



Climate Change in the Northern Forest: Impacts and Adaptation

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Compass Land Consultants



Information and Resources

Michigan Forest Ecosystem Vulnerability Assessment and Synthesis: A Report from the Northwoods Climate Change Response Framework Project



Forest Management in a Changing Climate

Extension Bulletin E-3255, July 2014

Forest Adaptation Glossary

New terms at change and vocabulary he concepts a

Adaptation: Taking impacts of climate c

Adaptive Capacity: and individuals to m realize benefits, thro behavior. Adaptive (natural ecosystems) community wildfire)

Agreement: The ext support of a vulner



Figure 1: Agreement, I et al. 2014.

Alternate Ecological characteristics of a b invasive stresses of a b a different set of long are usually less diver lower quality) ecolog consumption.

Asynchrony: When i sequences, or togethe spring flower break i insect pollinators, res

Cascading impacts: and/or function of ar by a new element or impacts can lead to c

Forest Management in a Changing Climate

Extension Bulletin E-3223, July 2014

Adaptation Strategies and Approaches

Foresters and forest owners will respond to climate

They will also have different institutional constraints when it comes to taking action. Plan on it is crucial for foresters to consider what their

Forest Management in a Changing Climate

Extension Bulletin E-3221, July 2014

How the Climate Affects Forests

Forests are affected by the local climate, in addition to being affected by short-term weather events. Michigan's climate has been changing over the past several decades, and continued climate change could result in many impacts to forests in our state.

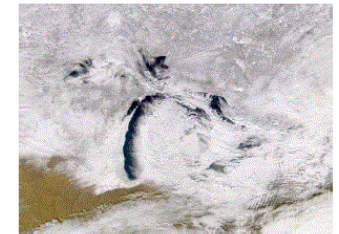
Effects on Forests

How does the climate affect forests? There are many direct and indirect ways. An example of a direct effect might be changes in phenology, for example when trees leaf-out in the spring or when flower buds open. An indirect effect might be the damage done by an insect whose range expands due to warmer winters.

Many forest processes are regulated by photoperiod and less driven by climate change. Other processes are influenced by temperature and other weather variables. The timing of leaf expansion is a common example. Dr. Andy Burton (Michigan Technological University) has observed that sugar maple growing season length has increased by 11.5 days over the past 20 years across a range of sites in Michigan.⁴

Forests are ecological systems that may be slow to respond to climate change. Much of the change is not predicted to occur until the middle of this century. In particular, mature trees are long-lived organisms and may not be good indicators of climate change. However, tree regeneration patterns may be early indicators, especially along ecotones of change (e.g. forest-prairie, hardwood-boreal). Regeneration of red maple and black ash is occurring in certain boreal forests, which is not typical.⁵ Studies are underway examining changes across ecotones in Michigan, Wisconsin, and Minnesota.

More mobile taxa, such as birds and mammals, have experienced expansions in ranges.⁶ These wildlife species serve important roles in the distribution and success of forest regeneration. Moose populations have declined across most of their southern range. Warmer temperatures are an important driver of that dynamic.⁷



Michigan's climate is influenced by the Great Lakes. Forests in Michigan are adapted to areas of lake-effect snowfall and characteristic winter weather. Image courtesy the SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE.

The Earth's climate is changing. Many trends have been tracked, some reaching back tens of thousands of years. Trees and forests are sensitive to a range of environmental conditions, including the climate. In addition to climate, there are other factors to which forests respond, such as human activities and management, biological relationships, and invasive pests. All of this creates a dynamic within which forests grow and change. How much do climate factors need to change before forests change in a significant way? This question is almost impossible to answer, although there is no doubt about impending change. Climate influences will vary between different forest types and will be complicated by ecological complexities.

Table 1.

Strategies	1a. Mai
	1b. Mai
	1c. Mai
Strategies	2a. Mai
	2b. pathog
	2c. Pre
	2c. Mar
Strategies	3a. Alte
	3b. Alte
	3c. Alte
Strategies	4a. Pri
	4b. Pri
	4c. Esta
Strategies	5a. Pri
	5b. Mai
	5c. Ret
	5d. Ret
	5e. Esta
Strategies	6a. Mai
	6b. Exp

Evidence of Change

Historical data goes back about one hundred years for some climate measures. There are a variety of ways climate factors can be inferred, such as pollen cores in bogs and the study of tree rings. Globally, some measures go back 100,000 years. Records over the past 100 years demonstrate some remarkable trends that cannot be attributed to natural causes. These trends vary somewhat across regions, but the overall picture points to a warming, more erratic climate.

Across the entire state, Michigan's average annual temperature increased over 2.4 °F from 1895-2013.¹ Winter temperatures have risen faster (3.3 °F) during the same time, particularly winter low temperatures (3.7 °F). Extreme high temperature periods have increased across the Midwest, including higher night temperatures and higher humidity.

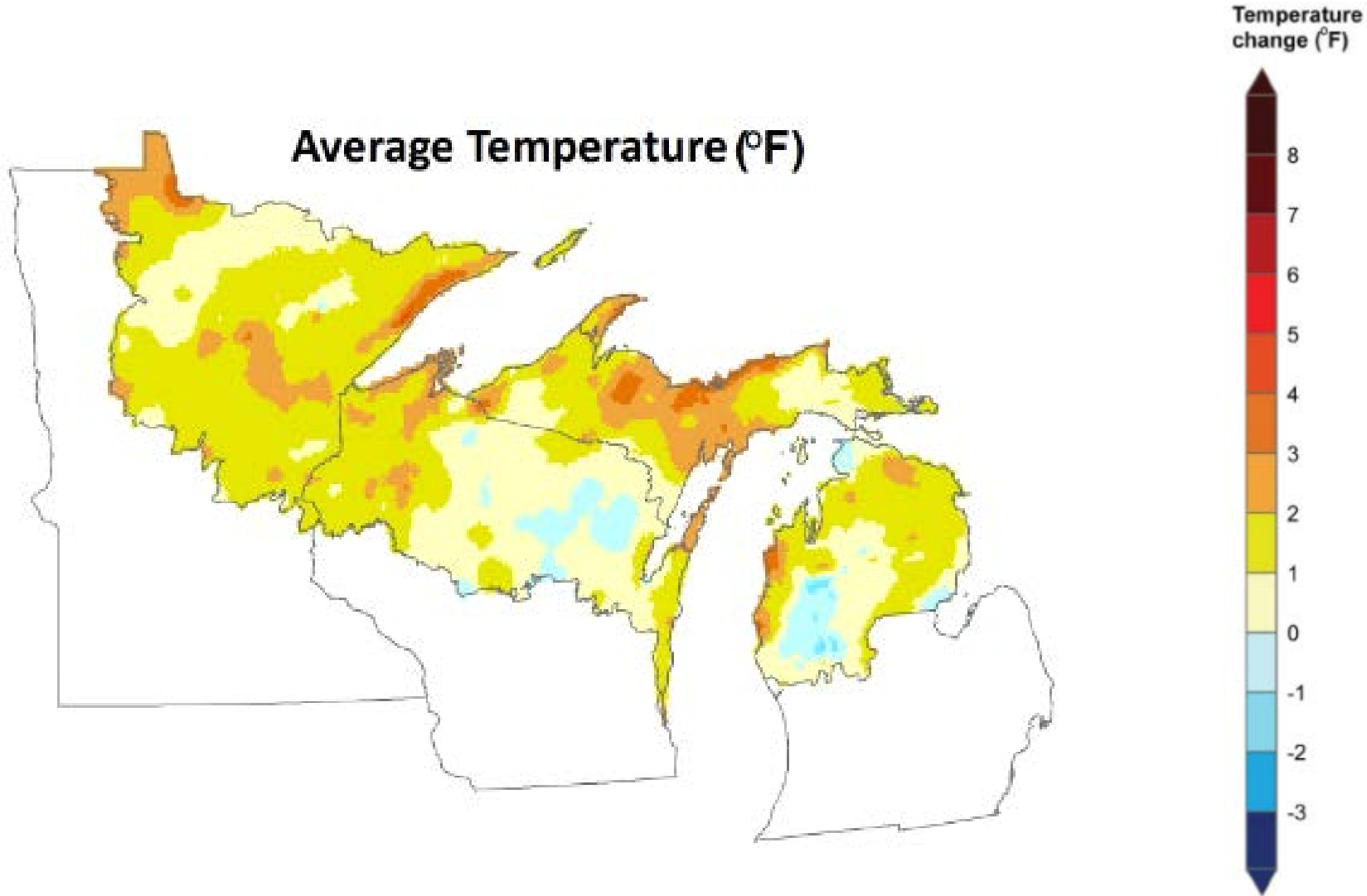
Average annual precipitation has increased by 3.5 inches, with the greatest increases in the summer and fall.¹ There is variation across the state, with some areas experiencing significant droughts. The interaction of temperature, precipitation, and seasonality is important to forests.

Heavy rainfall events (+3 inches in a single event) have become more frequent in Michigan, as well as across the Midwest.² As a greater proportion of precipitation is delivered in large events, there can be longer periods between rain events.

Recent severe events, such as the burst of tornadoes across southern Michigan in 2012 and the northward migration of tornadoes suggest change but long-term records for these phenomena are limited.³

