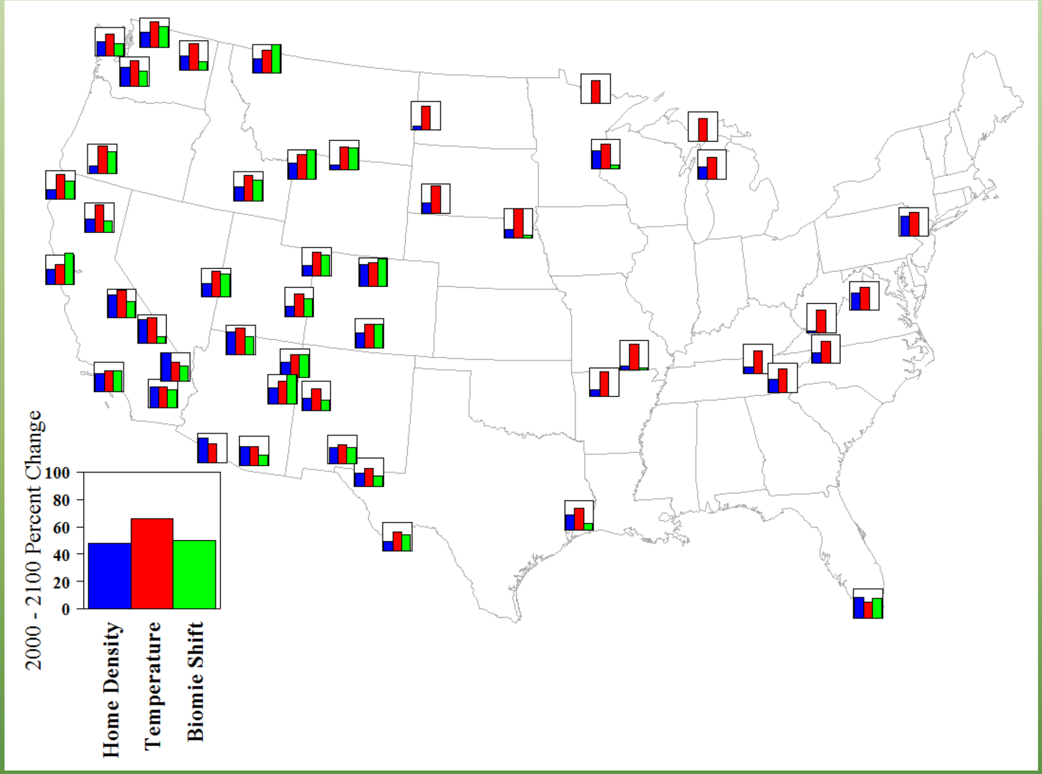
- The rates of global change and sensitivity to these changes differ among protected areas.
- There is a need to assess vulnerability across networks of protected areas to determine which are most at risk and to lay the basis for adaptation strategies that are tailored to local conditions.

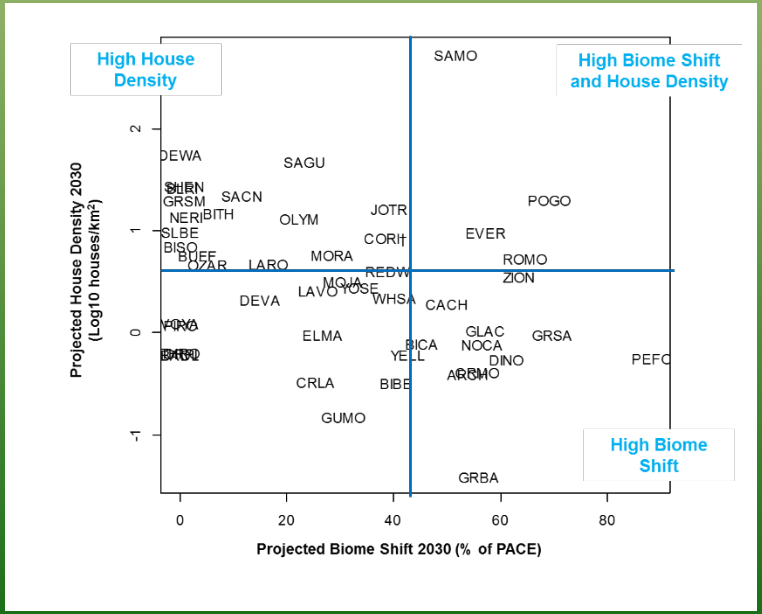
Example of Using Results for Vulnerability Assessment



Example of Using Results for Vulnerability Assessment

2000-2100





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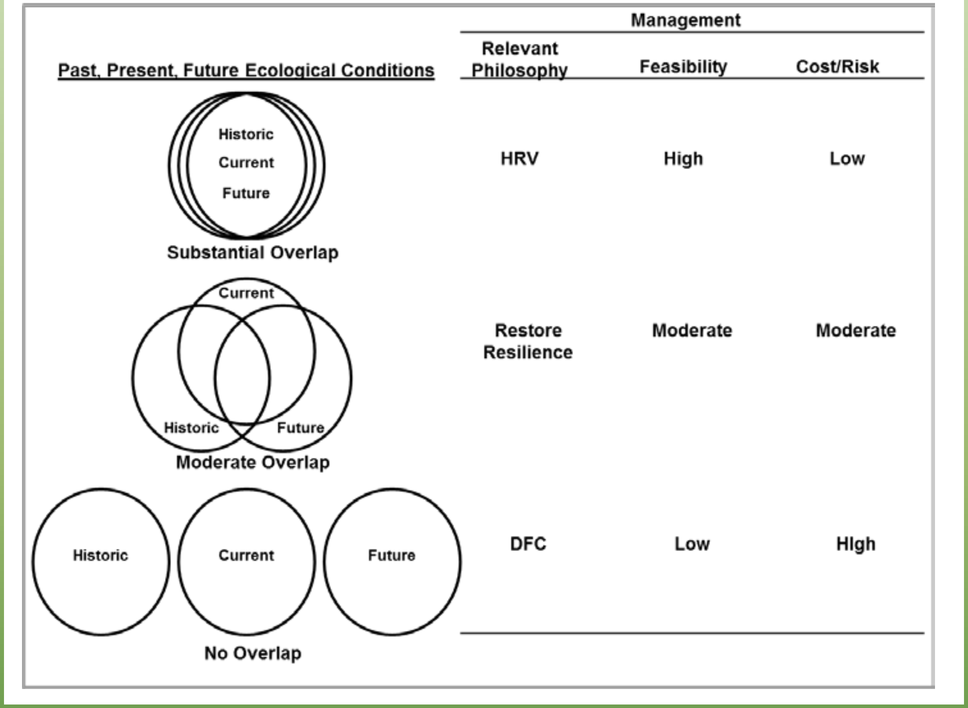
Example of Using Results for Vulnerability Assessment

Management Implications



Knowledge of differences in vulnerability among PACES can be used to guide adaptation strategies.

