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science for a changing world

Agents of change in the Sierra Nevada: Facing an unprecedented and unpredictable future

Nathan L. Stephenson

U.S. Department of the Interior
U.S. Geological Survey

Why are we here?

(1) The future we face is unprecedented.

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Heraclitus: “τὰ ὄντα ἰέναι τε πάντα καὶ μένειν οὐδέν.”

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(4) This workshop aims to make progress toward this end.

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The good old days: Static management

Historical (or natural) range of variability

Historical (or natural) range of variability

The unprecedented future: Shooting at a rapidly moving target

The unprecedented future: Shooting at a rapidly moving target

The unpredictable future:
We don’t know the target’s path

Agents of change

Climatic changes:

- Observed climatic changes & effects so far
- Projections for the future
- Thresholds and surprises
- The geoengineering wildcard

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Strategies for shooting at a moving target:

- Restraint
- Resistance
- Resilience
- Realignment

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Agents of change

Climatic changes:

Observed climatic changes & effects so far

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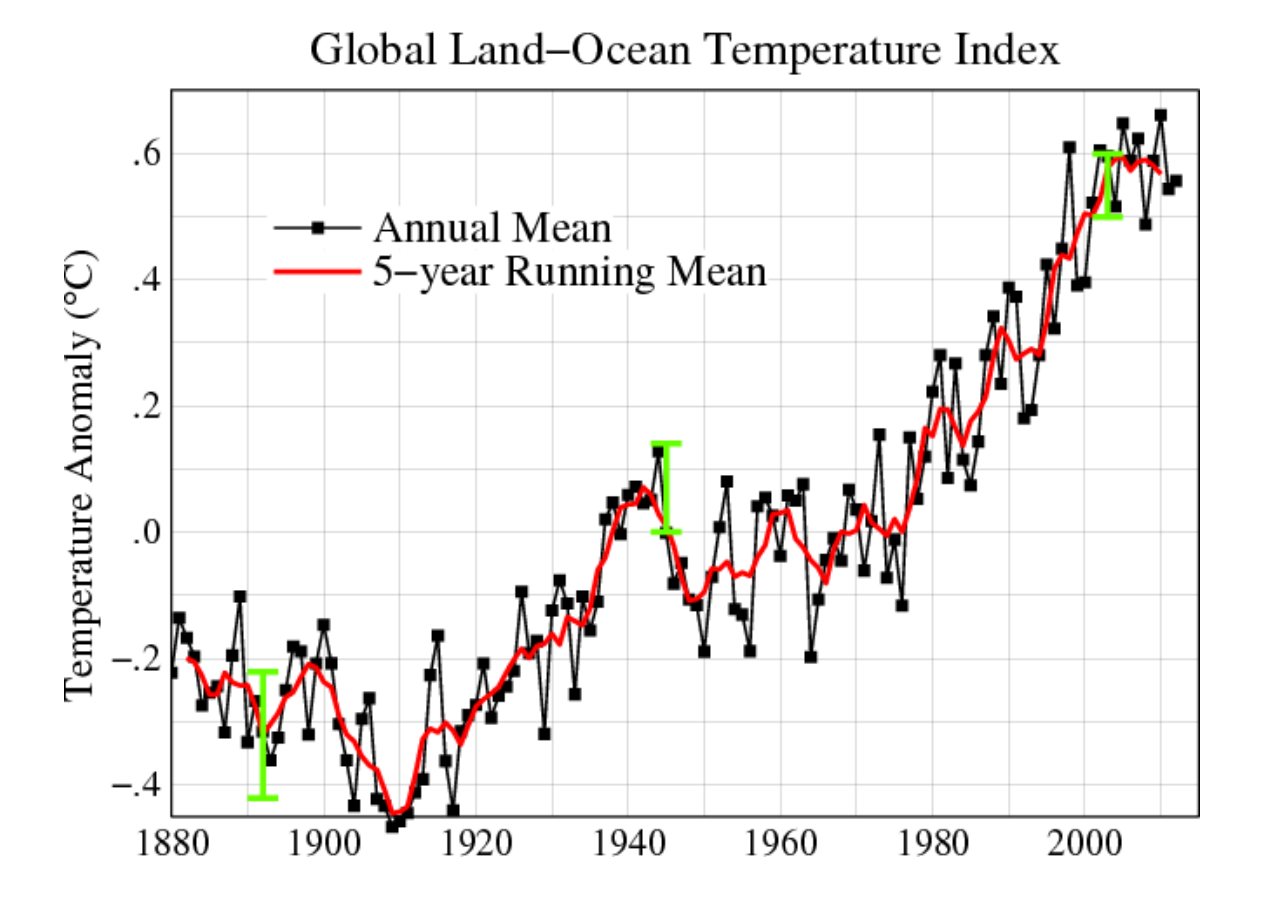
Recent global temperatures are certainly the warmest since good records began in the late 1800s,
and may even be the warmest in the last few thousand years.



NASA – GISS 2013

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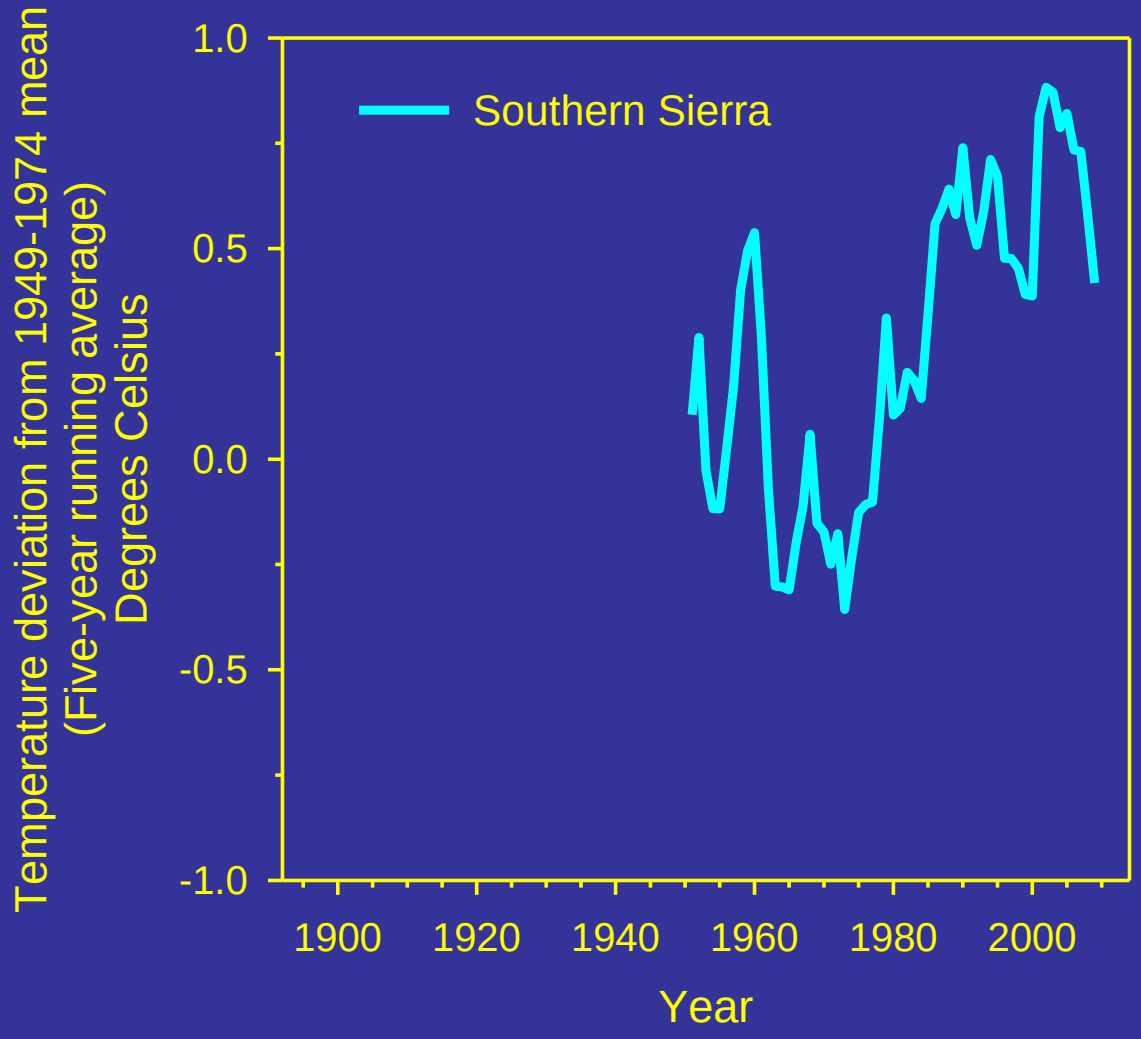
Similarly, the southern Sierra Nevada has generally been warming …