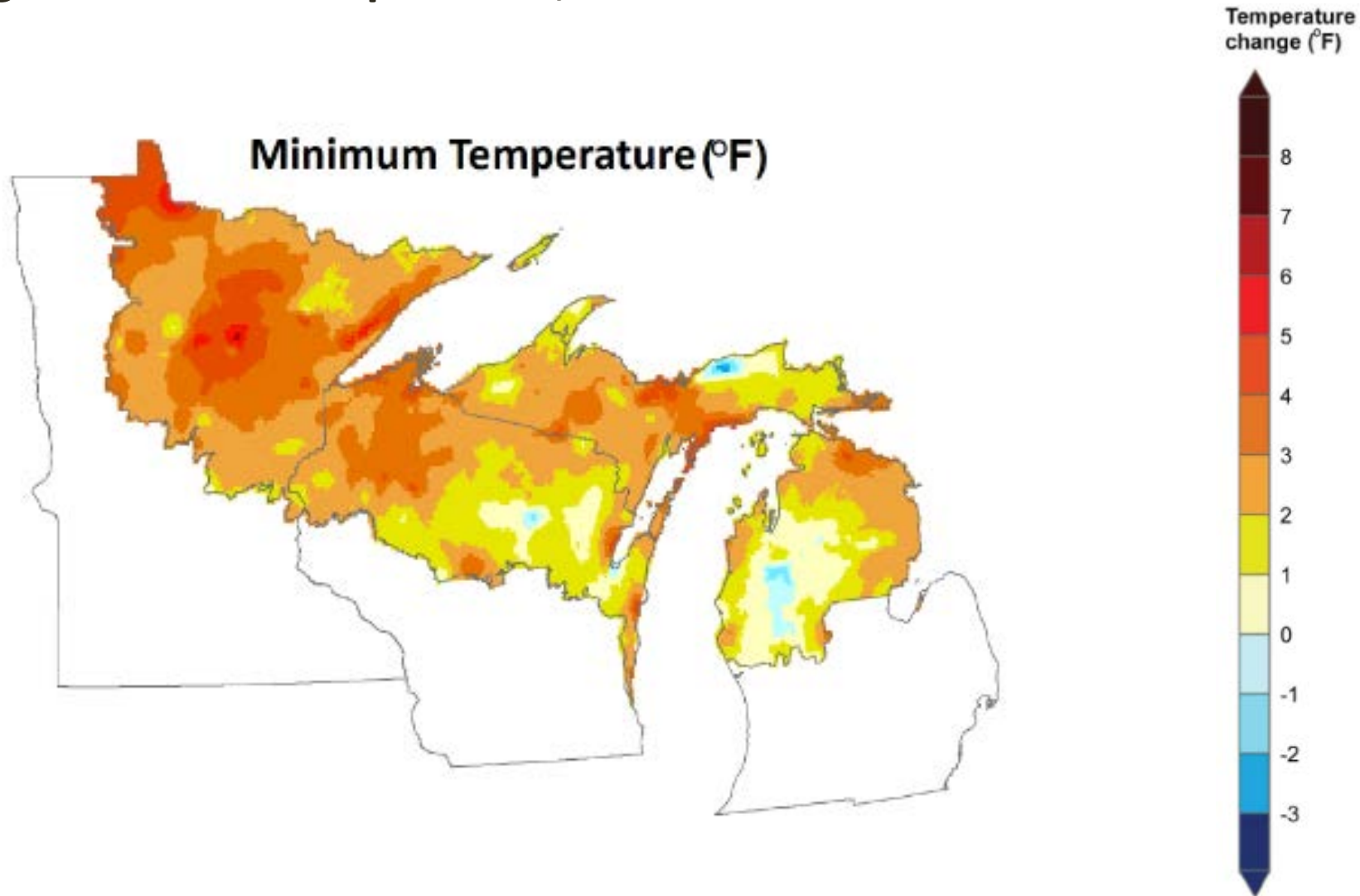
Observed Temperature Changes

Change in Annual Temperature, 1901-2011



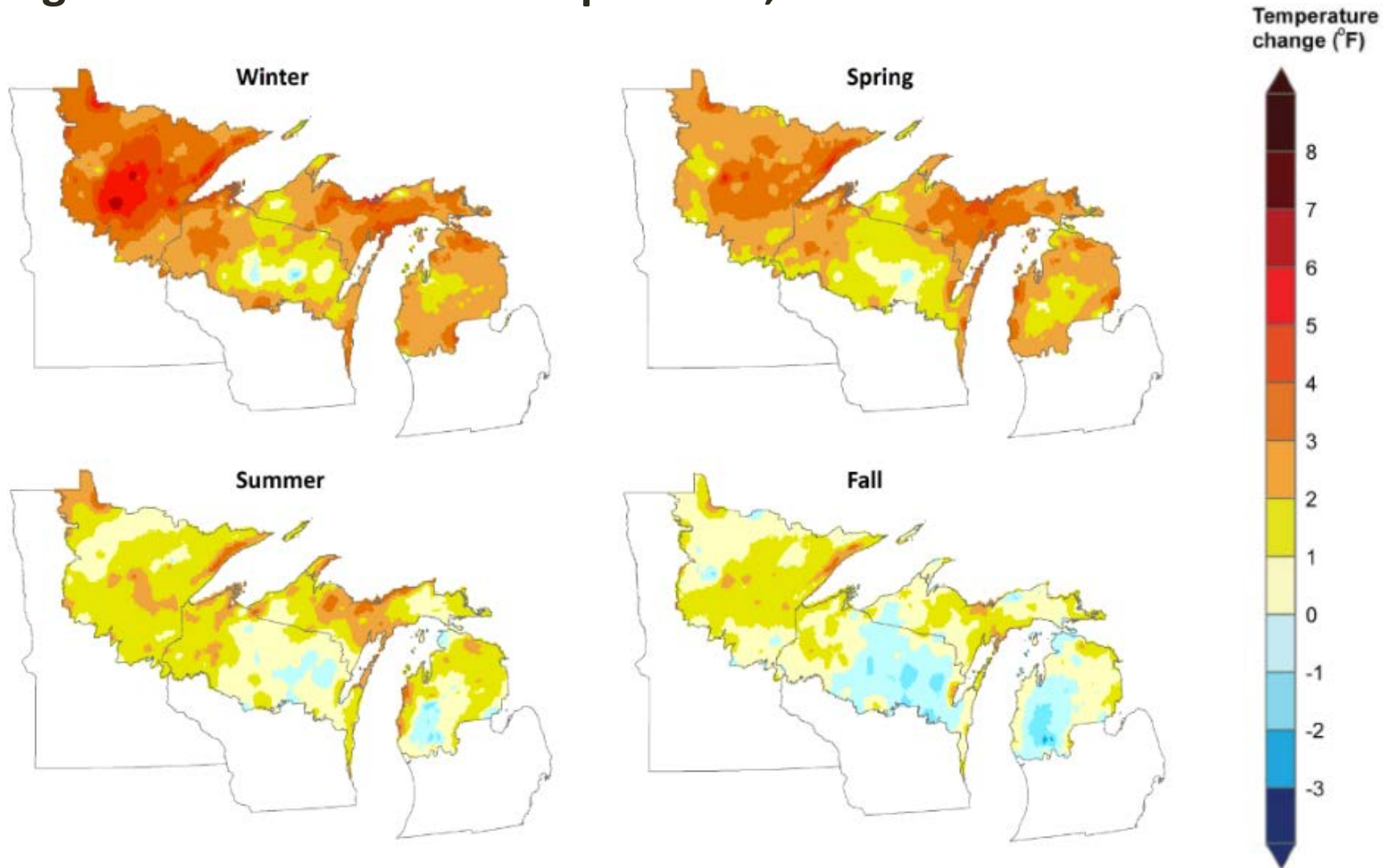
Observed Temperature Changes

Change in Annual Temperature, 1901-2011



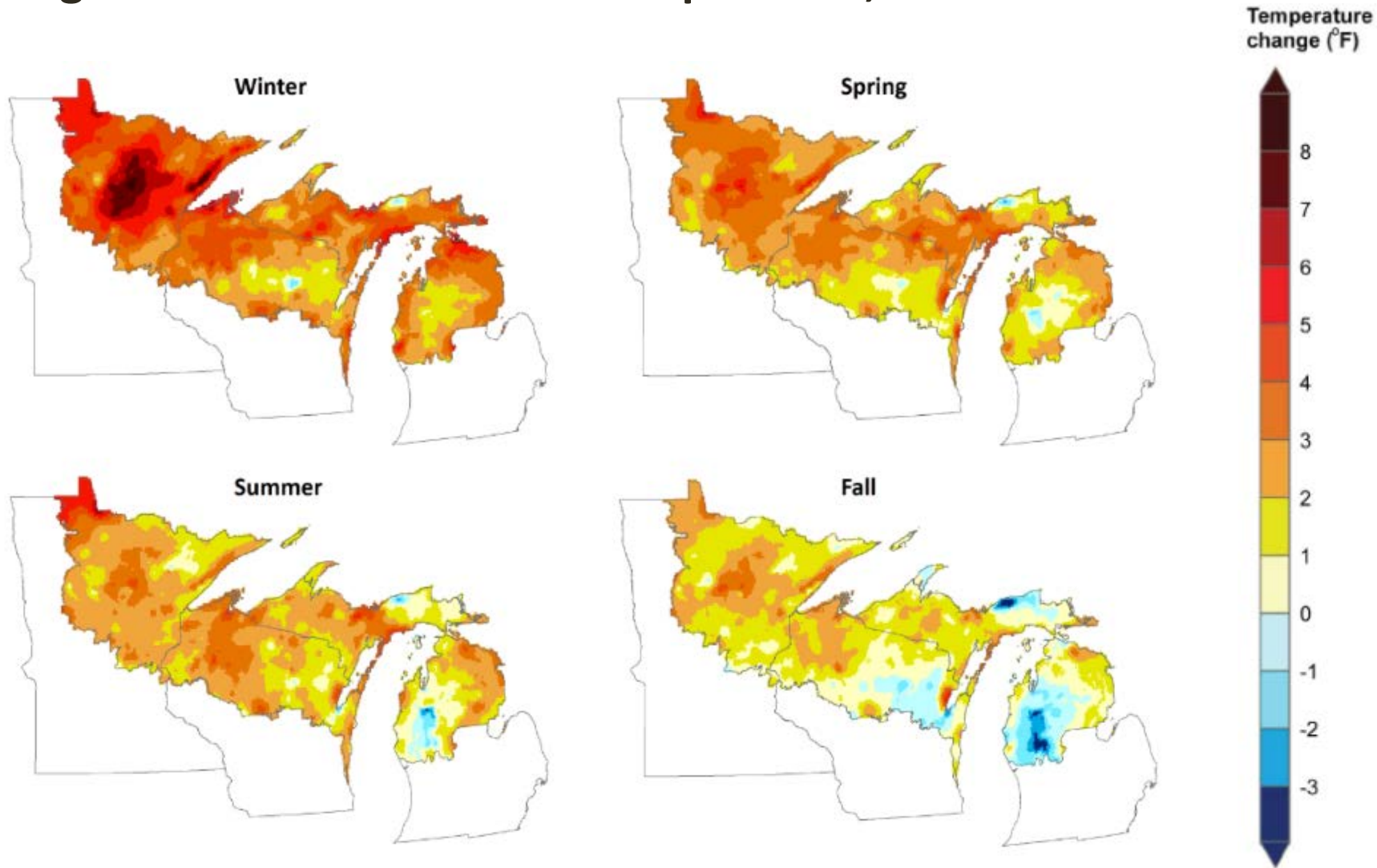
Observed Temperature Changes

Change in Seasonal Mean Temperature, 1901-2011



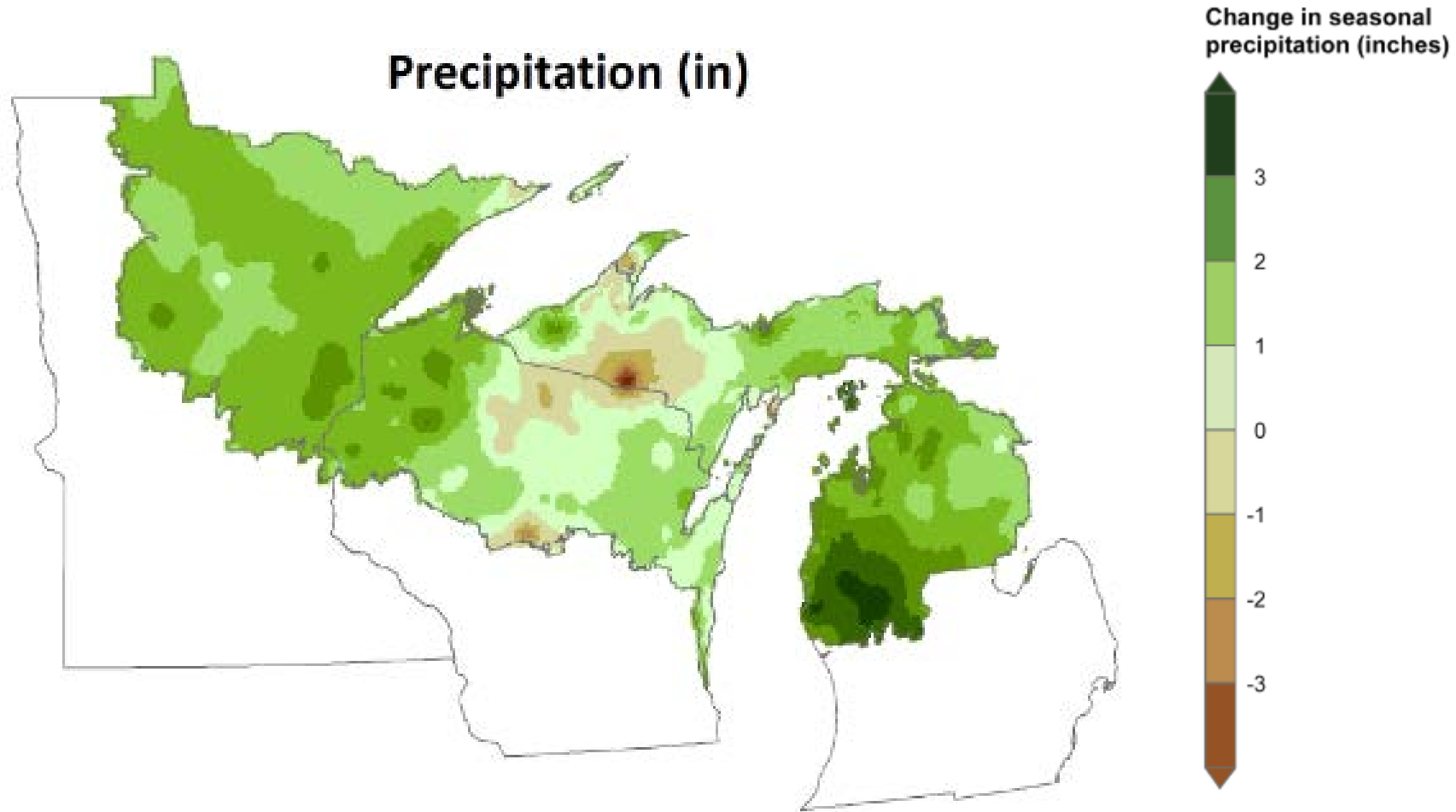
Observed Temperature Changes

Change in Seasonal Minimum Temperature, 1901-2011



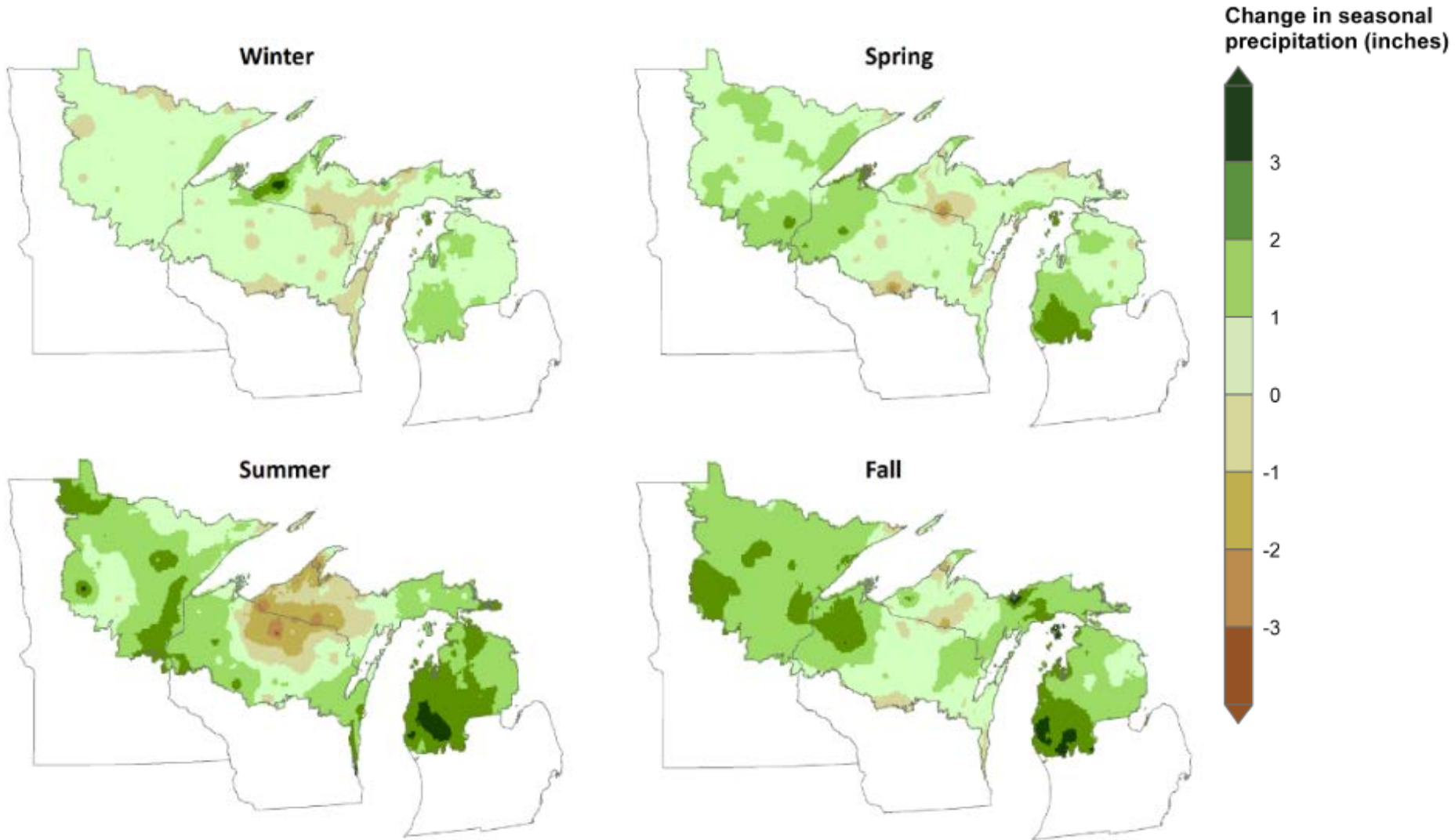
Observed Precipitation Changes

Change in Annual Precipitation 1901-2011



Observed Precipitation Changes

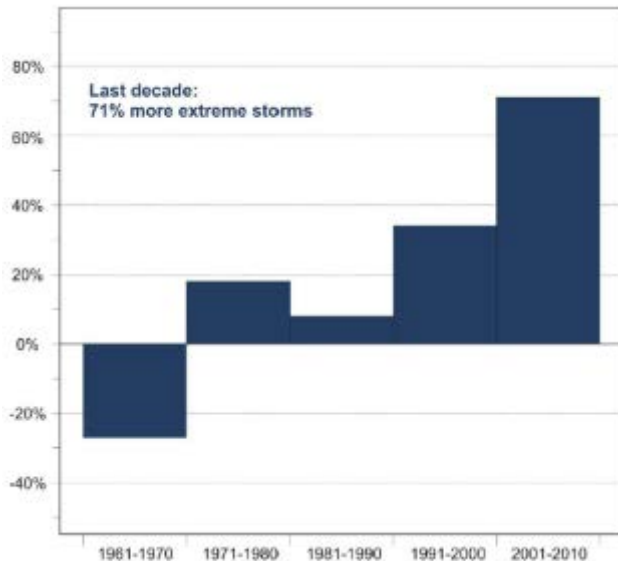
Change in Seasonal Precip, 1901-2011



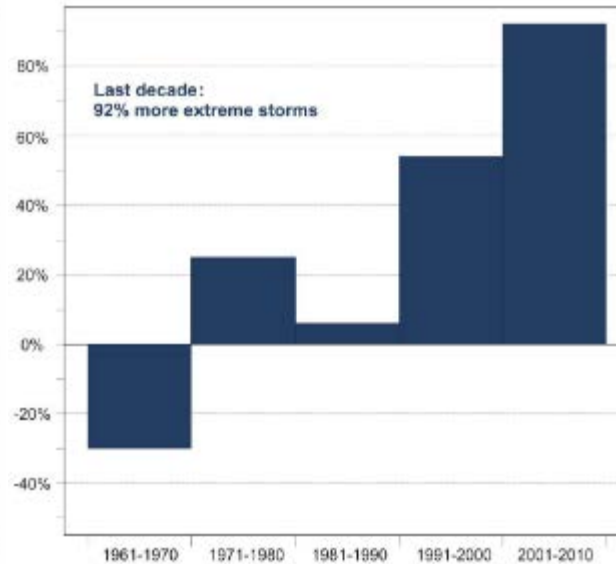
Observed Trends in Extreme Weather