US NPS Policy Implications

- **Expand on current capabilities to enable vulnerability assessments across the NPS system;**
- **Ensure that resource managers in individual units have access to the results of vulnerability assessments to inform local decision making;**
- **Execute vulnerability assessments in the context of a program to define, monitor, and evaluate status of ecological integrity across the NPS system.**

New Science

Ecological Forecasting

Hindcasting (1980-2010) and Forecasting (2010-2100)

Downscaled Climate
(CMIP5 / AR5)

Land use
(SERGoM model)

Ecosystem Process
(TOPS BIOME-BGC & LPJ models)

(Snow, runoff, soil moisture, fire, NPP, phenology)

Habitat Type Distribution
Climate envelope models;
Habitat suitability models;
Disturbance models;
Connectivity/dispersal models

Habitat Types: GNLCC
Whitebark Pine
Lodgepole pine
Douglas Fir
Aspen
Sagebrush

Habitat Types: APLCC
Spruce/Fir
Oak/Hickory
Oak/Pine
Maple/Beech/Birch

Assess

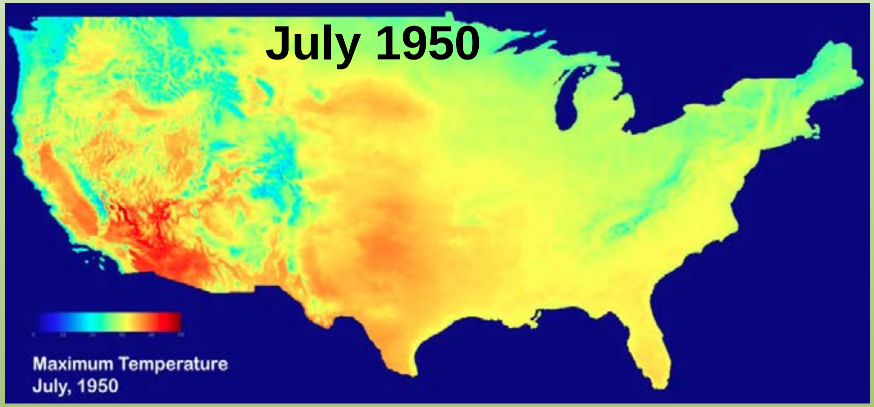
Forest Melton

Step 2. Assess Vulnerability

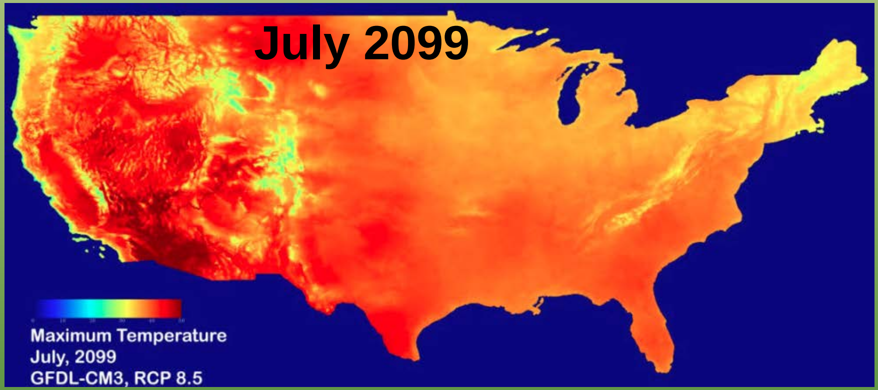
Downscaled Climate Scenarios

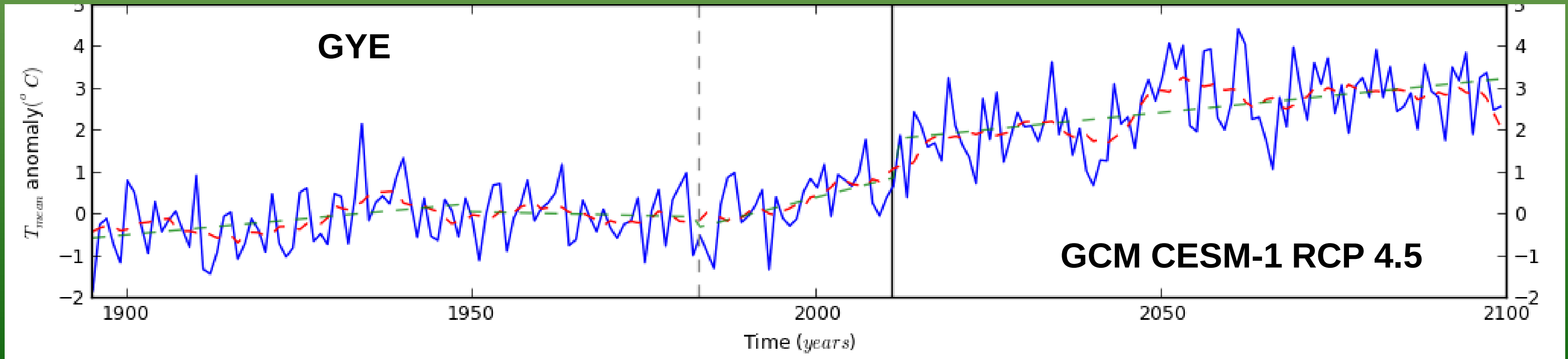
- **Downscaled CMIP5 scenarios completed, Version 1.0 using the NASA Earth Exchange (Thrasher et al., *in prep*)**
- **Monthly, 800m scenarios for all CMIP5 models and RCPs**
- **Bias-Correction Spatial Disaggregation using 800m PRISM as reference**
- **Data currently being prepared for distribution from the NASA Center for Climate Simulation (NCCS)**