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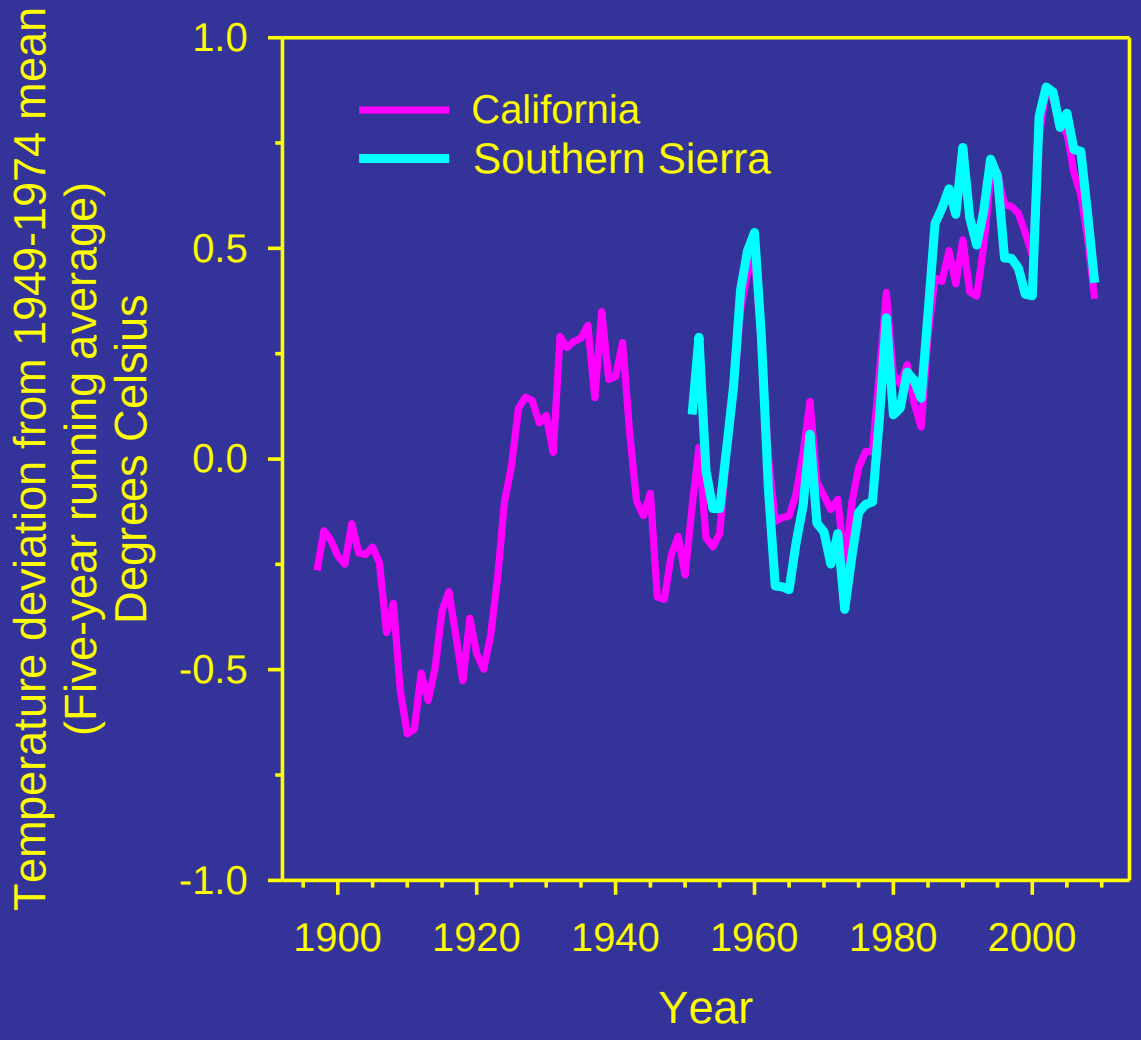
Das & Stephenson 2013, *SEKI NRCA*

… perhaps by ~1 °C (~2 °F) over the last century.



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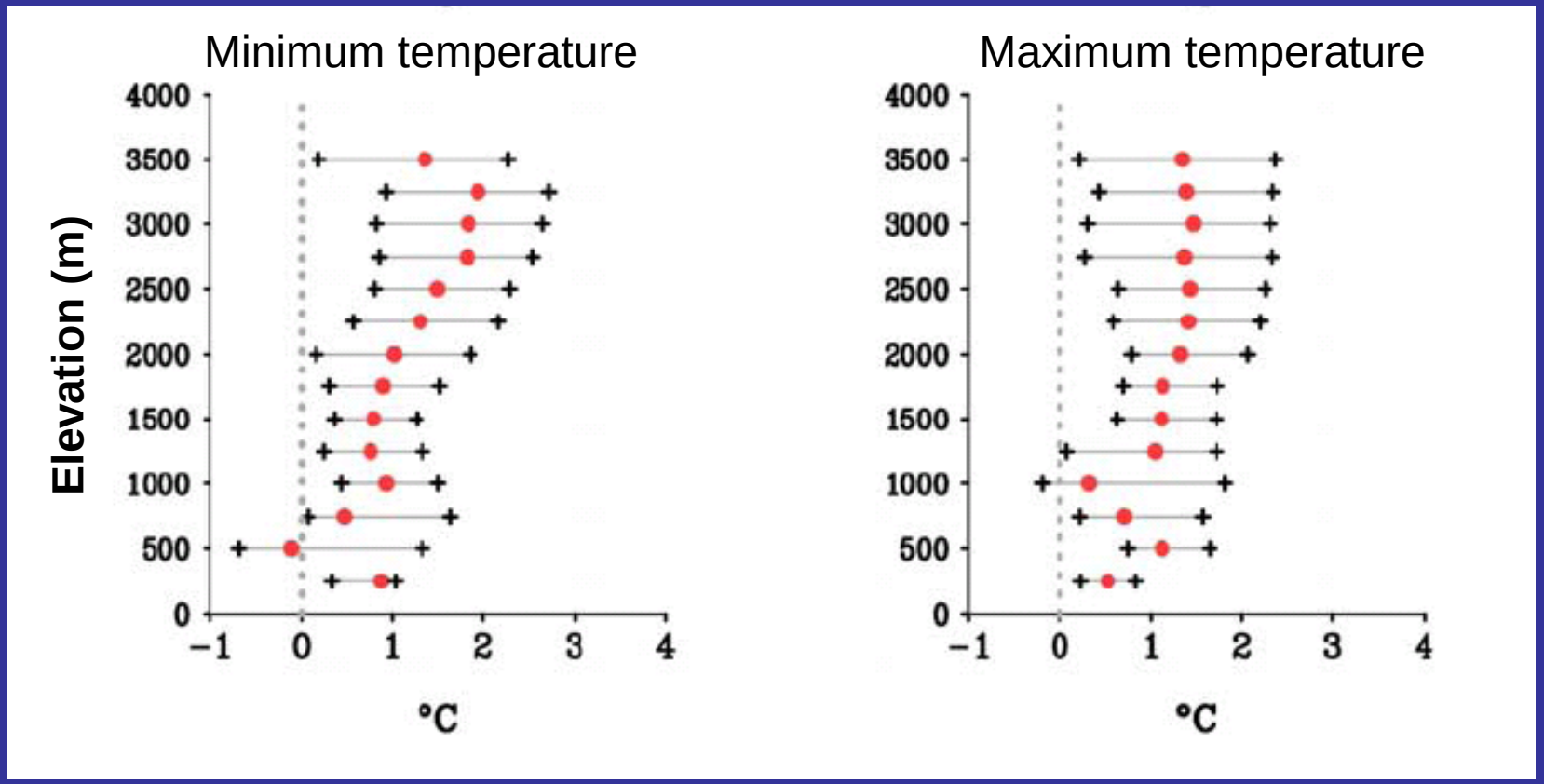
Das & Stephenson 2013, *SEKI NRCA*

The rate of the warming seems to increase with elevation.