Frequency of 3"+ rainstorms

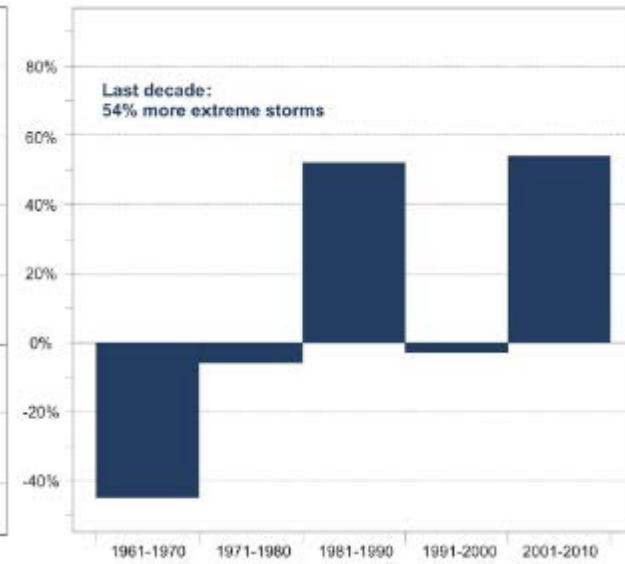
Minnesota



Wisconsin



Michigan

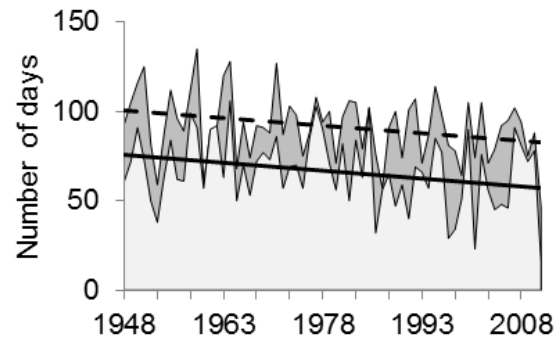


Less Frozen Ground

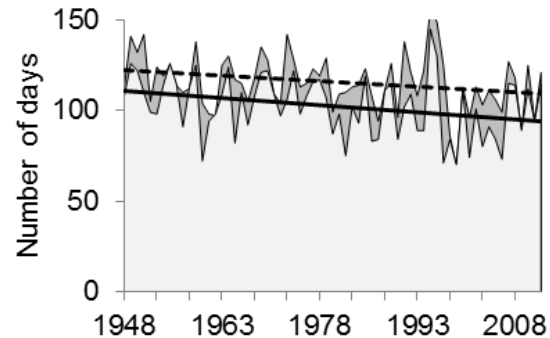
Frozen ground conditions have decreased over the last 60+ years – WI example



Dane County



Onieda County

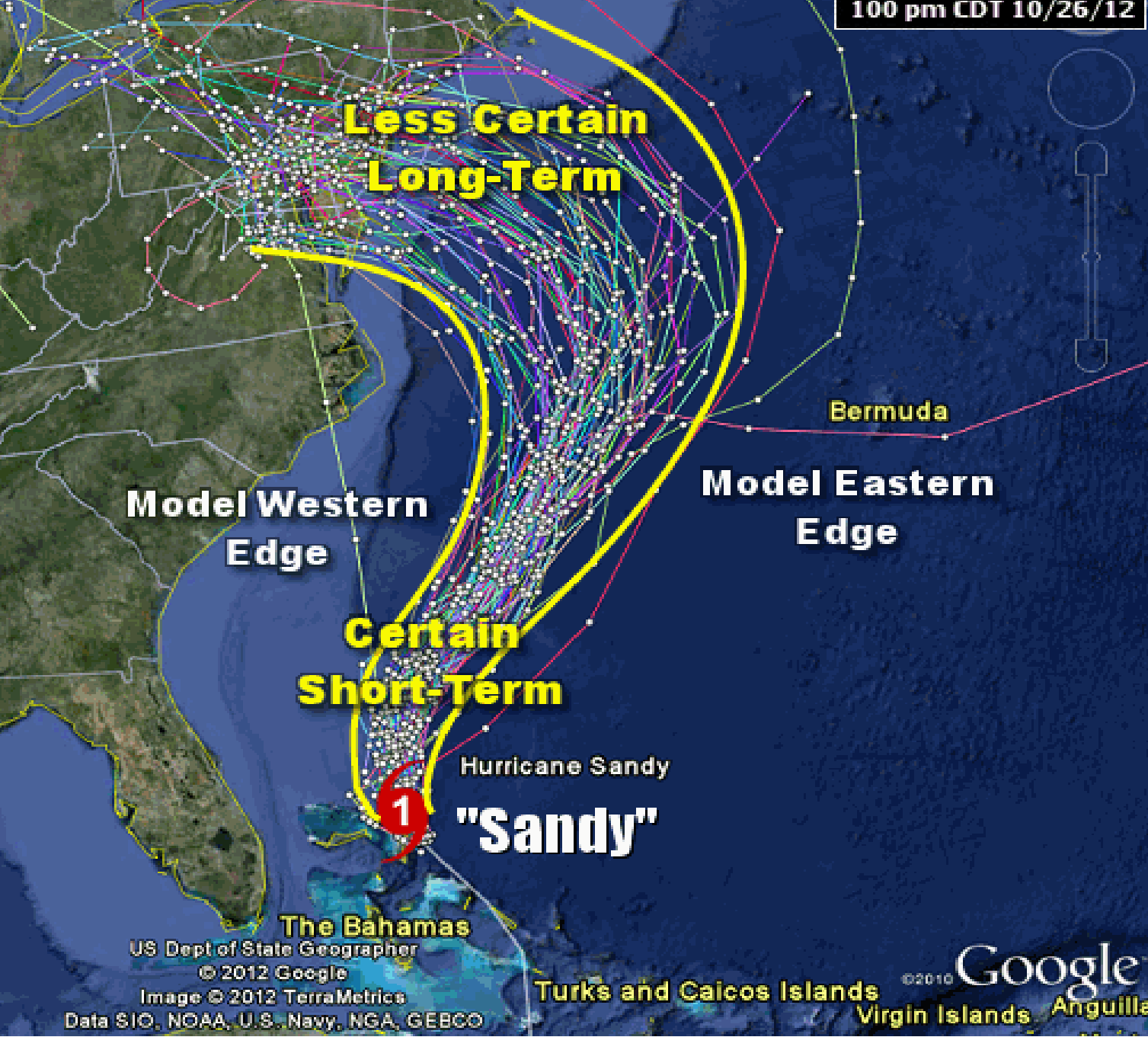


Phenology Changes

- 1-2 more freeze-thaw cycles per yr since 1900
- 6-8 day advance in growing season since 1950
- 1.4 days/decade earlier ice out since 1916
- Many other observed changes! (mammals, birds, etc.)



100 pm CDT 10/26/12



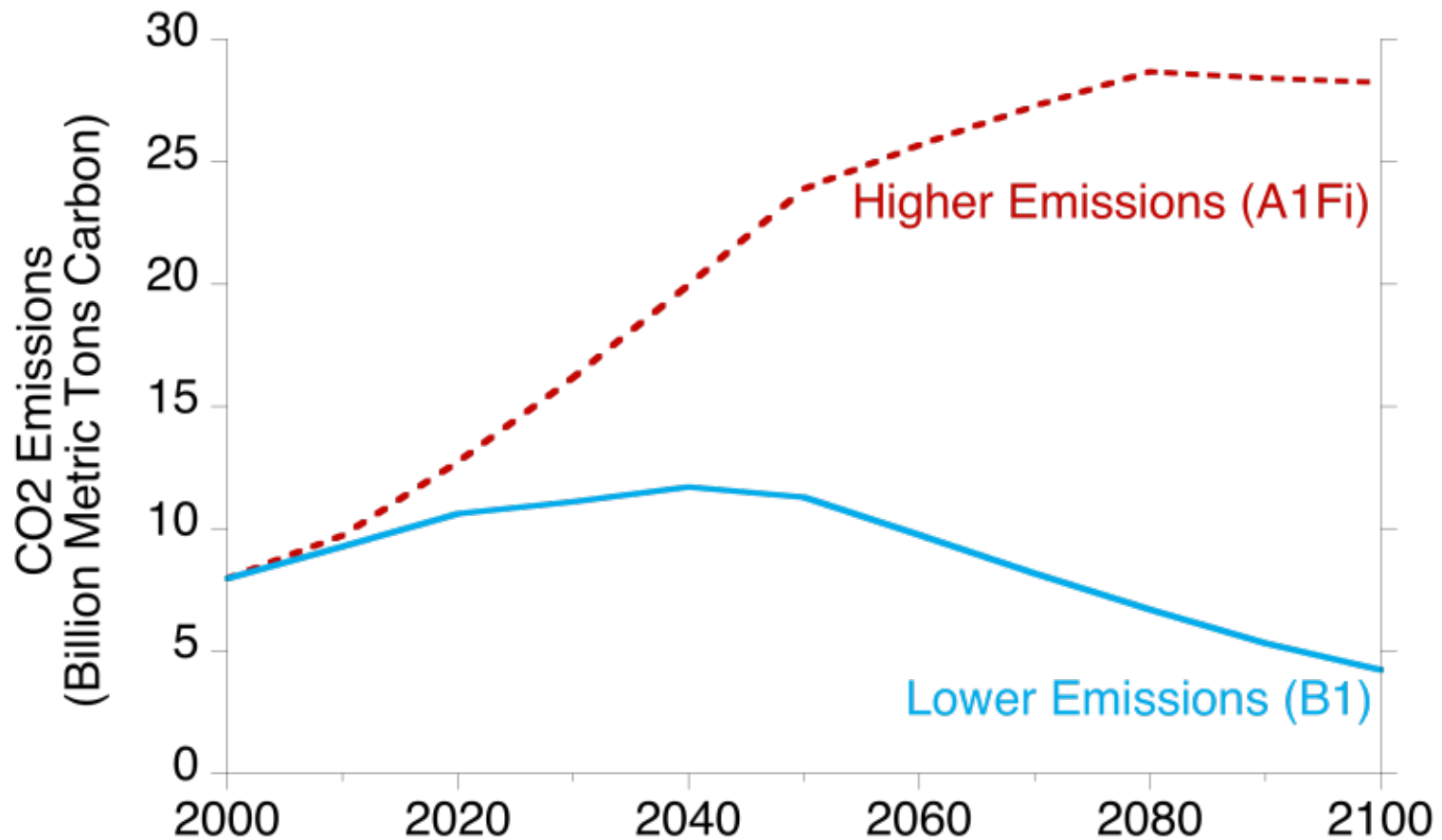
Source:
NOAA 2012

US Dept of State Geographer
© 2012 Google
Image © 2012 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