Max temp, PRISM



Max temp,
Downscaled 800m CMIP5 GFDL-CM3, RCP 8.5



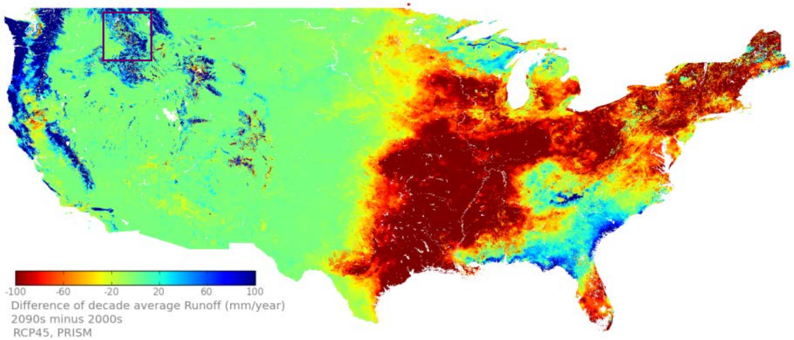


Forest Melton

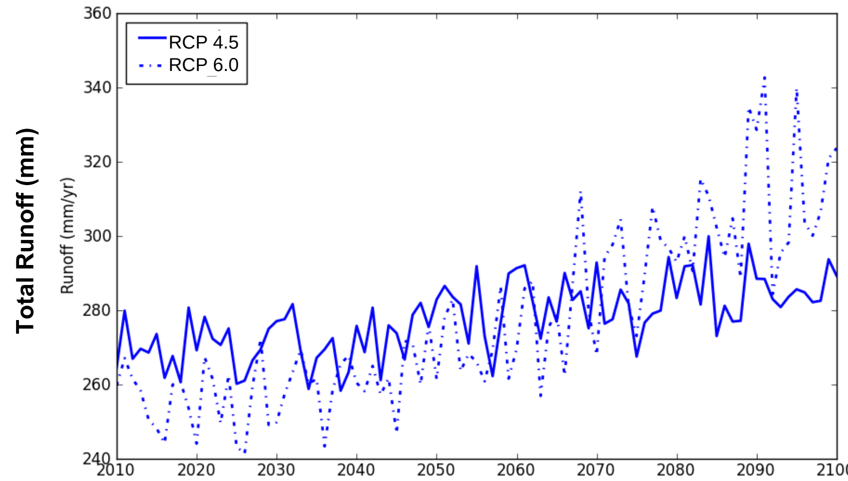
Step 2. Assess Vulnerability

TOPS Results

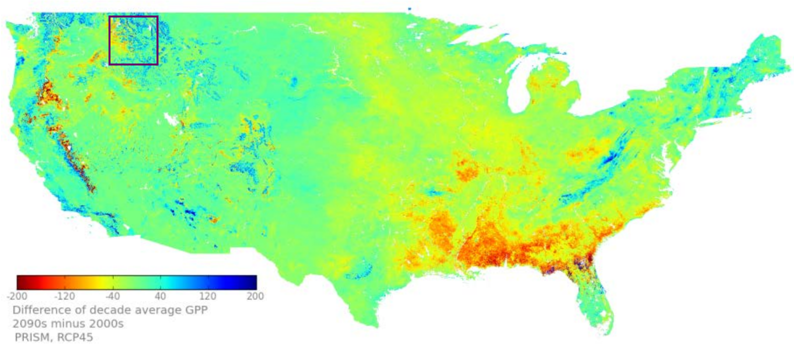
Change in Annual Runoff
RCP 4.5 Ensemble Avg. (2090s – 2000s)

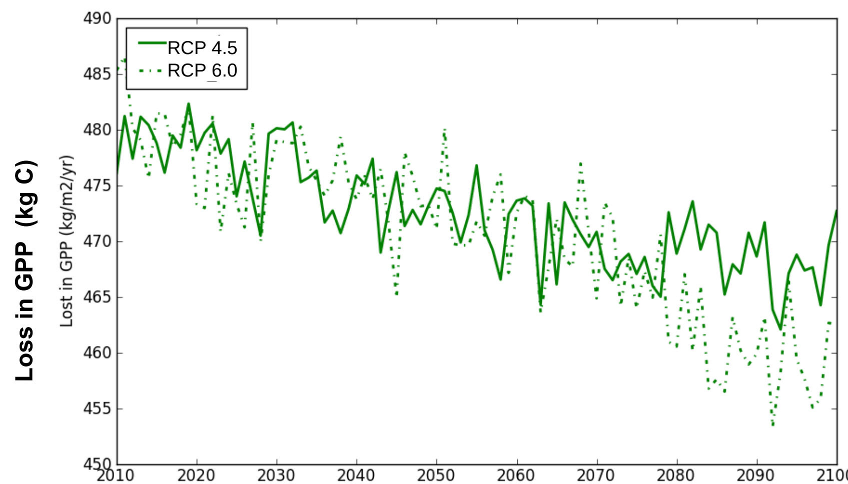


Coupled climate and land use change impacts over Greater Yellowstone Ecosystem



Change in Gross Primary Production (GPP)
RCP 4.5 Ensemble Avg. (2090s – 2000s)