1979 – 2006 temperature trends in the Sierra Nevada:



Diaz & Eischeid, *Geophys. Res. Lett.*, 2007

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Photo by G. K. Gilbert

What are some effects?

(1) Glaciers are melting

Darwin glacier, Kings Canyon National Park, Sierra Nevada

Photo by H. Basagic

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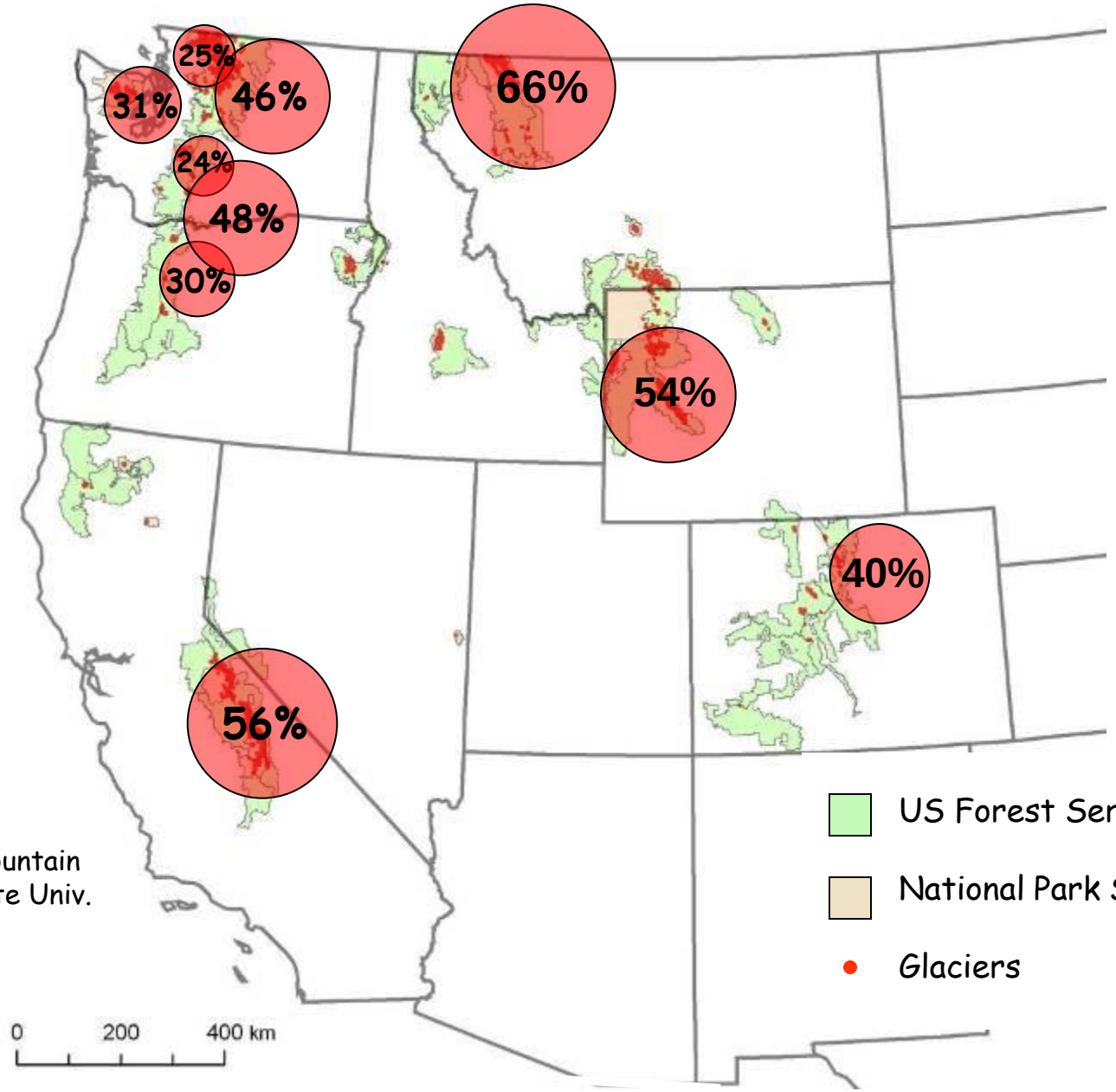
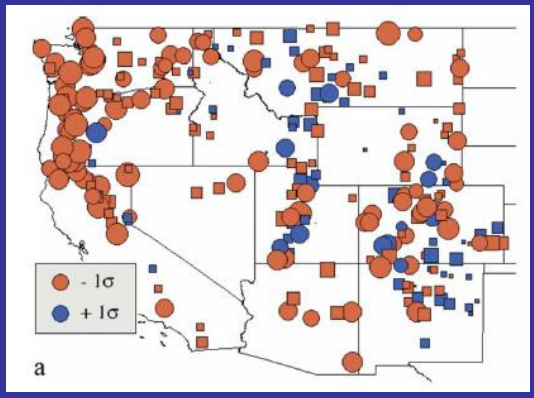
Fraction of Glacier Area Lost since 1900



Andrew G. Fountain
Portland State Univ.

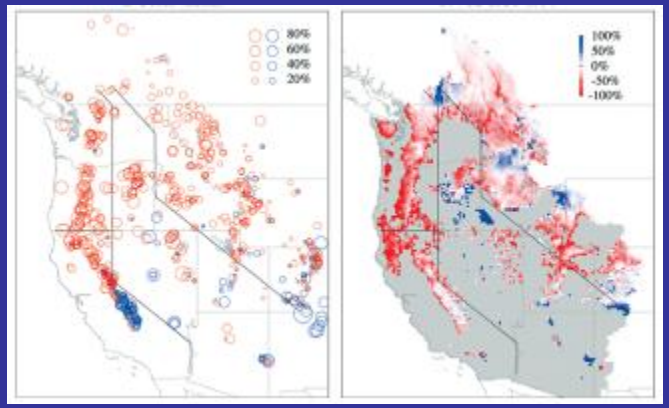
(2) Summers are getting longer and drier:

Snow fall is declining (relative to rain):



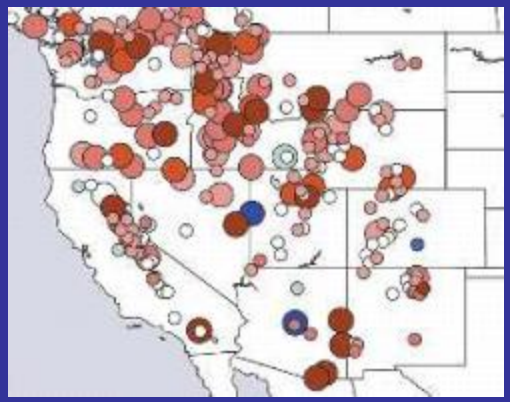
Knowles et al., *J. Climate*, 2006

Snowpack water content is declining:



Mote et al., *BAMS*, 2005

Spring snowmelt is arriving earlier:



Stewart et al., *J. Climate*, 2004

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In the southern Sierra, snowpack has been declining below about 8500 ft, but increasing above that.