©2010 Google
The Bahamas
Turks and Caicos Islands
Virgin Islands
Anguilla

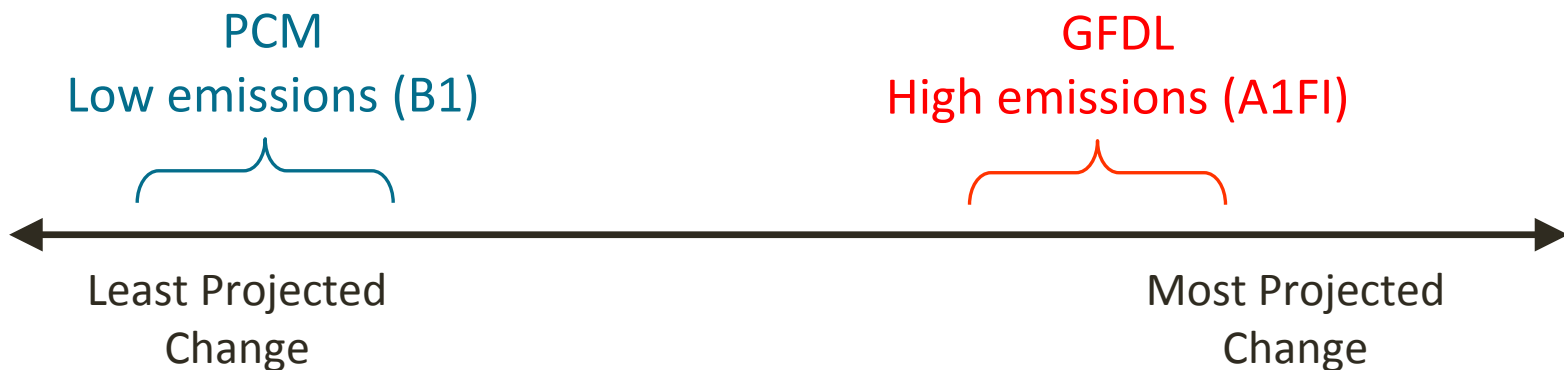
Future Change - Uncertainty

Two scenarios of future GHG emissions



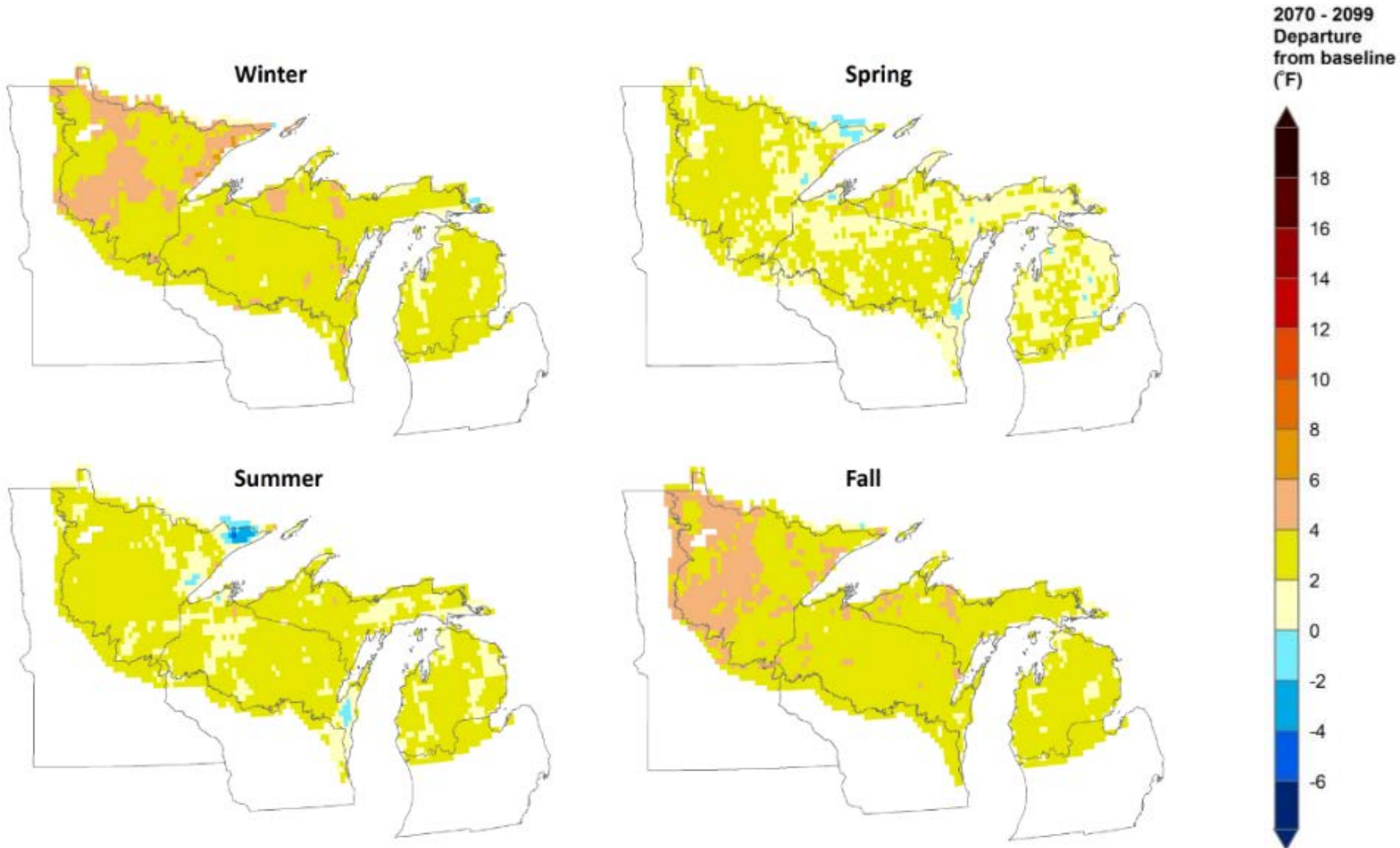
Future Change - Uncertainty

- Pay attention to the range of possible change
 - PCM B1: low emissions + less sensitive GCM
 - GFDL A1FI: high emissions + more sensitive GCM
- Projections are consistent with other data sets
- Think of them like bookends:



Projected Temperature Change (F)

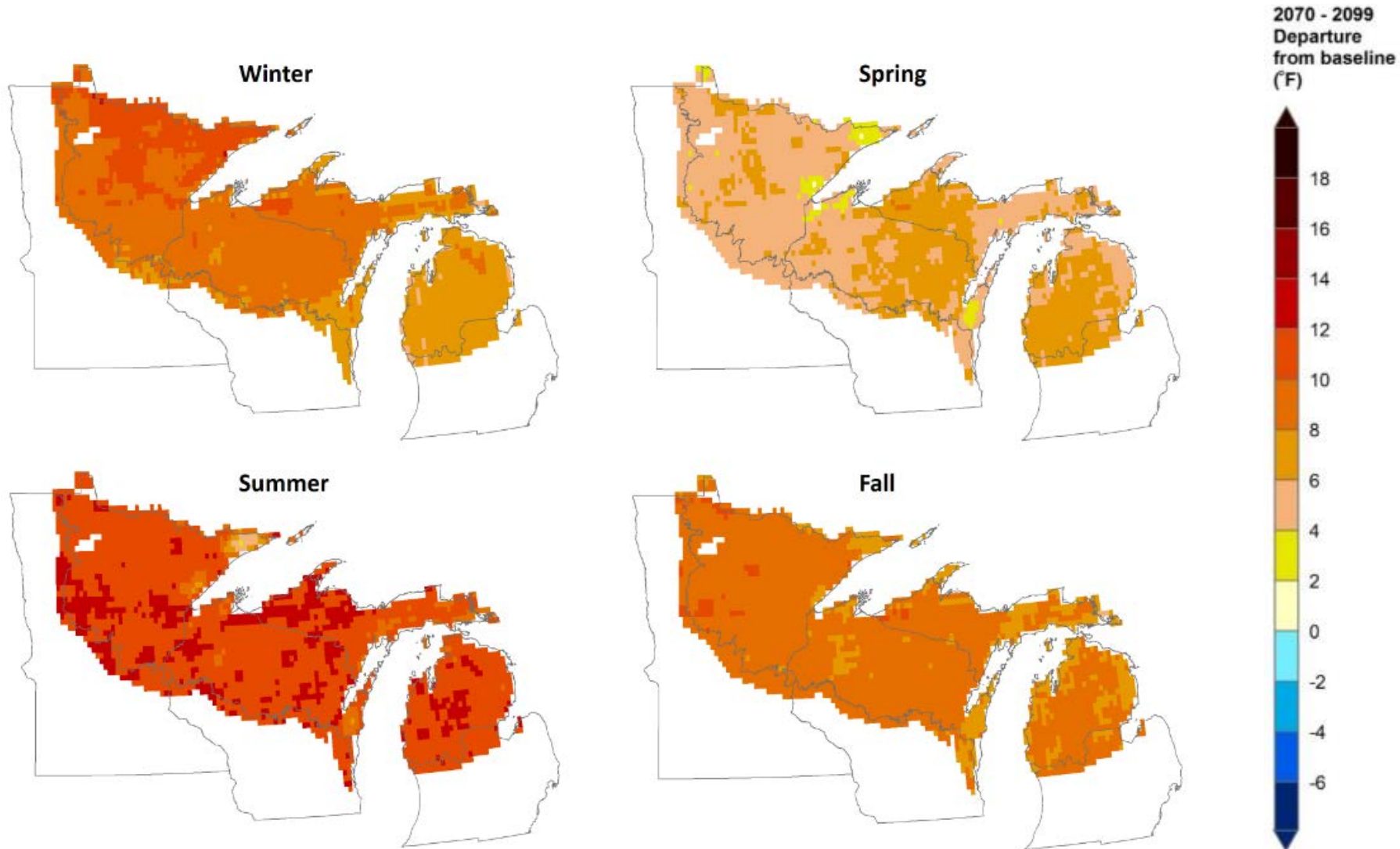
PCM B1 – Less Change Scenario, 2070-2099



Sources: Stoner et al. 2012, Hayhoe et al. 2011.

Projected Temperature Change (F)

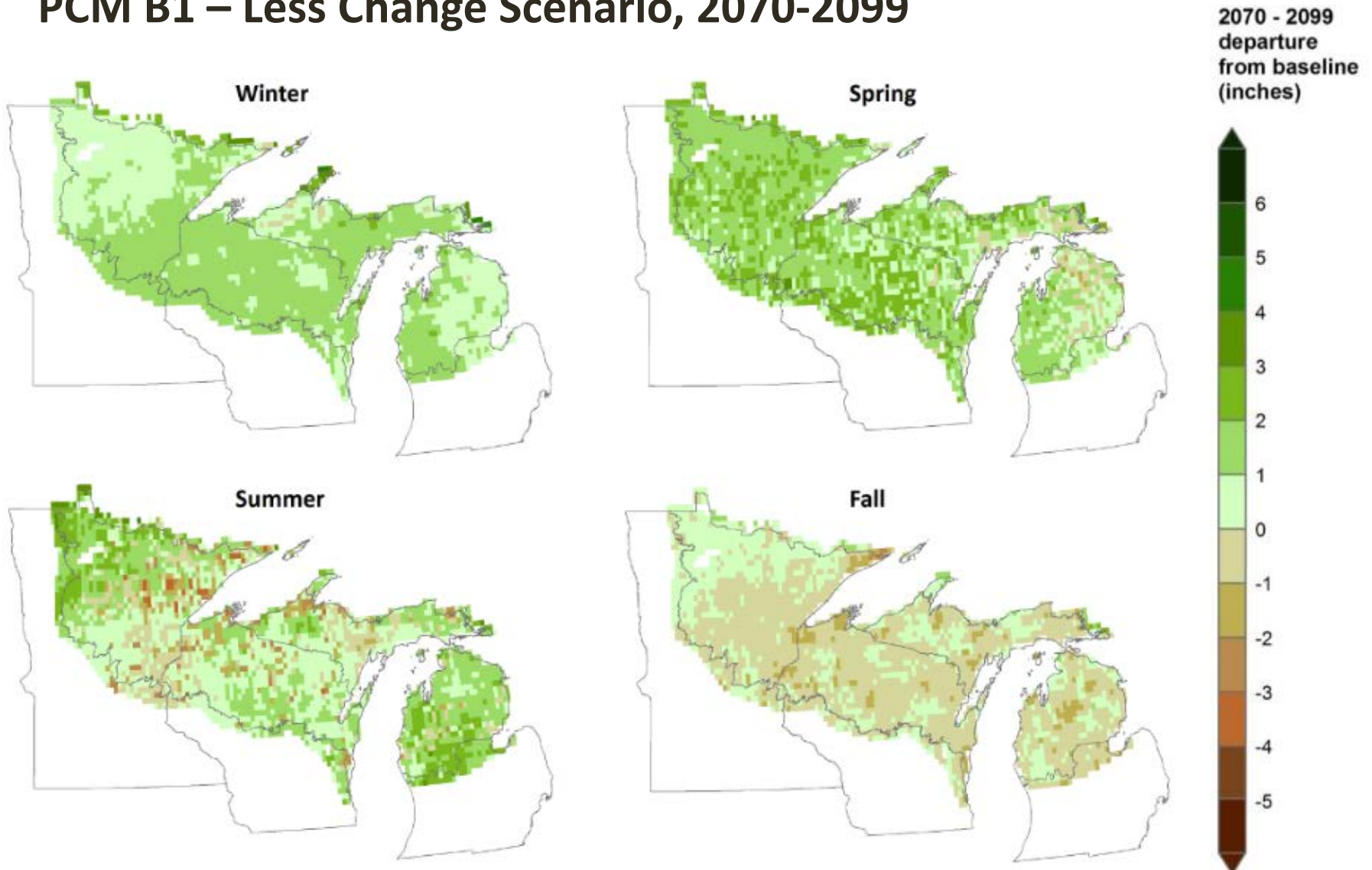
GFDL A1FI – More Change Scenario, 2070-2099



Sources: Stoner et al. 2012, Hayhoe et al. 2011.