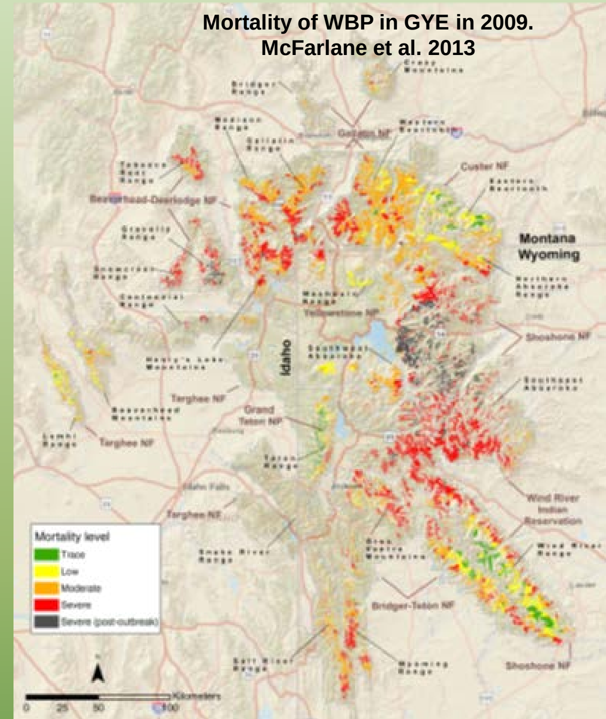


New Science

Whitebark Pine in GYE

Overview

- Keystone species
- High adult mortality
- Listed as candidate species
- Grizzly bear relisted



Management Questions

- Range change under future climate?
- Settings allowing reproduction?
- Where to focus treatment of competitors, translocation?

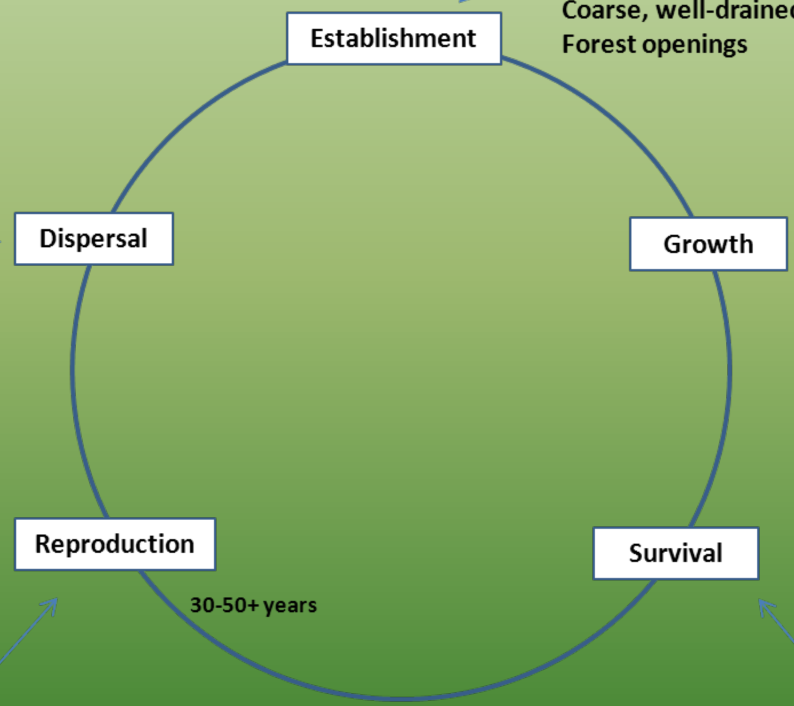
Collaborators

GYCC WBP Subcommittee

New Science

Life History Stages of WBP and Potential Limiting Factors

Genetics
Seed mass
Subalpine conditions
Spring snow pack
Wind protection
Coarse, well-drained soils
Forest openings



PPT primarily as snow
Earlier snowmelt
Mesic June Temp
Long growing season

- degree-days > 5 °C
- mean temperature of
- the warmest month
- date when degree-days > 5 °C reaches 100.

Mountain pine beetle
White pine blister rust
Competition
Severe fire
Climate change

PPT primarily as snow
Earlier snowmelt
Mesic June Temp
Long growing season

Clark's Nutcracker
Other species?

New Science

Data Sources

Source	Life History Stage				
	Adults	Seedling Saplings	Growth Rates	Mortality (Adults)	Reproduction (cones)
GYCC	Stand type Canopy cover Maturity Presence Dominance			Perimeters of burned WBP Canopy damage	
WLIS	Density	Regen (Y/N)		BR presence BR % infection % WBP mortality	
FIA	Presence Density by size class	Seedling Sapling density	DBH remeasure	Remeasurement of marked trees	
GYRN I&M	Density by size class	Density by size class		Mortality rate BR presence	Presence by size class
USDA FS				Pest detection Damage type Severity Dead trees/ac	