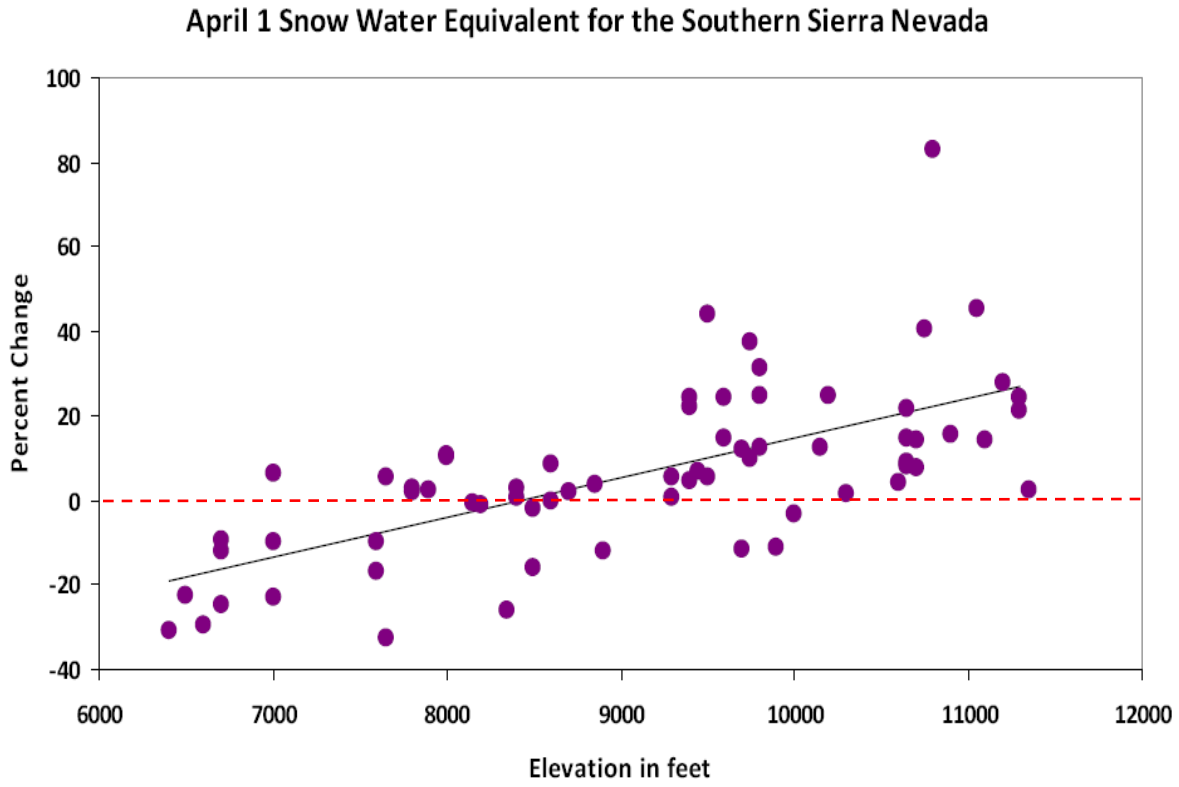

Figure 47. Variation in the percent change in April 1 snow water equivalent calculated along the linear trend line for the period of record versus the snow course elevation.

Andrews 2013, *SEKI NRCA*

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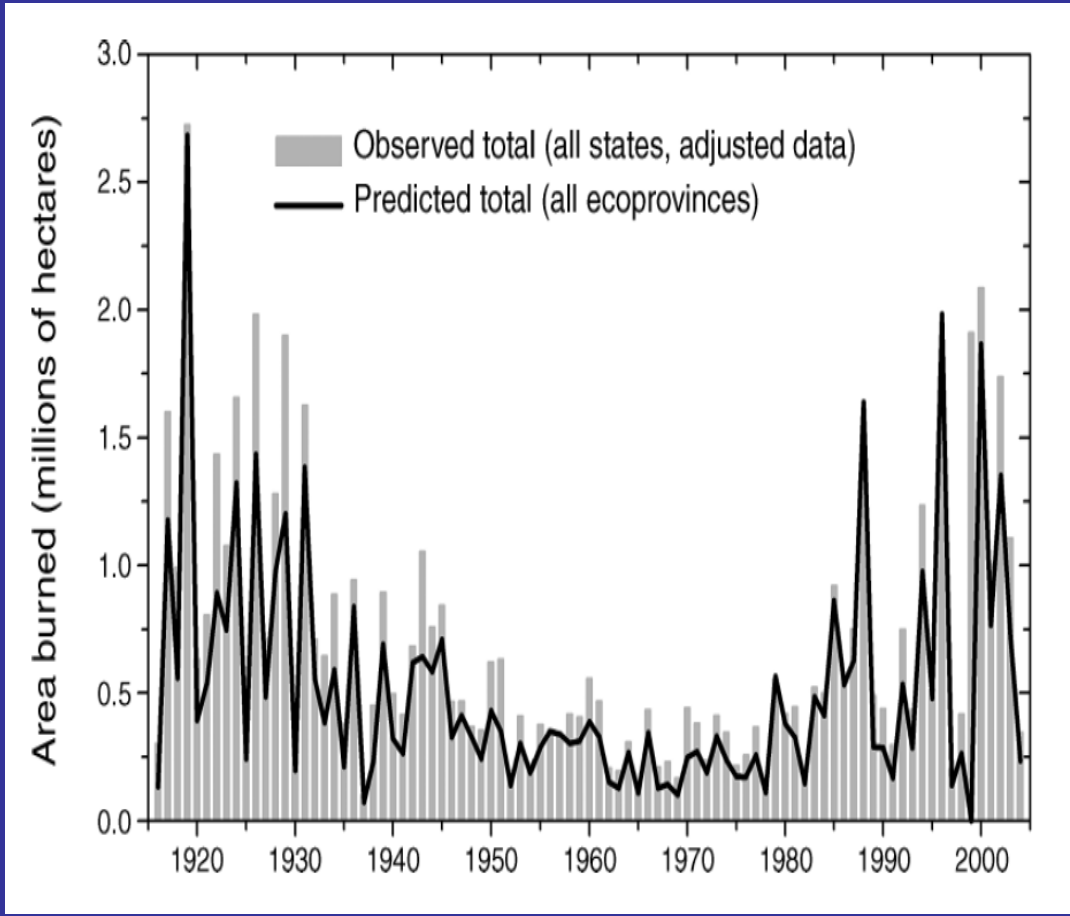
(3) Area burned is increasing, fire season is lengthening, and fires are harder to control.

Photo: N. Stephenson



Littell et al. 2009, *Ecol. Appl.*

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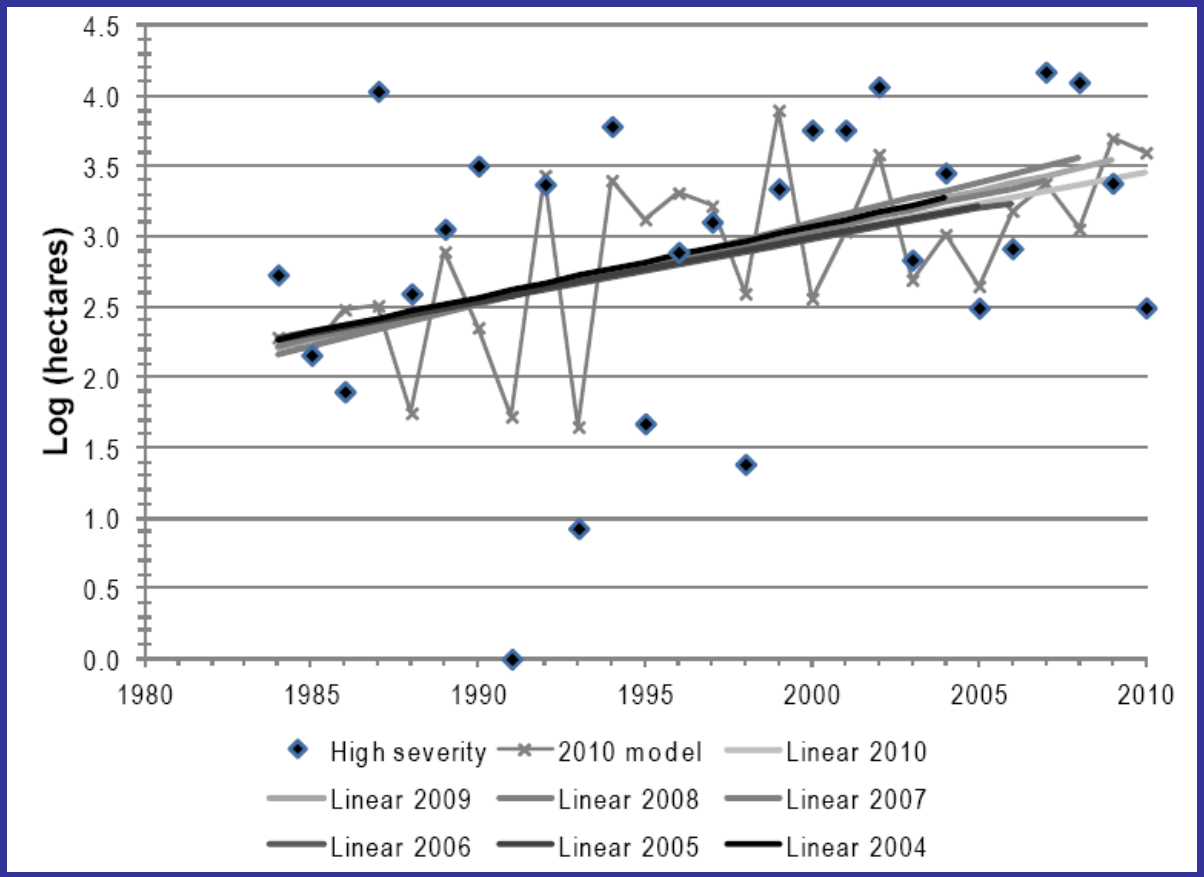
The area of yellow pine – mixed conifer forest burned in high-severity wildfires has increased.