Projected Precipitation Change (in)

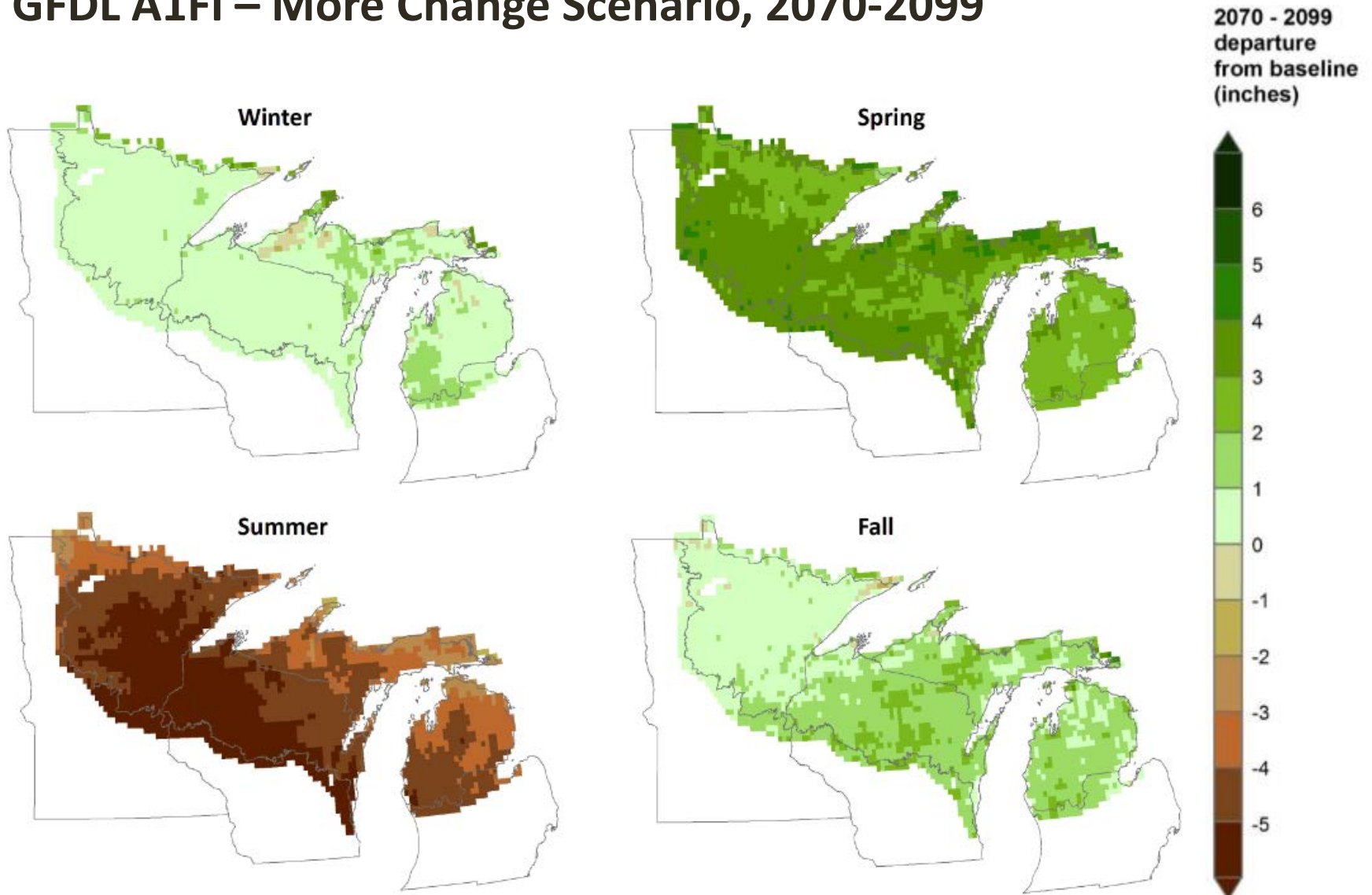
PCM B1 – Less Change Scenario, 2070-2099



Sources: Stoner et al. 2012, Hayhoe et al. 2011.

Projected Precipitation Change (in)

GFDL A1FI – More Change Scenario, 2070-2099

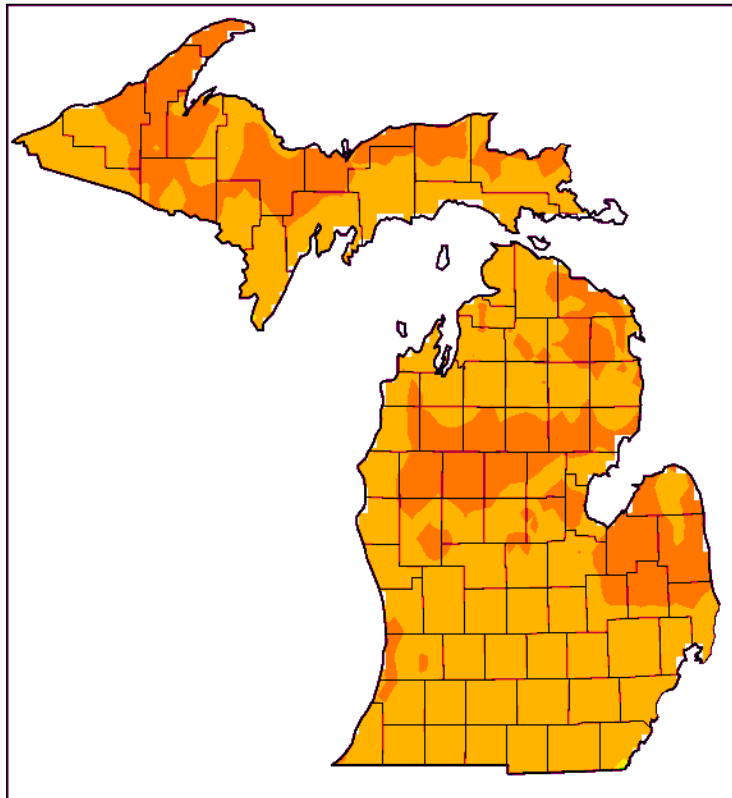


Sources: Stoner et al. 2012, Hayhoe et al. 2011.

Last Spring Frost

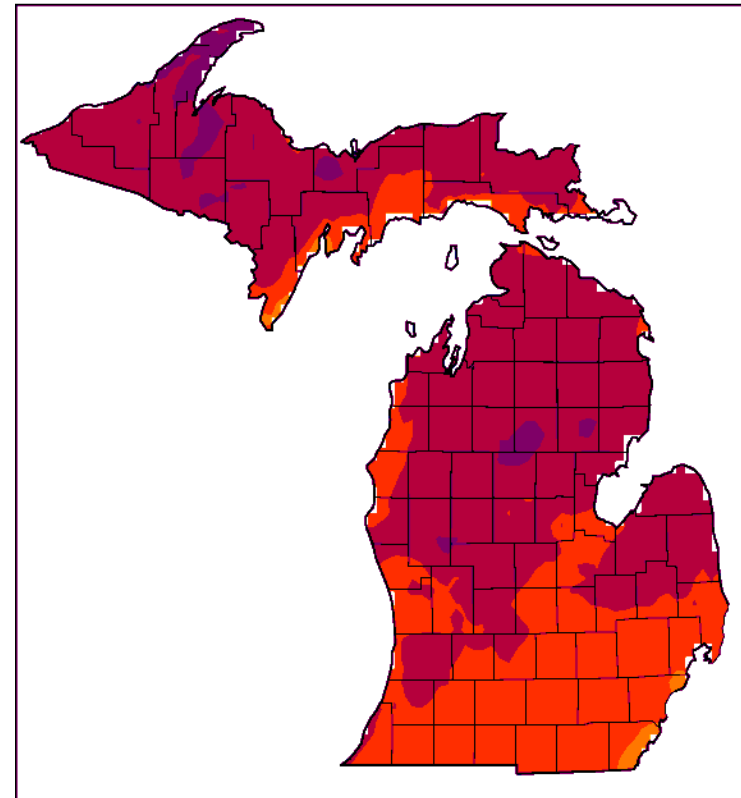
Low

LastSpringFreeze B1Late21-20C3M



High

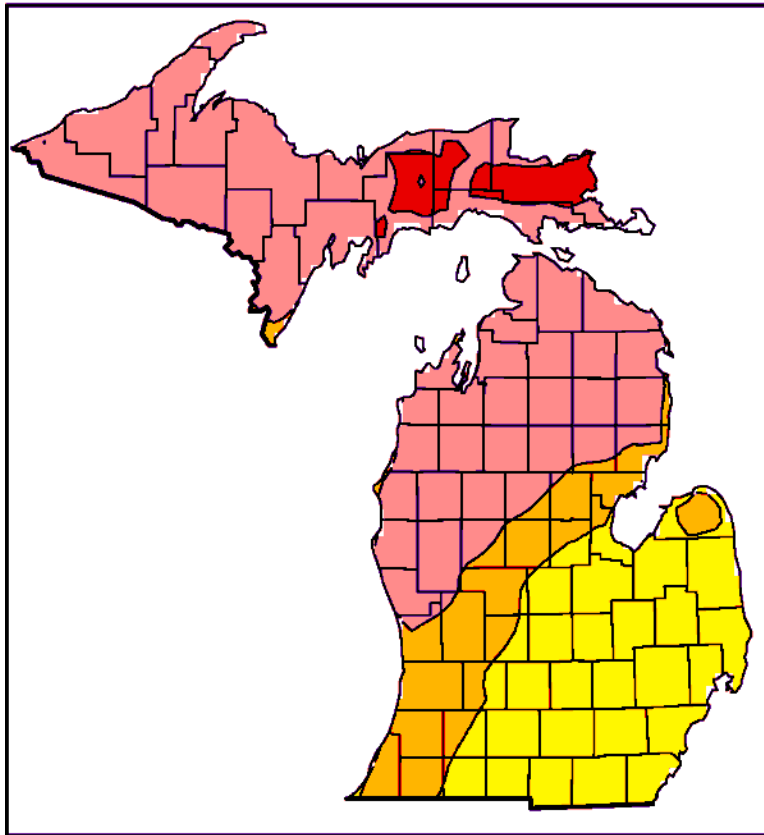
LastSpringFreeze A2Late21-20C3M



Snowpack ≥ 10 in.

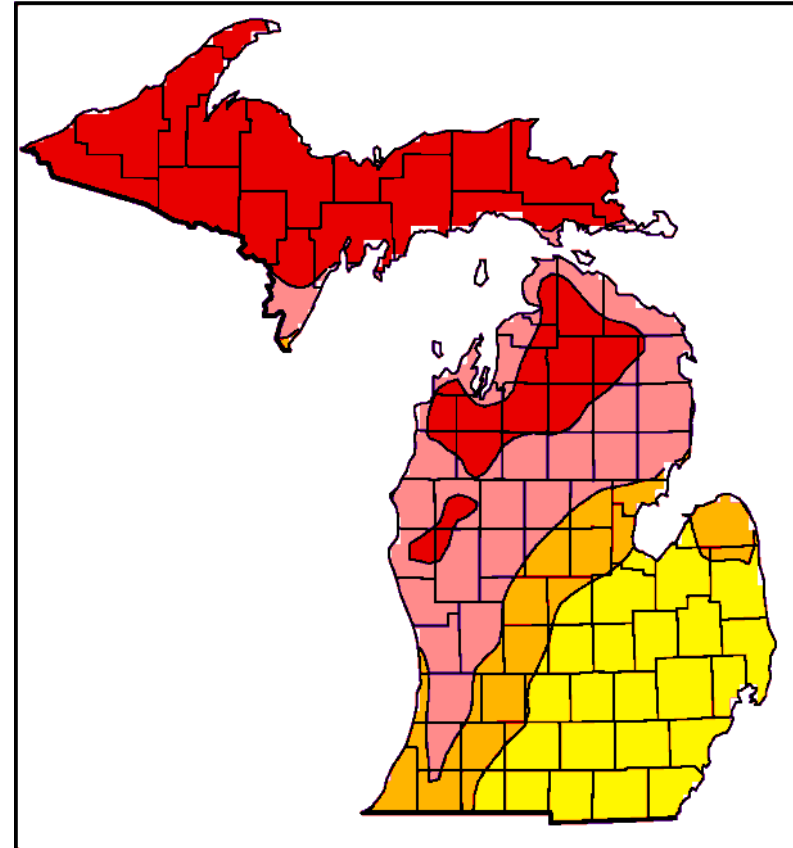
Low

Change Numb Dys Depth 10in+ B1Late21-20C3M



High

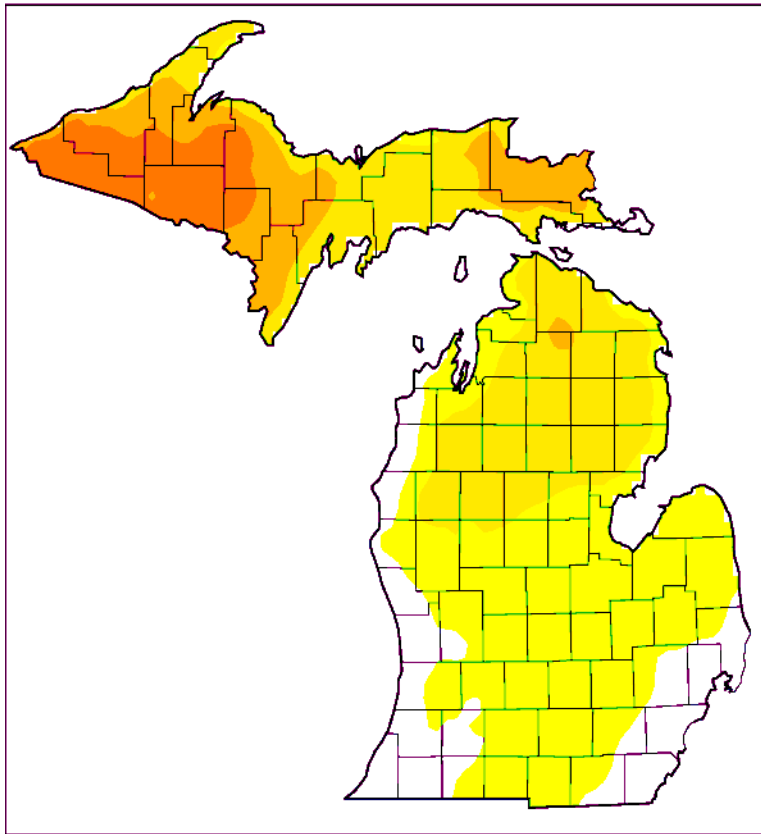
Change Numb Dys Depth 10in+ A2Late21-20C3M