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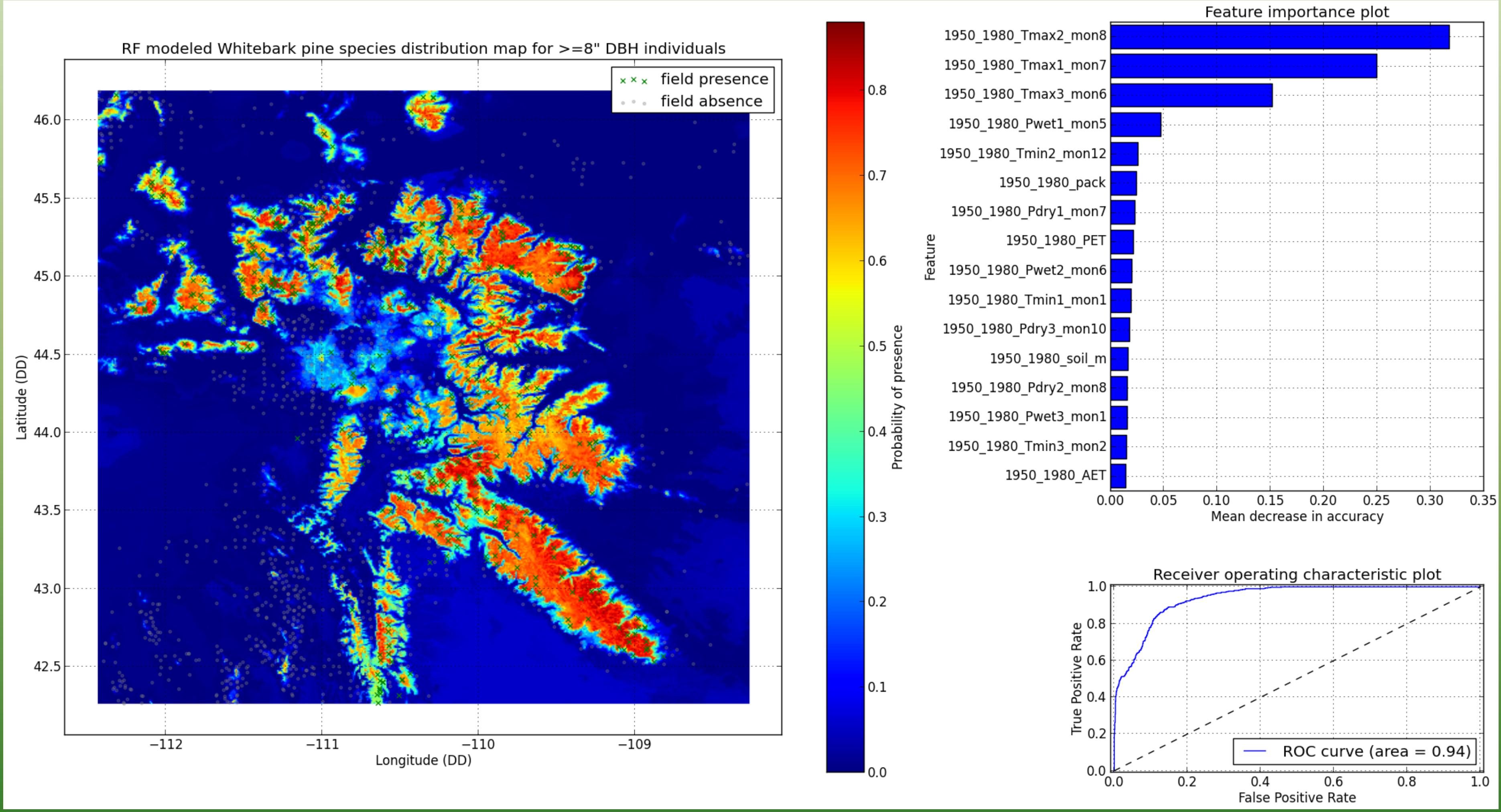
New Science

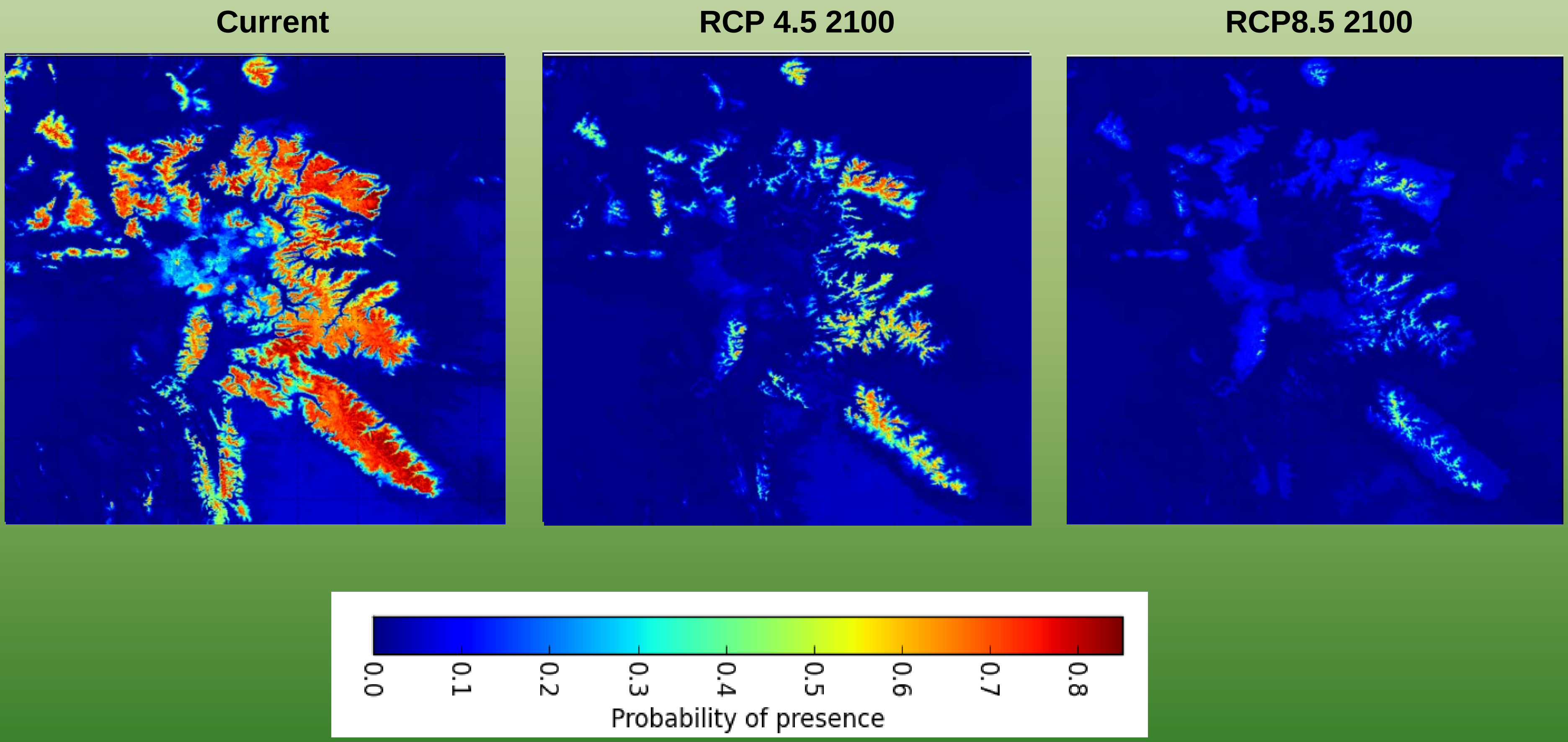
Modeled Presence of Adults (>8” dbh)