Sierra Nevada, Modoc Plateau, and southern Cascades, 1984-2010:



Miller & Safford 2012, *Fire Ecology*

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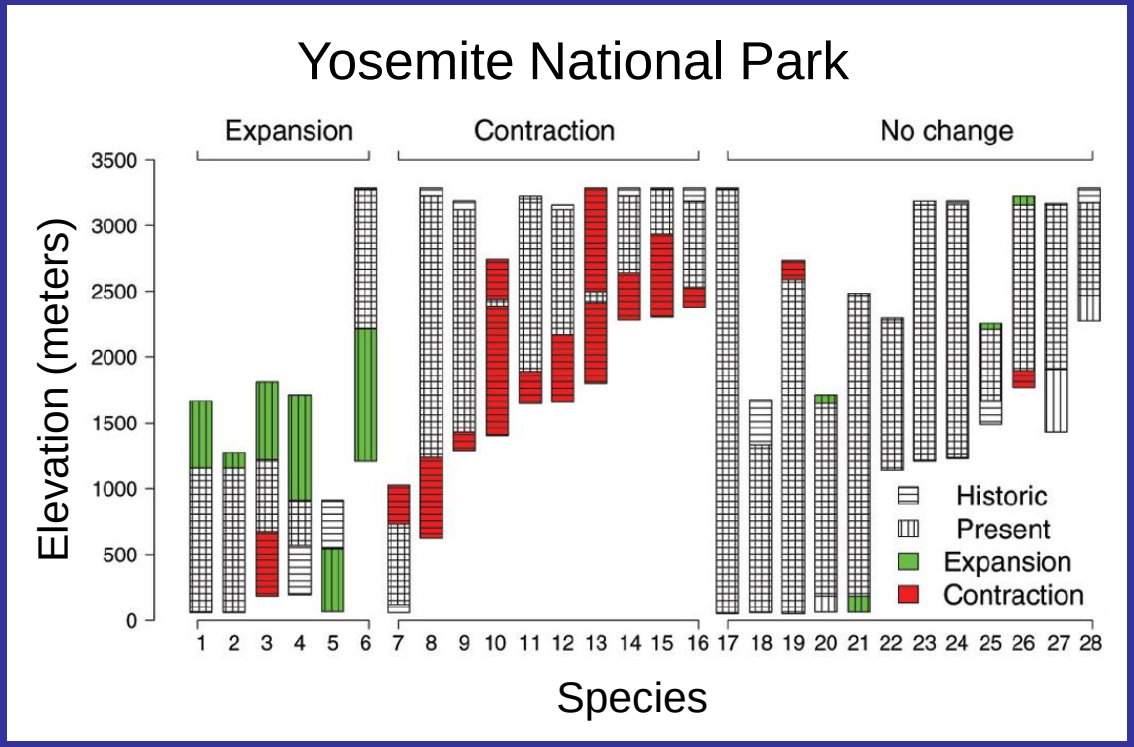
(4) Some mammals have been moving to higher elevations.



Moritz et al., *Science* 2008

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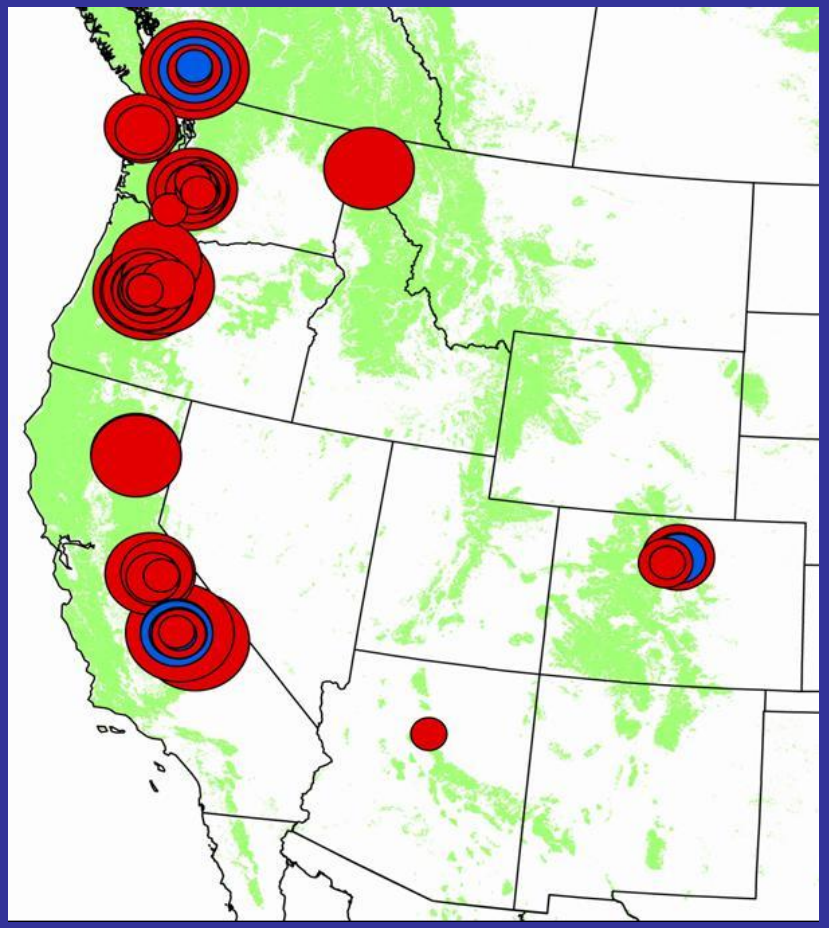
(5) “Background” tree death rates have roughly doubled over the last few decades.



van Mantgem et al. 2009, *Science*

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Agents of change

Climatic changes:

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The main uncertainty isn't about IF it's going to keep getting warmer, but rather by how much and how fast ...

… like rolling up your car windows in Visalia in August.