Nights Below 0 °F

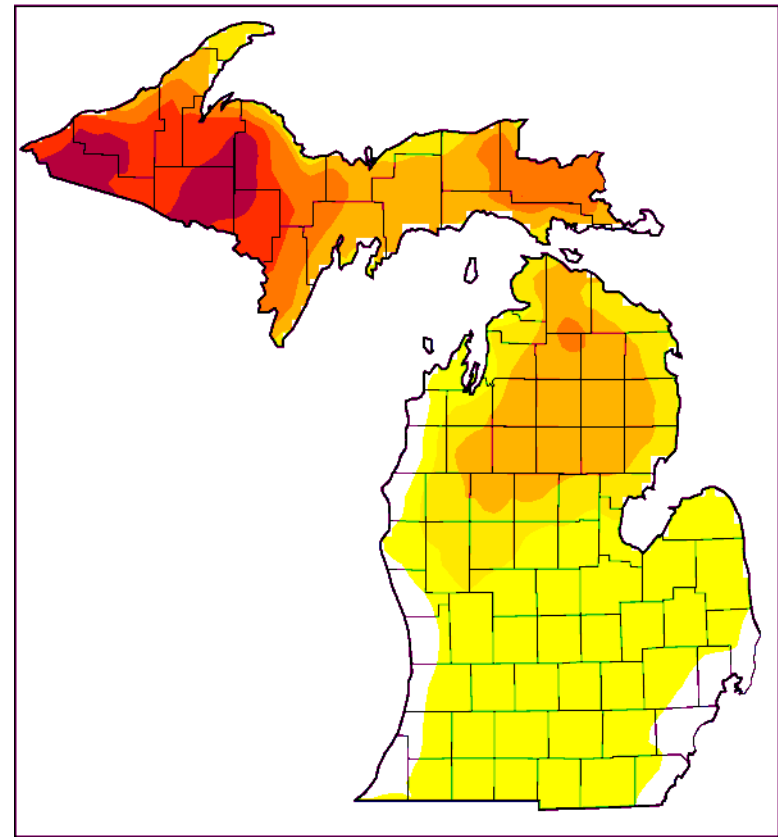
Low

0F- Days B1Late21-20C3M



High

0F- Days A2Late21-20C3M



Winter Severity Index

Current

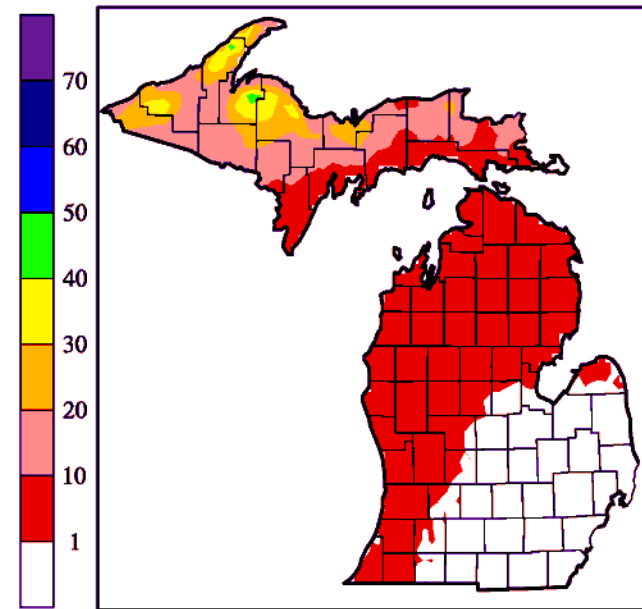
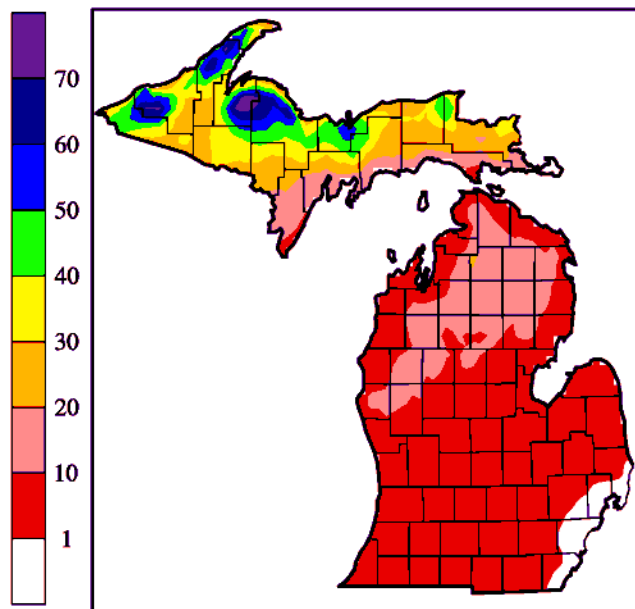
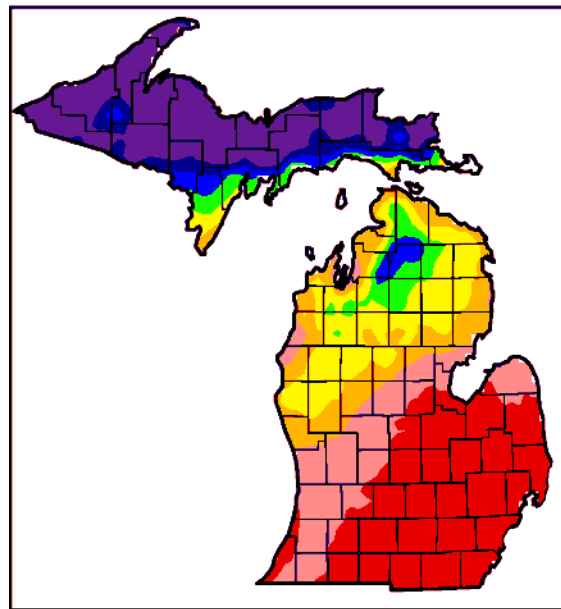
Low

High

WSI Late20th

WSI Late21st B1

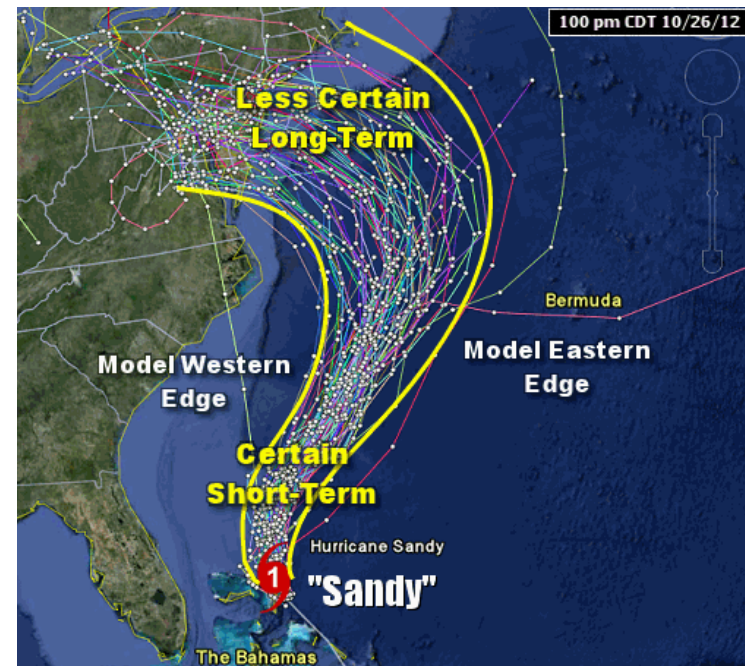
WSI Late21st A2



Other Projected Changes

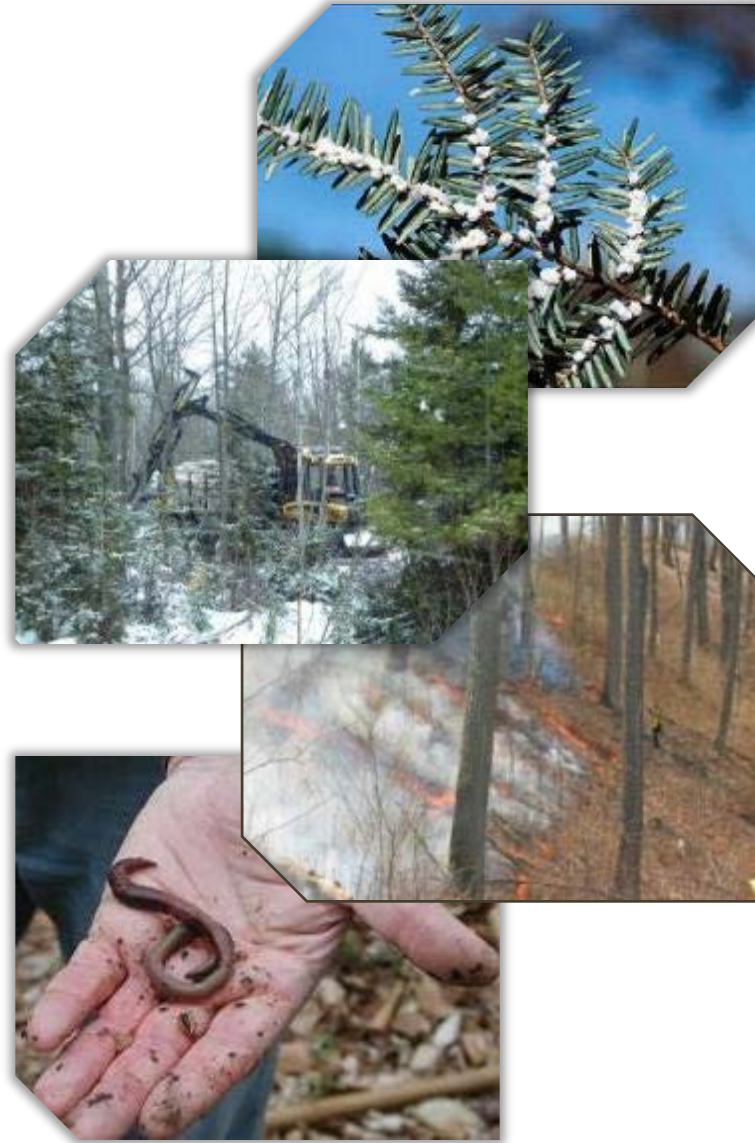
By 2100, northern Michigan can expect:

- 40-80% decrease in snow-water equivalent
- 30-50 fewer days with frozen ground
- Earlier snowmelt
- More freezing rain
- 2-3 more freeze-thaw cycles
- 30-70 day increase in the growing season



Impacts on Forests

- Longer growing season
- CO₂ fertilization
- Altered soil moisture
- Extreme weather events
- Less frozen ground
- Increased fire risk
- **Species range shifts**
- Increased stressors



Key Ecological Attributes: Repurposed

- The existing KEAs provide important information about the condition of the forest
 - Good ecological condition would be expected to increase the adaptive capacity of a forest, making in more resilient to climate change
- **Which of the existing KEAs are particularly relevant in light of climate change?**

KEAs from Two-Hearted:

- 1) Total Stocking**
- 2) Acceptable Growing Stock
- 3) Tree Species Diversity**
- 4) Tree Species Evenness**
- 5) Large Live Trees
- 6) Large Snags
- 7) Large Coarse Woody Debris**
- 8) Established Seedlings**
- 9) Desirable Established Seedlings**

NEW Climate Informed Metrics

- The idea of KEAs can be extended to climate change adaptation, where KEAs can indicate whether forests are:
 - At risk due to climate change
 - Improving the adaptive capacity (resilience) of forests to climate change impacts
 - Transitioning forests to conditions that are expected to be more in line with the range of potential future climates
- These are used in conjunction with standard KEAs, such as diversity values

New Climate Adaptation KEAs

- 10) Risk of Decline – Trees**
- 11) Risk of Decline – Established Saplings**
- 12) Risk of Decline – Established Seedlings**

New Risk Metrics

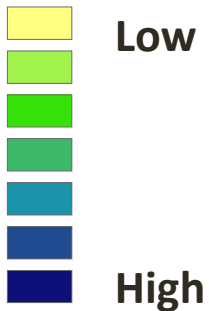
Are the trees in this stand/forest/area at risk from climate change?