Tony Chang, Nate Piekielek

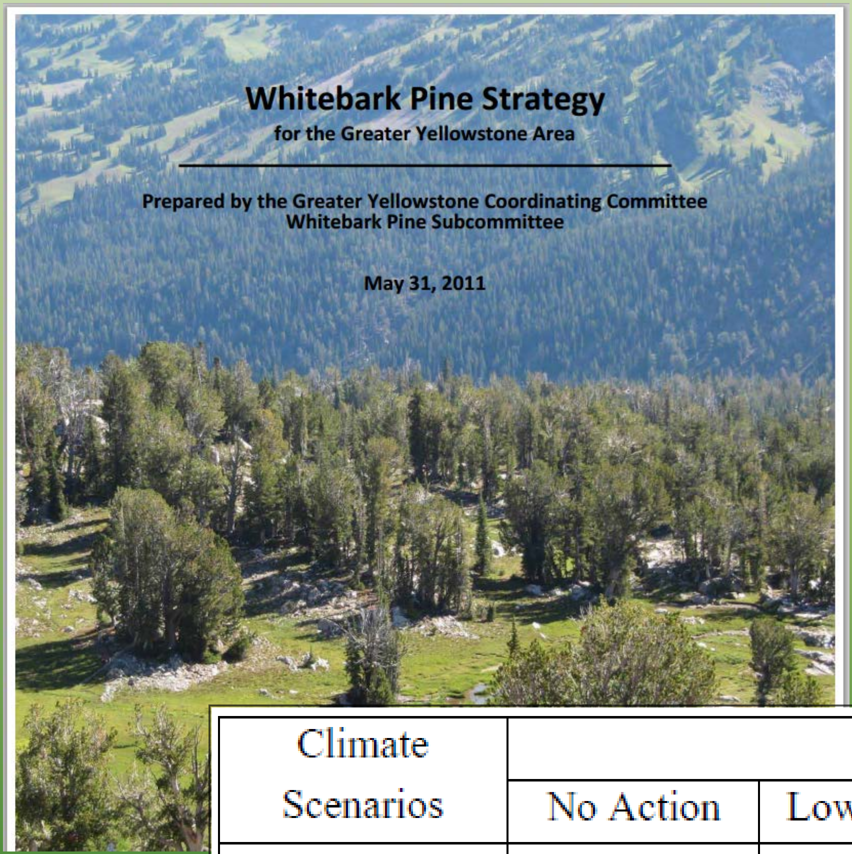
New Science

Adults (>8” dbh) Projected under CESM-1 BGC Climate



Tony Chang, Nate Piekielek

Inform Decision Support and Policy



Goal: Use Whitebark Pine vulnerability assessment to identify adaptation options

- **Evaluate current WBP strategy against forecasts**
- **Create two additional spatially-explicit strategies that are responsive to changes expected under climate change**

Climate Scenarios	WBP Management Options			
	No Action	Low (GYCC 3-yr plan)	Medium	High
RCP 4.5				
RCP 6.0				
RCP 8.5				

Regan Nelson

LCC-VP
LANDSCAPE CLIMATE CHANGE VULNERABILITY PROJECT

Step 4. Design and deliver adaptation strategies

Goal: Demonstrate "cross-jurisdictional" adaptation planning and increase likelihood of implementation by designing strategies that:

1. Maximize "return on investment" among all GYCC partners through integrated spatially-explicit strategies
2. Work within policy constraints and management philosophies of collaborators