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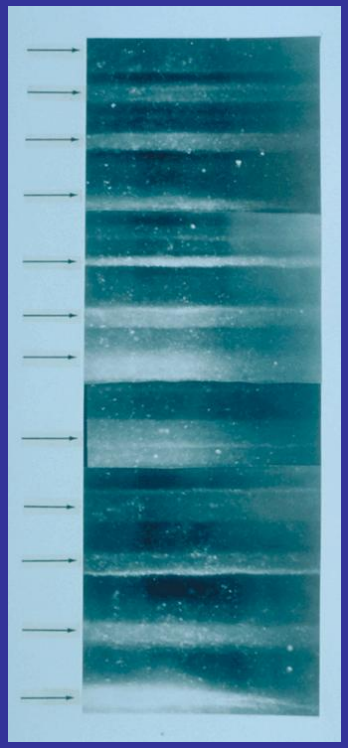
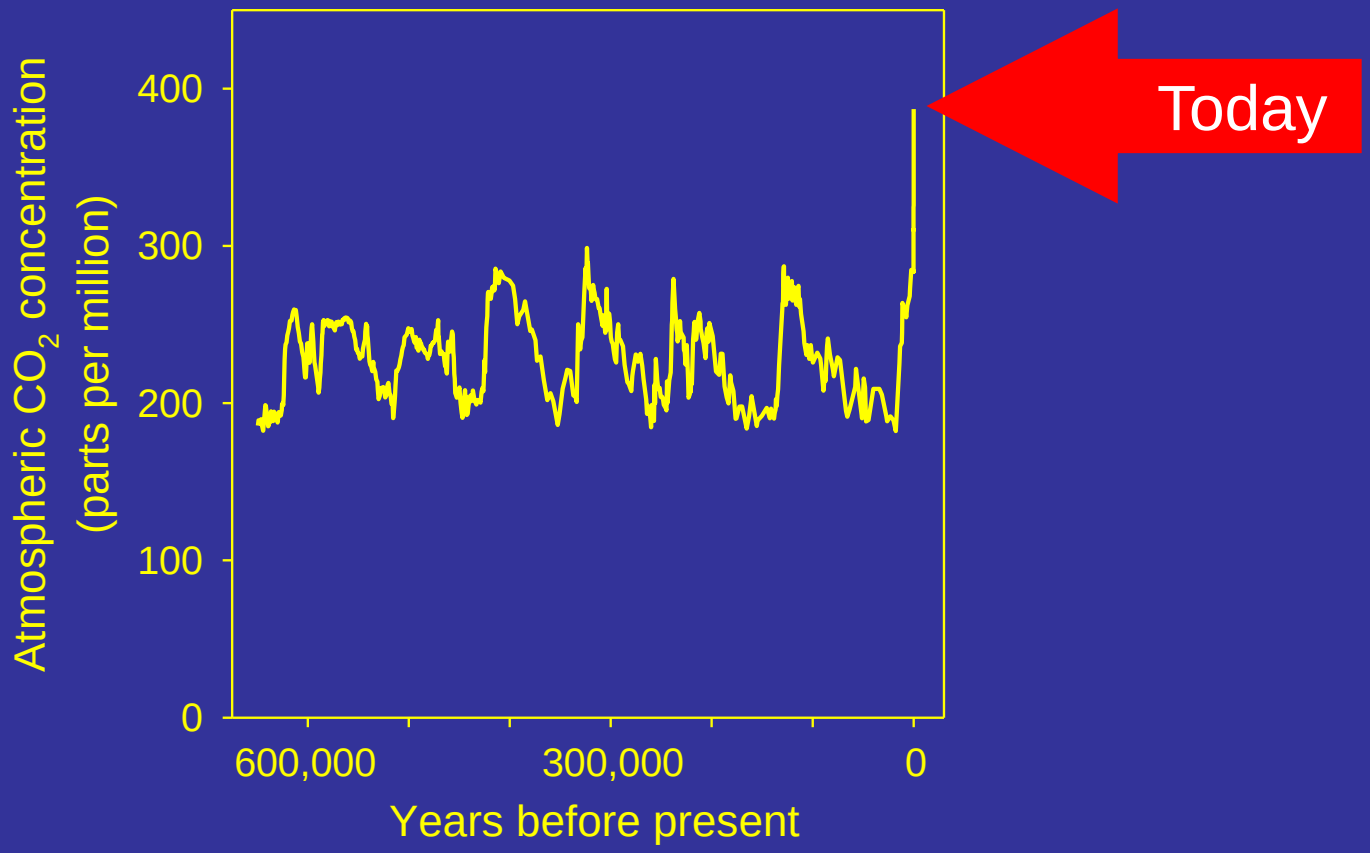
Rolling up the Earth's "car windows": Current atmospheric CO_2 concentrations are the highest in at least the last 650,000 years, and probably in the last 20 million years.



Ice core with bubbles



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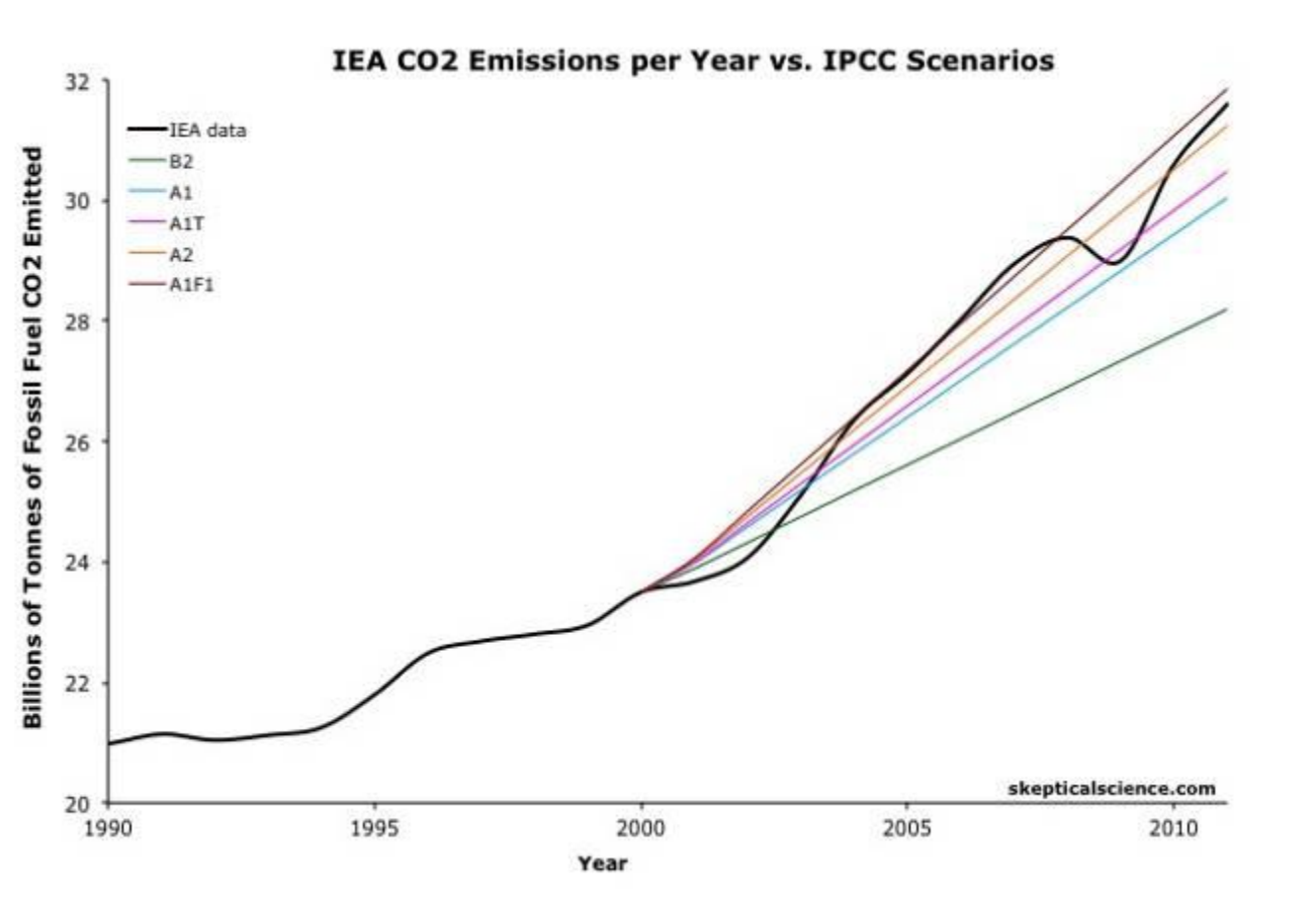
Actual greenhouse gas emissions have been on the high end of the emissions scenarios used by IPCC since 2000.

(The graph shows CO_2 emissions, not atmospheric CO_2 concentrations!)