- Integrates Climate Change Tree Atlas projections, which are part of published vulnerability assessments
- “At risk” species identified for an ecoregion
 - Suitable habitat reduced >20% by 2100
- **IMPORTANT: Metric signals that species is at risk of decline across a general region, but it is up to manager to evaluate that information given local knowledge**

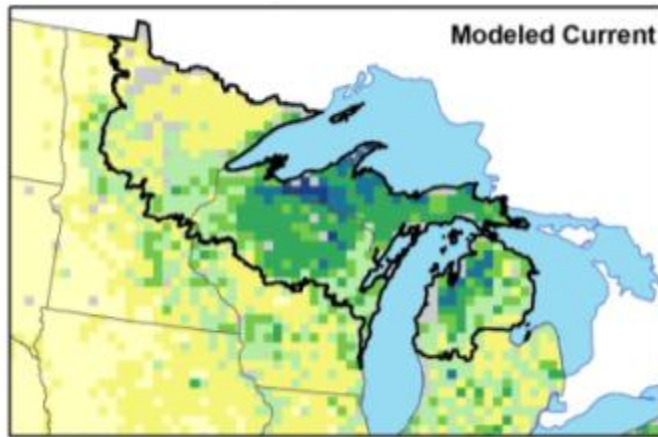
Species Range Shifts

Sugar Maple

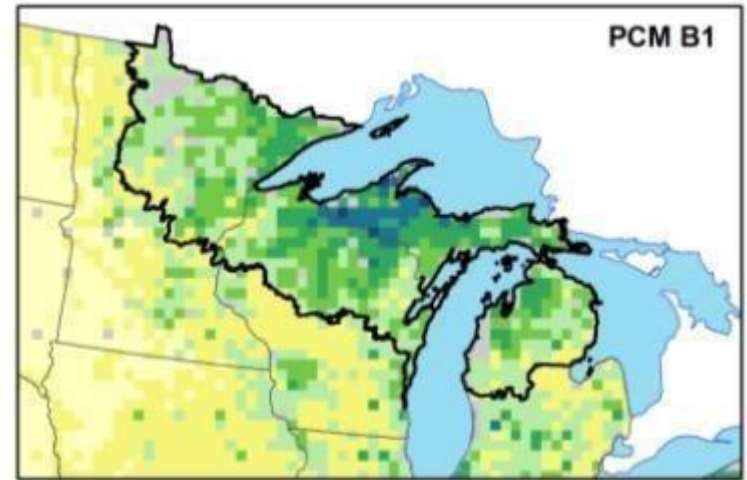
Importance
Value



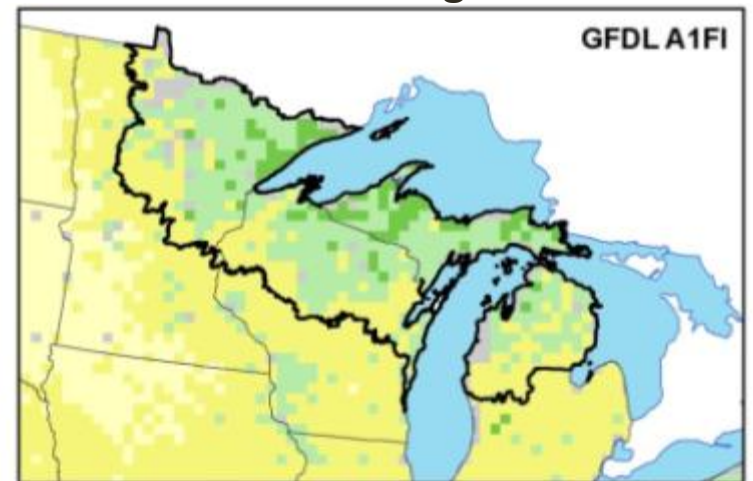
Current



2070-2100 Low



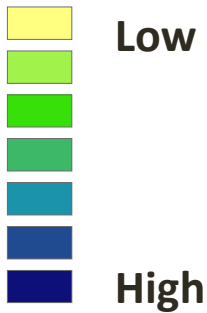
2070-2100 High



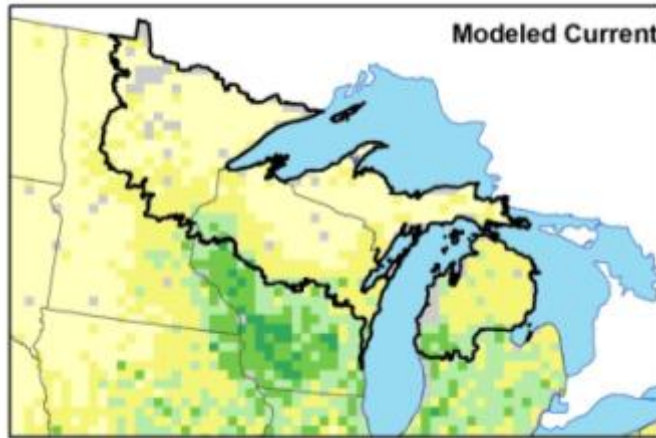
Species Range Shifts

White Oak

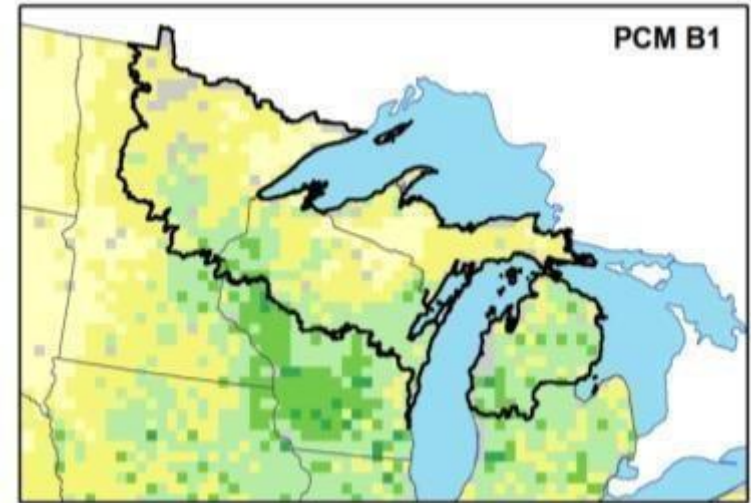
Importance
Value



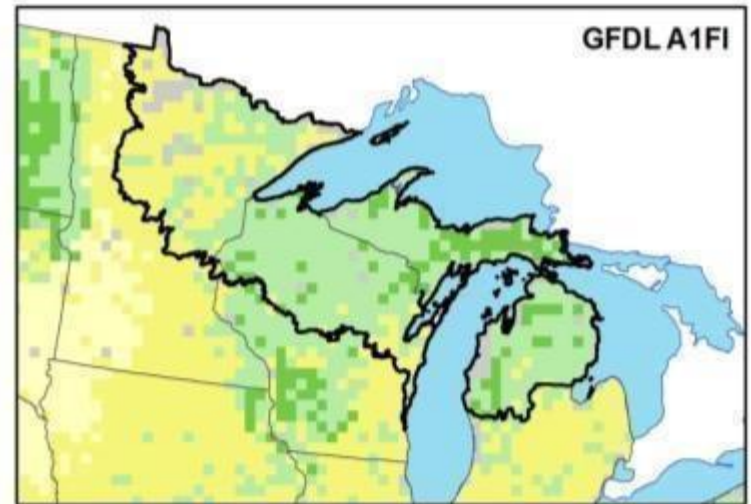
Current



2070-2100 Low



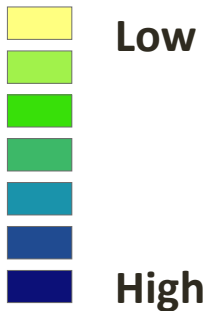
2070-2100 High



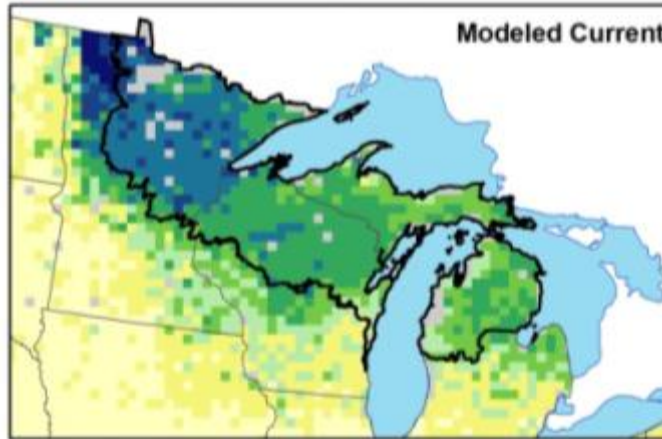
Species Range Shifts

Quaking Aspen

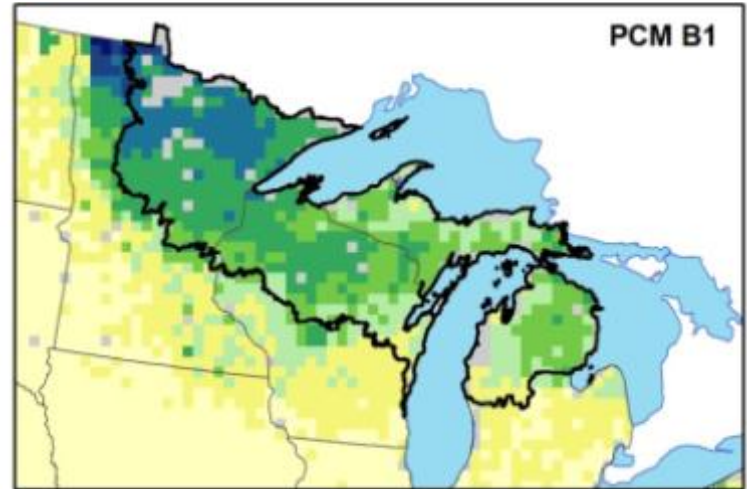
Importance
Value



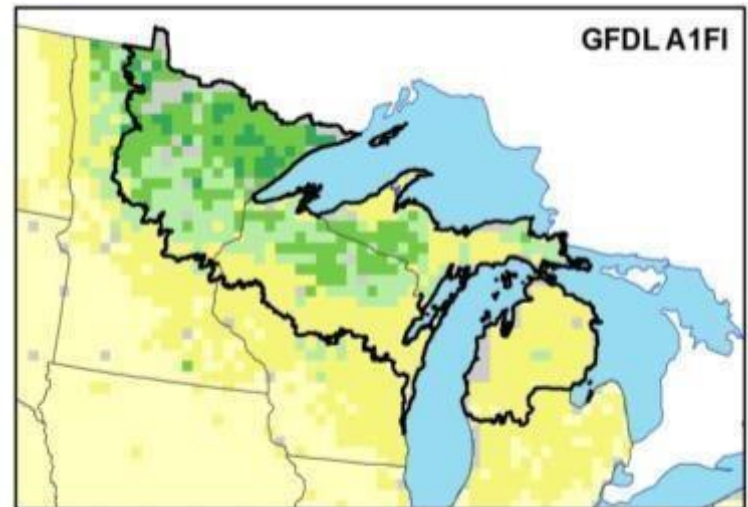
Current



2070-2100 Low



2070-2100 High



Climate Change Projections for Individual Tree Species PCM B1 Scenario (Less Change)



Generally expected to decrease	Little Change	Generally expected to increase	New Suitable Habitat (Tree Atlas)	Not sure (Disagreement among models)
<u>Substantial Declines:</u> Black spruce Mountain maple* White spruce <u>Smaller declines:</u> Balsam fir Balsam poplar Boxelder* Bur oak* Jack pine Northern white-cedar Paper birch River birch* Rock elm* Tamarack*	Bitternut hickory* Chestnut oak* Chokecherry* Eastern cottonwood* Eastern hophornbeam* Pin cherry* Ohio buckeye* Pin cherry* Pin oak* Striped maple* Swamp white oak*	<u>Substantial Increases:</u> Black locust* Black walnut* Sassafras* Shagbark hickory* <u>Smaller Increases:</u> American beech American elm American hornbeam* Black cherry Black oak Black willow* Blackgum* Eastern redcedar* Flowering dogwood* Honeylocust* Northern red oak Scarlet oak* Silver maple* Slippery elm* Sycamore* White ash	Hackberry* Mockernut hickory* Osage-orange* Pignut hickory* Red mulberry* Yellow-poplar*	<u>(Atlas/LANDIS):</u> American basswood (0/+) Bigtooth aspen (0/+) Black ash (0/-) Eastern hemlock (0/-) Eastern white pine (0/+) Green ash (-/+) Northern pin oak (0/-) Quaking aspen (-/+) Red maple (0/+) Red pine (0/-) Sugar maple (0/+) Yellow birch (0/-) White oak (+/0)
*Species only modeled by the Tree Atlas (DISTRIB) Note: model results only				

Source: Handler, S.; et al. 2014. **Michigan forest ecosystem vulnerability assessment and synthesis: a report from the Northwoods Climate Change Response Framework**. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. GTR-NRS-133. 229p. <http://www.treesearch.fs.fed.us/pubs/45688>.