<table>
<tr><th colspan="4">Greater Yellowstone Ecosystem</th></tr>
<tr><th>Agency/Allocation</th><th>Legal Direction/Mgt Philosophy</th><th>WBP Restoration Tools allowed or likely</th><th>% WBP</th></tr>
<tr><td>National Forests</td><td>• Multiple use
• Ecological integrity</td><td>All
• Planting seedlings/sowing seeds
• Pruning
• Wildland and prescribed fire use
• Targeted fire suppression
• Mechanical thinning
• Research/Monitoring</td><td>5%</td></tr>
<tr><td>NF – Wilderness Area</td><td>Most actions prohibited or discouraged</td><td>• Wildland fire use
• Research/Monitoring</td><td>54%</td></tr>
<tr><td>NF – Inventoried Roadless Areas</td><td>Actions less restricted but remoteness an issue</td><td>• Planting seedlings/sowing seeds
• Wildland fire use
• Research/Monitoring
• Mechanical thinning (but requires USDA Secretarial approval)</td><td>27%</td></tr>
<tr><td>Yellowstone National Park</td><td rowspan="2">Park Service Policy:
"Take no action that would diminish the wilderness eligibility of an area" AND/BUT "Management actions…should be attempted only when knowledge and tools exist to accomplish clearly articulated goals."</td><td>• Wildland fire use
• Research/Monitoring</td><td>10%</td></tr>
<tr><td>Grand Teton National Park</td><td>• Planting seedlings/sowing seeds
• Pruning
• Wildland fire use
• Research/Monitoring</td><td>3%</td></tr>
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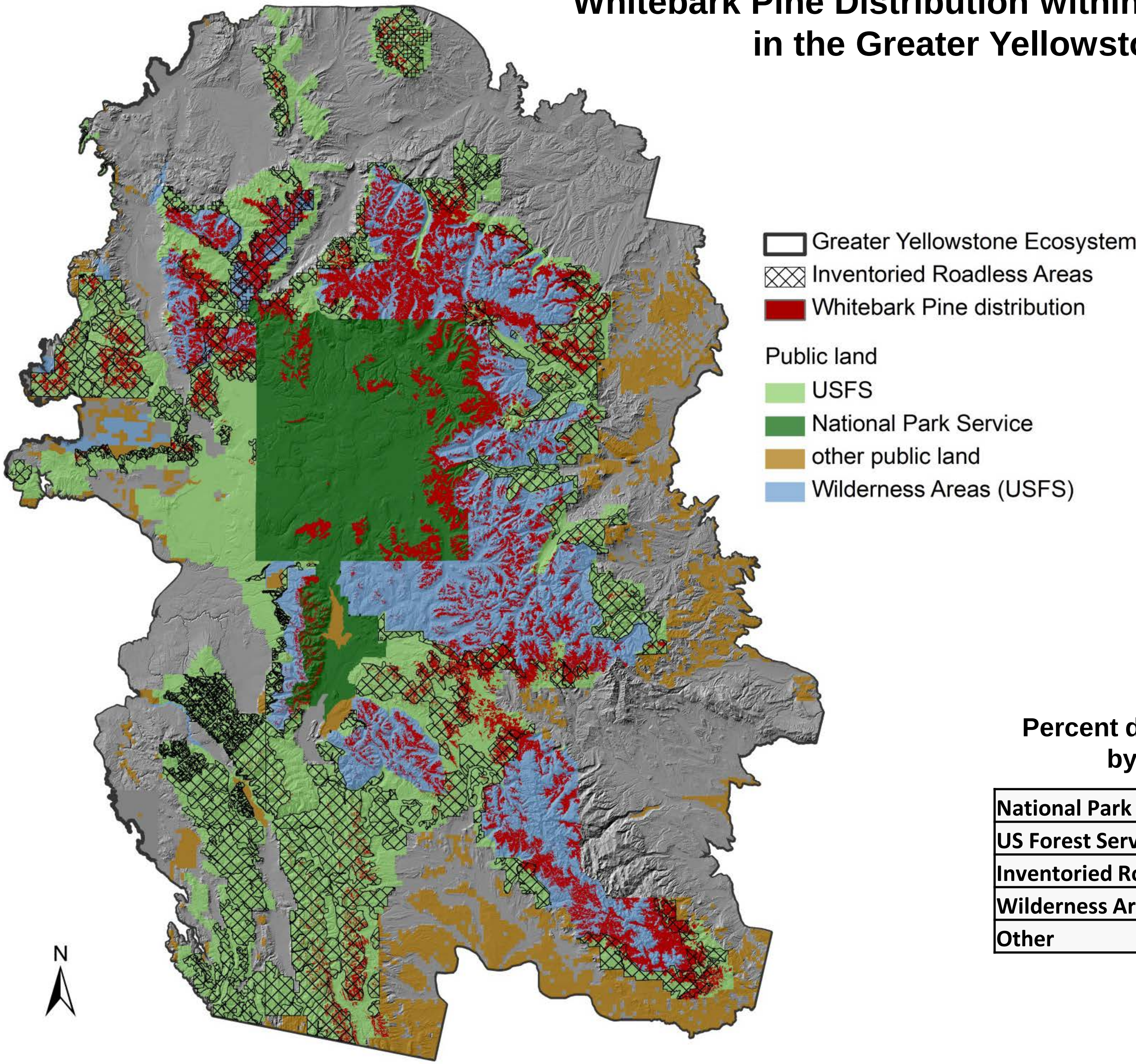
Whitebark Pine Distribution within Management Categories in the Greater Yellowstone Ecosystem

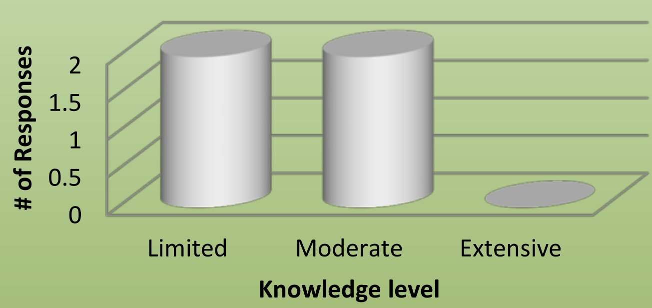


Percent distribution of Whitebark Pine by Management Category

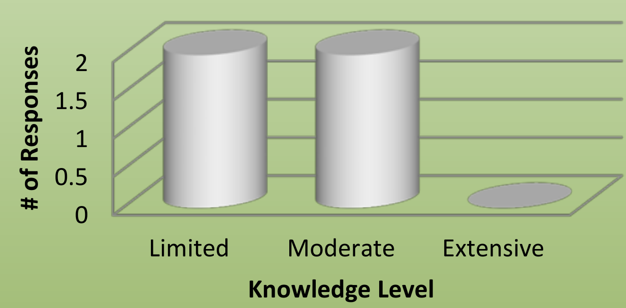
National Park Service	13.16
US Forest Service	5.55
Inventoried Roadless Areas (USFS)	27.23
Wilderness Areas (USFS)	53.79
Other	0.05

Collaborator Pre-project Survey Results

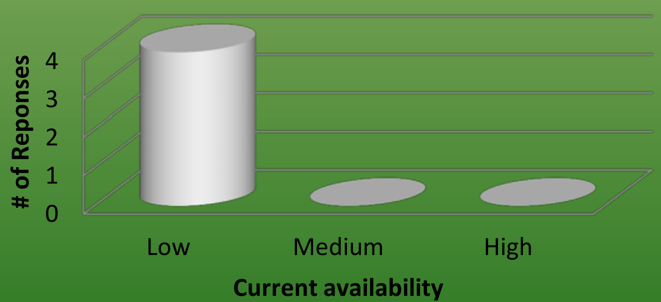
Level of Knowledge of past climate and land use change



Level of Knowledge of future climate and land use change



Current availability to collaborators of data to be generated by this project



Comments by collaborators:

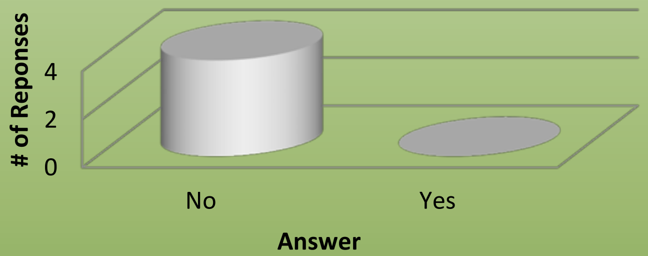
- *"We have very little knowledge of past climate change and land use surrounding [our unit]."*