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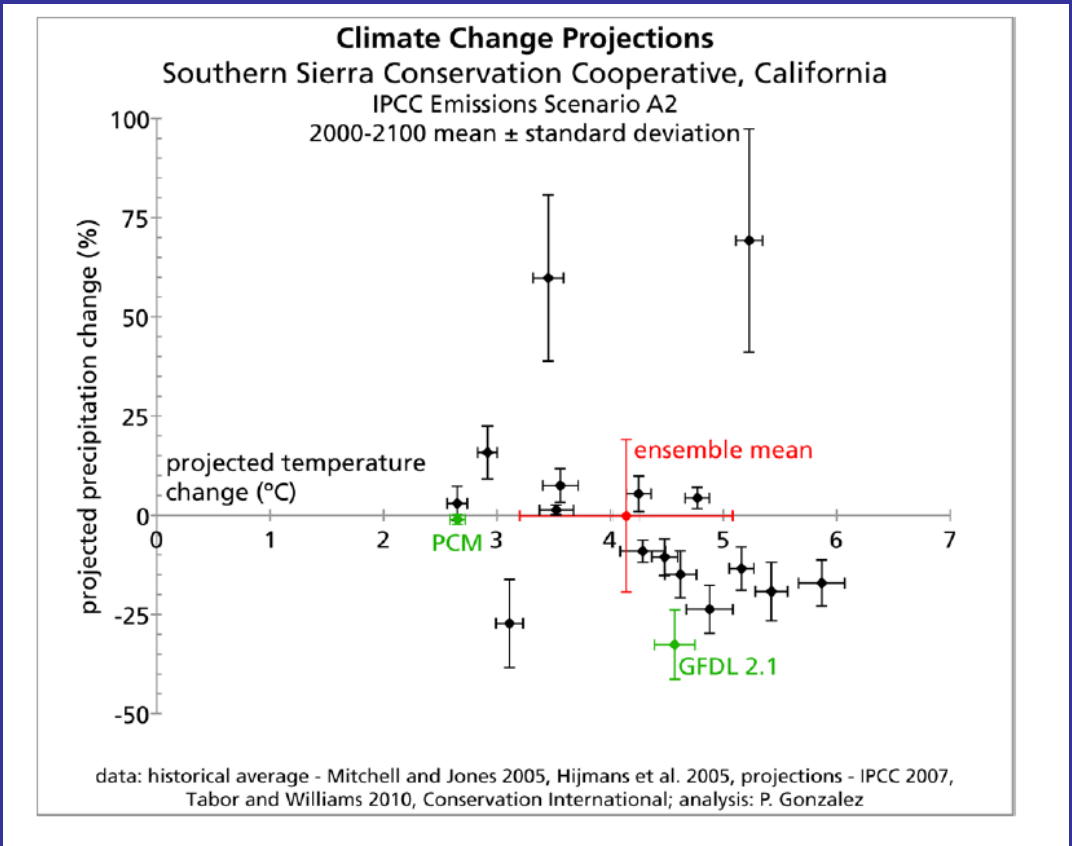
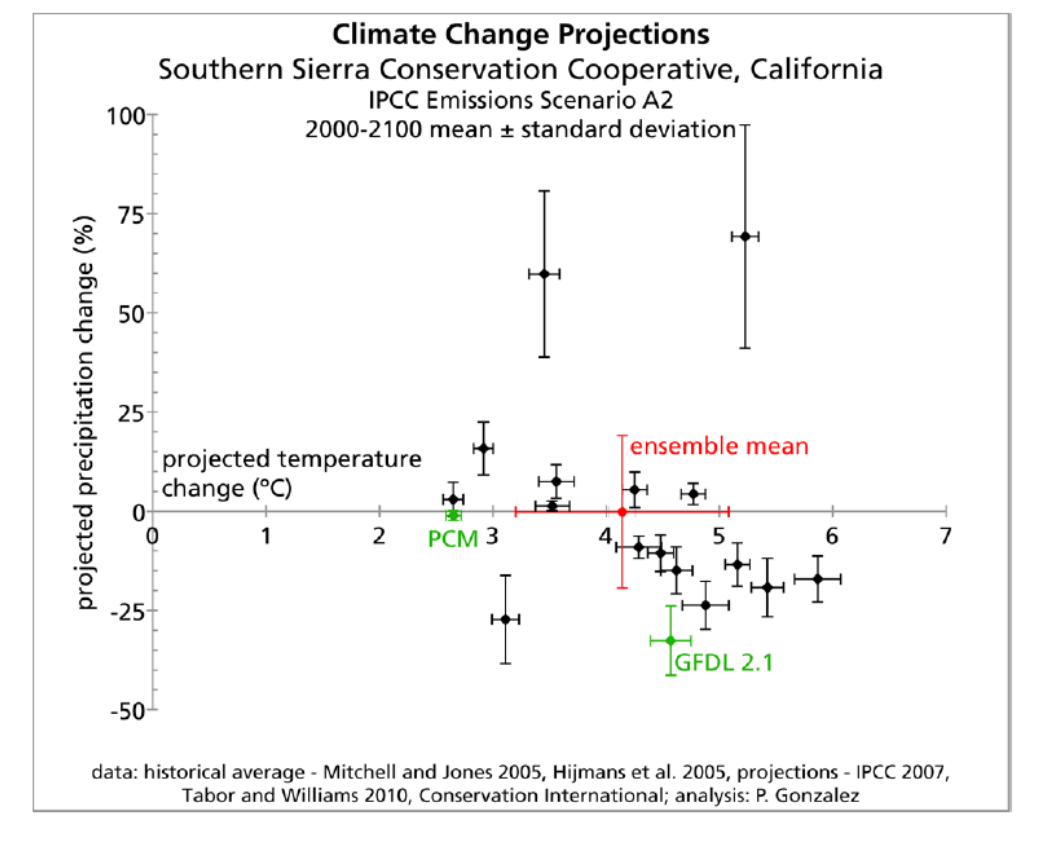
- For our region, projected warming by the end of this century ranges from ~2.5 to 6° C (~4.5 to 10.5° F).



Gonzalez 2012, NPS Climate Change Response Program

USGS

- For our region, projected warming by the end of this century ranges from ~2.5 to 6° C (~4.5 to 10.5° F).
- Precipitation could either increase or decrease substantially.



Gonzalez 2012, NPS Climate Change Response Program

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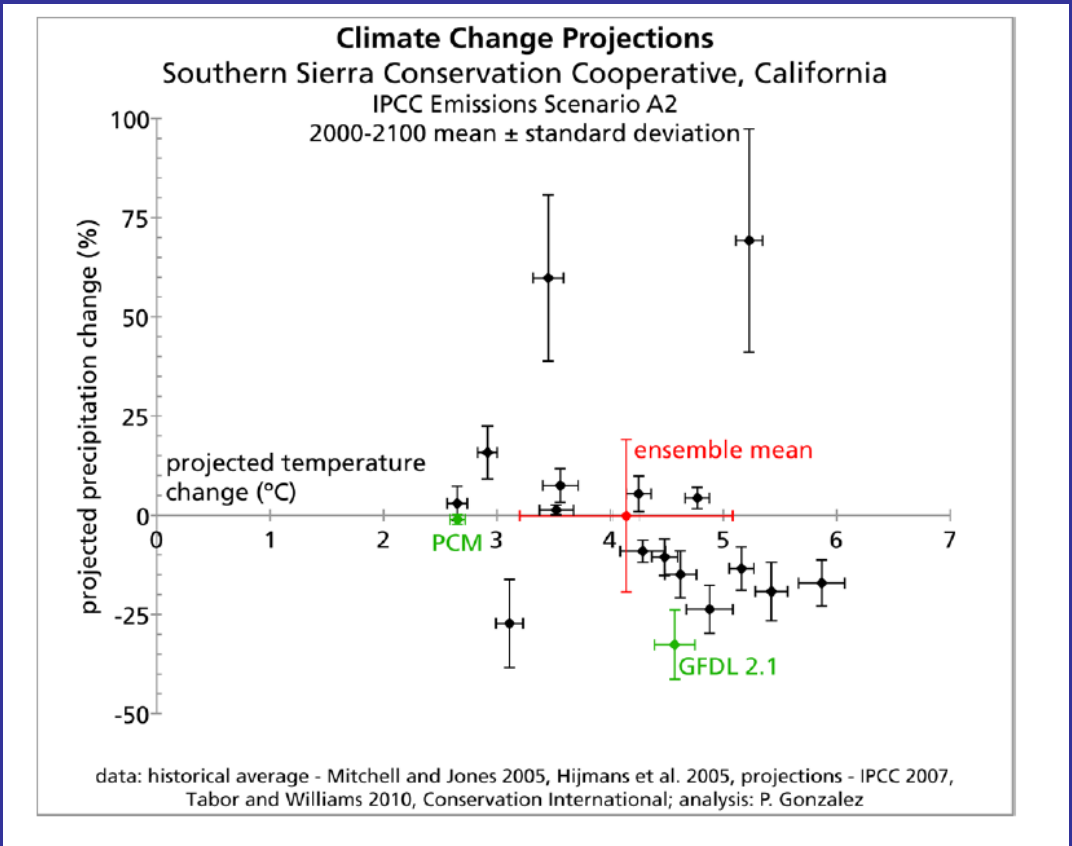
- For our region, projected warming by the end of this century ranges from ~2.5 to 6° C (~4.5 to 10.5° F).
- Precipitation could either increase or decrease substantially.
- Any way you look at it: unprecedented and unpredictable.