Climate Change Projections for Individual Tree Species GFDL A1FI Scenario (Greater Change)



Generally expected to decrease	Little Change	Generally expected to increase	New Suitable Habitat (Tree Atlas)	Not sure (Disagreement among models)
<u>Substantial Declines:</u> Balsam fir Balsam poplar Black spruce Chokecherry* Jack pine Mountain maple* Northern white-cedar Paper birch Pin cherry* Quaking aspen Tamarack* White spruce Yellow birch <u>Smaller declines:</u> Black ash Bigtooth aspen Eastern hemlock Eastern white pine Red maple Red pine Striped maple*	Peachleaf willow*	<u>Substantial Increases:</u> American elm American hornbeam* Bitternut hickory* Black locust* Black walnut* Black willow* Blackgum* Boxelder* Bur oak* Eastern cottonwood* Eastern redcedar* Flowering dogwood* Pin oak* Sassafras* Shagbark hickory* Silver maple* Slippery elm* Swamp white oak* White ash <u>Smaller Increases:</u> Chestnut oak* Eastern hophornbeam* Honeylocust* Ohio buckeye* River birch* Rock elm* Scarlet oak* Sycamore* White oak	Black hickory* Blackjack oak* Chinkapin oak* Common persimmon* Eastern redbud* Hackberry* Mockernut hickory* Osage-orange* Pawpaw* Pignut hickory* Post oak* Red mulberry* Shellbark hickory* Shingle oak* Sugarberry* Wild plum* Yellow-poplar*	<u>(Atlas/LANDIS):</u> American basswood (+/--) American beech (0/-) Black cherry (0/-) Black oak (++/-) Green ash (+/-) Northern pin oak (++/--) Northern red oak (0/-) Sugar maple (--/+)
*Species only modeled by the Tree Atlas (DISTRIB) Note: model results only				

Source: Handler, S.; et al. 2014. **Michigan forest ecosystem vulnerability assessment and synthesis: a report from the Northwoods Climate Change Response Framework**. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

GTR-NRS-133, 229p. <http://www.treearch.fs.fed.us/pubs/45688>

New Risk Metrics

Northern Hardwood Stand:

Species	Basal Area	Stems Per Acre	Freq. (%)	Proportion of Stand (IV %)
Sugar maple	79.0	117.1	100.0	40.8
White ash	33.1	30.7	96.2	17.9
American basswood	18.5	23.7	73.1	12.3
Yellow birch	7.7	12.4	53.8	7.0
Bigtooth aspen	10.0	16.1	15.4	5.5
Red maple	4.2	8.6	42.3	5.0
Northern red oak	1.5	0.7	42.3	3.2
American elm	0.4	0.4	34.6	2.4
Paper birch	1.9	5.3	11.5	2.0
Black ash	1.5	2.6	7.7	1.2
Black cherry	0.4	0.2	15.4	1.1
Eastern hemlock	1.2	1.9	3.8	0.8
Quaking aspen	0.8	0.6	7.7	0.8
Total	160.2	220.3		100.0

New Risk Metrics

Northern Hardwood Stand:

Low (PCM B1)

Species	Basal Area	Stems Per Acre	Freq. (%)	Proportion of Stand (IV %)	Future: Current Habitat	Change Class	At-risk Proportion of Stand (%)
Sugar maple	79.0	117.1	100.0	40.8	0.8	No Change	0.0
White ash	33.1	30.7	96.2	17.9	1.6	Increase	0.0
American basswood	18.5	23.7	73.1	12.3	1.1	No Change	0.0
Yellow birch	7.7	12.4	53.8	7.0	0.8	Decrease	7.0
Bigtooth aspen	10.0	16.1	15.4	5.5	1.0	No Change	0.0
Red maple	4.2	8.6	42.3	5.0	1.0	No Change	0.0
Northern red oak	1.5	0.7	42.3	3.2	1.3	Increase	0.0
American elm	0.4	0.4	34.6	2.4	2.3	Increase	0.0
Paper birch	1.9	5.3	11.5	2.0	0.7	Decrease	2.0
Black ash	1.5	2.6	7.7	1.2	0.7	Decrease	1.2
Black cherry	0.4	0.2	15.4	1.1	2.4	Large Increase	0.0
Eastern hemlock	1.2	1.9	3.8	0.8	1.2	Increase	0.0
Quaking aspen	0.8	0.6	7.7	0.8	0.6	Decrease	0.8
Total	160.2	220.3		100.0		Proportion at-risk:	11.0

New Risk Metrics

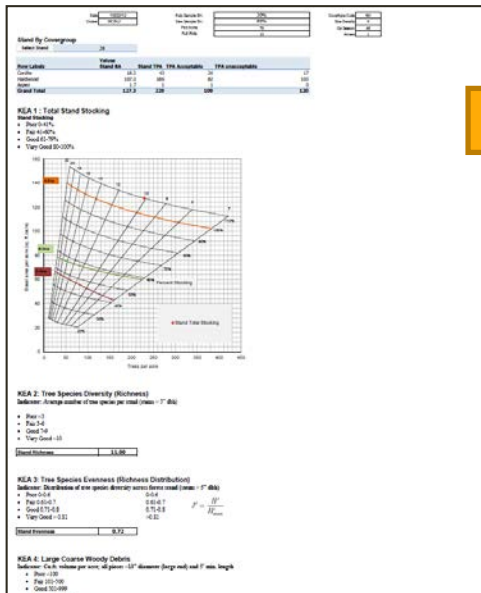
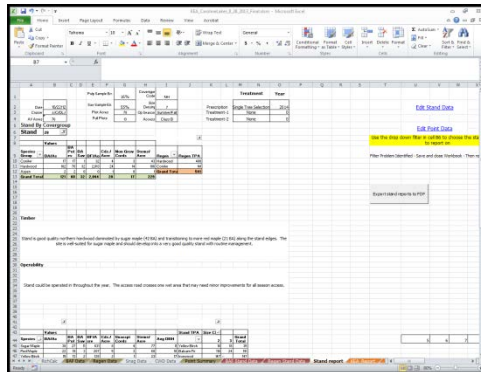
Northern Hardwood Stand:

Low (PCM B1)

High (GFDL A1F1)

Species	Basal Area	Stems Per Acre	Freq. (%)	Proportion of Stand (IV %)	Future: Current Habitat	Change Class	At-risk Proportion of Stand (%)	Future: Current Habitat	Change Class	At-risk Proportion of Stand (%)
Sugar maple	79.0	117.1	100.0	40.8	0.8	No Change	0.0	0.3	Large Decrease	40.8
White ash	33.1	30.7	96.2	17.9	1.6	Increase	0.0	1.9	Increase	0.0
American basswood	18.5	23.7	73.1	12.3	1.1	No Change	0.0	1.4	Increase	0.0
Yellow birch	7.7	12.4	53.8	7.0	0.8	Decrease	7.0	0.2	Large Decrease	7.0
Bigtooth aspen	10.0	16.1	15.4	5.5	1.0	No Change	0.0	0.4	Large Decrease	5.5
Red maple	4.2	8.6	42.3	5.0	1.0	No Change	0.0	0.6	Decrease	5.0
Northern red oak	1.5	0.7	42.3	3.2	1.3	Increase	0.0	1.1	No Change	0.0
American elm	0.4	0.4	34.6	2.4	2.3	Increase	0.0	3.2	Large Increase	0.0
Paper birch	1.9	5.3	11.5	2.0	0.7	Decrease	2.0	0.2	Large Decrease	2.0
Black ash	1.5	2.6	7.7	1.2	0.7	Decrease	1.2	0.6	Decrease	1.2
Black cherry	0.4	0.2	15.4	1.1	2.4	Large Increase	0.0	1.4	Increase	0.0
Eastern hemlock	1.2	1.9	3.8	0.8	1.2	Increase	0.0	0.4	Large Decrease	0.8
Quaking aspen	0.8	0.6	7.7	0.8	0.6	Decrease	0.8	0.2	Large Decrease	0.8
Total	160.2	220.3		100.0			Proportion at-risk: 11.0			Proportion at-risk: 63.0

Massive Excel workbook



Stand 28 example (small regen not shown)

KEA 7: Climate Adaptation Risk - Overstory

Indicator: Percentage of stand overstory composed of species which are at risk in a PCM scenario

- Poor $\geq 60\%$
- Fair 40-59%
- Good 21-39%
- Very Good $< 20\%$

Stand Overstory PCM %	12.36%
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Indicator: Percentage of stand overstory composed of species which are at risk in a GFDL scenario

- Poor $\geq 60\%$
- Fair 40-59%
- Good 21-39%
- Very Good $< 20\%$

Stand Overstory GFDL %	58.64%
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KEA 8: Climate Adaptation Risk - Established Regeneration (1" - 4.5" DBH)

Indicator: Percentage of established stand regeneration at risk in a PCM scenario

- Poor $\geq 60\%$
- Fair 40-59%
- Good 21-39%
- Very Good $< 20\%$

Stand Regeneration PCM %	36.57%
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Indicator: Percentage of established stand regeneration at risk in a GFDL scenario

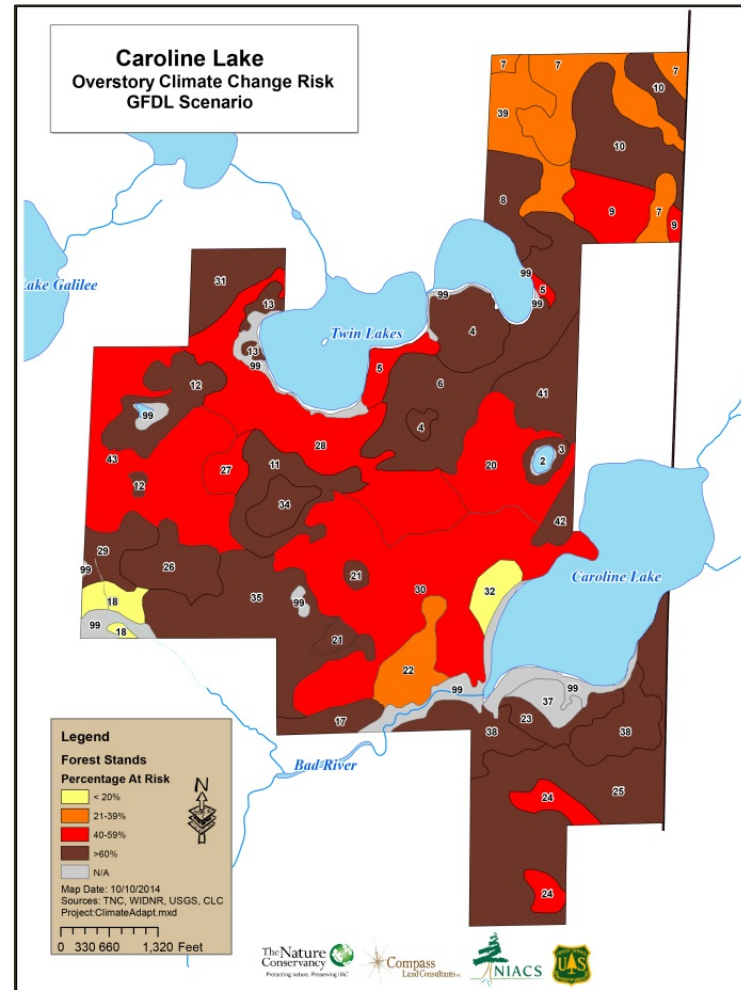
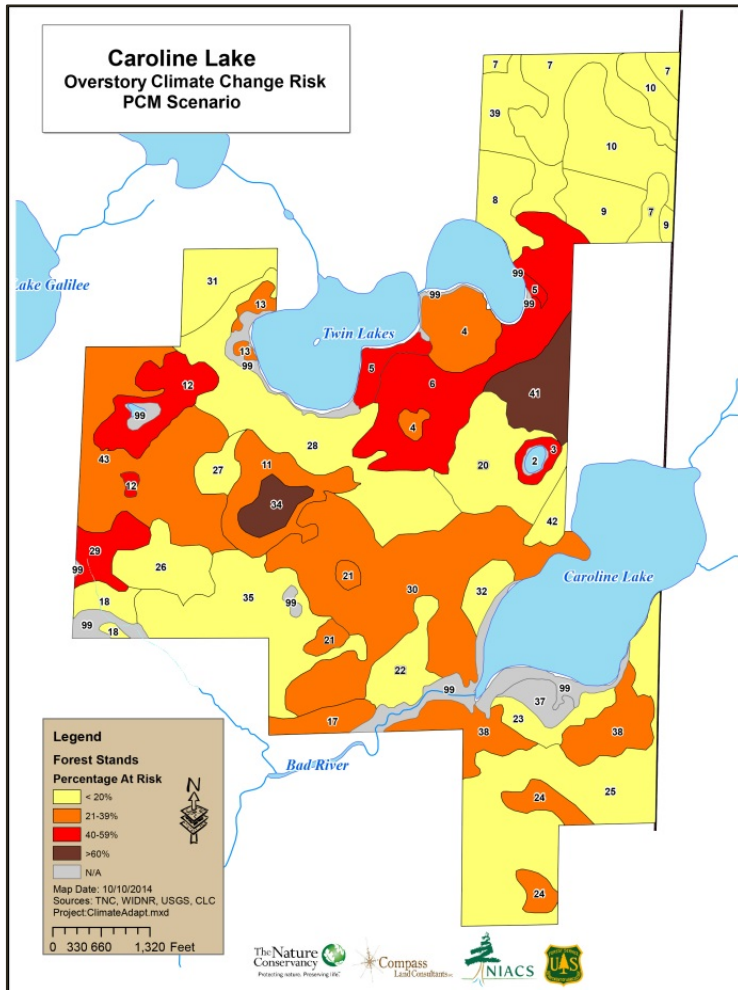
- Poor $\geq 60\%$
- Fair 40-59%
- Good 21-39%
- Very Good $< 20\%$

Stand Regeneration GFDL %	82.84%
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Risk by stand (overstory):

Low (PCM B1)

High (GFDL A1F1)



Applied in the Real World...

- Using Climate informed inventory to guide management activities on the ground
 - Important not to lose sight of overall management goals
 - Biodiversity
 - Protection of water quality and ecosystem function
 - Sustainable timber production
 - Understanding CIMs helps us determine how climate change may impact our ability to meet those goals
 - Silvicultural prescriptions are developed understanding challenges and opportunities
 - Evaluate effectiveness over time – Monitoring

Acknowledgements

NIACS (& USFS)

- Chris Swanston
- Stephen Handler
- Maria Janowiak

Compass Land Consultants

- Jon Fosgitt
- Todd Bishop

The Nature Conservancy

- Matt Dallman (WI)
- Tina Hall (MI)
- Kim Hall (in MI, works regionally)

USFS Northern Research Station

- Susan Stout (Project Leader)
- Scott Thomasma (NED)
- Mark Twery (retired, NED)
- Louis Iverson (Tree Atlas)
- Steve Matthews (Tree Atlas)
- Anantha Prasad (Tree Atlas)
- Matt Peters (Tree Atlas)

Wisconsin DNR

- Brad Hutnik