- *"Significant opportunities exist to have explicit examples of the interactions between climate change and land use change as we look towards the future."*

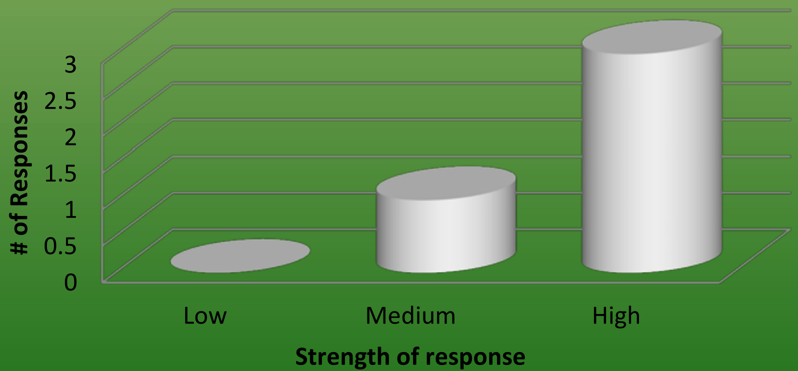
- *"This assessment is a first of its kind for [our unit]."*

Collaborator Pre-project Survey results

Does unit feel confident using vulnerability assessment data to generate and implement adaptation options?



Relevance of data generated by this project to managers



Information Needs ID'd by Managers:

- *How-to guides or hands-on training*
- *Downscaled data*
- *User-friendly tools*
- *Realistic approaches to begin planning and implementing adaptation*

Challenges facing Managers:

- *How to make good decisions given uncertainty*
- *How to develop cooperative approaches with neighboring jurisdictions*
- *What types of actions are appropriate given current policy direction*
- *Diminishing funding levels restricting ability to collect data and run models*

Products

Policy Reports

Amberg, Gross, et al. 2012. Badlands National Park: Climate change vulnerability assessment. Natural Resource Report NPS/BADL/NRR.

Gross et al. In Review. Understanding climate change impacts and vulnerability. In “Managing for Change: A Guide to Principles and Practice for Climate-Smart Adaptation”.

Gross & Rowland. In Review. Monitoring and evaluation in climate-smart conservation. In “Managing for Change: A Guide to Principles and Practice for Climate-Smart Adaptation”.

Olliff et al. In Prep. Responding to climate change in the NPS Intermountain Region: A Guide to Developing Park-based Adaptation Strategies. Natural Resource Report NPS/IMRO.

Olliff et al. In Prep. Developing partnerships and tools to promote climate change adaptation. Intermountain Region Crossroads in Science.

Outreach

Gross. Mountain Climate Research Conference (MtnClim). Oct 2012.

Gross. NPS Colorado River Steering Committee. March 2013.

Gross. NPS Intermountain Region Climate Workshop. Feb 2012.

Gross. NPS Isle Royale Scenario Workshop. Jan 2013.

Gross. North Central Climate Science Center, Adaptation Working Group. Apr 2013.

Hansen. North Central Climate Sciences Workshop. Nov 2012

Hansen. Ecological Society of America meeting. Aug 2012.

Hansen. Zool Soc of London & Wildlife Cons Soc Symposium on protected areas, Nov 2012.

Hansen. Montana EPSCoR meeting. Feb 2012.

Monahan. US Regional Association of the IALE. Apr 2012.

Olliff. The 11th Beinnial Scientific Conference on the Greater Yellowstone Ecosystem. Oct 2012.

Olliff. The Wildlife Society Conference. Oct 2013.

Olliff. IMR/DSC Climate Workshops. Feb 2012.

Olliff. National LCC meeting. Mar 2012.

Products

Science and Management Pubs

Gross et al. 2011. Remote sensing for inventory and monitoring of the U.S. National Parks. Remote sensing of protected lands. Taylor & Francis.

Gross. 2012. Ecological consequences of climate change: mechanisms, conservation, and management. Journal of Wildlife Management 76:1102-1103.

Monahan & Gross. 2012. Upstream Landscape Dynamics of US National Parks with Implications for Water Quality and Watershed Management. In: Sustainable Natural Resources Management. In Tech.

Olliff et al. 2013. Invasive Species – Exotic Fungus Works in Tandem with Natural Disturbance Agents to Alter Whitebark Pine… In Yellowstone's Wildlife in Transition, Harvard Univ Press.

Olliff et al. 2013. Understanding the Past: The History of Wildlife and Resource Management in the Greater Yellowstone Area. In Yellowstone's Wildlife in Transition, Harvard Univ Press.

Piekielek &Hansen. 2012. Extent of fragmentation of coarse-scale habitats in and around US National Parks. Biol Cons.

Theobald et al. 2012. Connecting natural landscapes using a landscape permeability model to prioritize conservation activities in the US. Cons Letters.

Theobald, DM 2013. Integrated land use and landscape change with conservation planning. In: Conservation Planning: shaping the future. Esri Press

Science and Management Manuscripts

Hansen et al. In Review. Exposure of US National Parks to Land Use and Climate Change 1900-2100. PNAS.

Monahan et al. In Prep. Forecasting Species' Responses to Climate Change at Management-relevant Scales: Limber Pine in Rocky Mountain National Park. PLOS One.

Piekielek and Hansen. In Review. Biophysical controls on land surface phenology of grasslands in the Upper Yellowstone River Basin. Remote Sensing of Environment.

Theobald. In Prep. Quantifying the ecological integrity of landscapes: a general model and US application. Landscape Ecology.

Proposals and Companion Funding

Hansen et al. Climate vulnerability assessment. USGS North Central Climate Sciences Center. $100,000. Funded.

Hansen, A.J. Building capacity in climate science. MT EPSCoR. $114,000. Funded

Avery, Gross, et al. Advancing National Park Service scenario planning: Developing integrated climate and impacts scenarios and evaluating their use in workshops. NOAA Regional Research Partnership $178,738. In Review.

Hansen et al. Informing implementation of the Greater Yellowstone Coordinating Committee's Whitebark Pine Strategy. North Central Climate Sciences Center. $447,000. In Review.