Gonzalez 2012, NPS Climate Change Response Program

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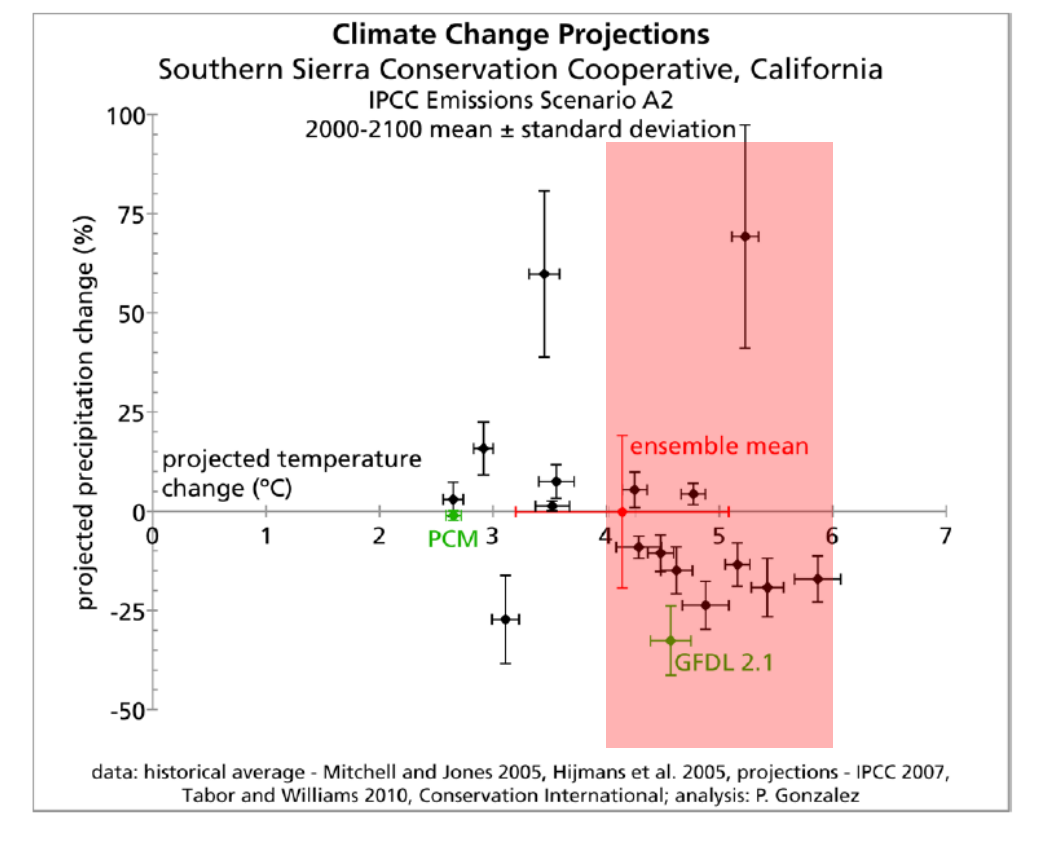
What does this range of projected warming mean?

By the end of this century we could conceivably get as much warming as happened from the last ice age to the present!



Gonzalez 2012, NPS Climate Change Response Program

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What kinds of changes could 4 to 6 °C of warming cause?

During the last ice age:

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During the last ice age:

Today:
Everglades National Park

USGS

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During the last ice age:

Today:
Sequoia National Park

USGS

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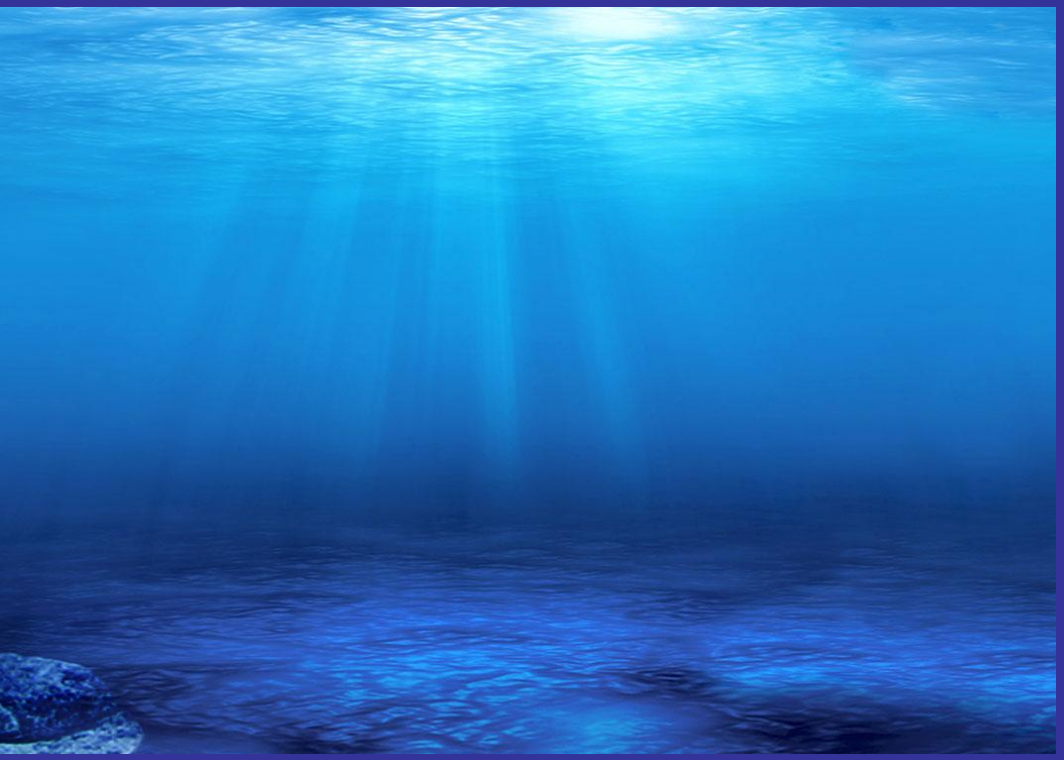

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What kinds of changes could 4 to 6 °C of warming cause?

During the last ice age:

Today:
Death Valley National Park

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Example: What can we expect for giant sequoias 100 to 150 years from now?

Can sequoias ...

USGS

Example: What can we expect for giant sequoias 100 to 150 years from now?

Can sequoias ...

... become established and thrive hundreds of meters higher?

USGS

Example: What can we expect for giant sequoias 100 to 150 years from now?

Can sequoias ...

... become established and thrive hundreds of meters higher?

We can expect unprecedented biotic changes

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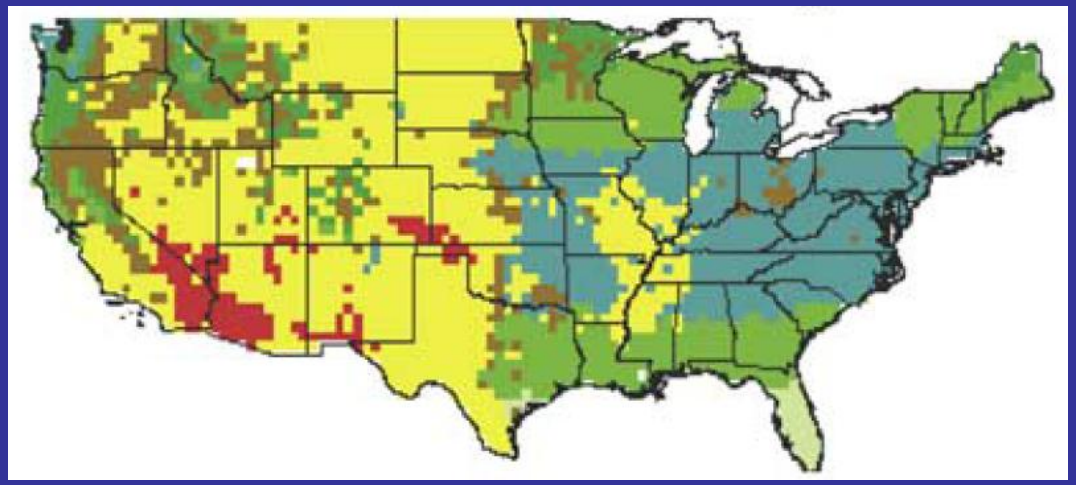
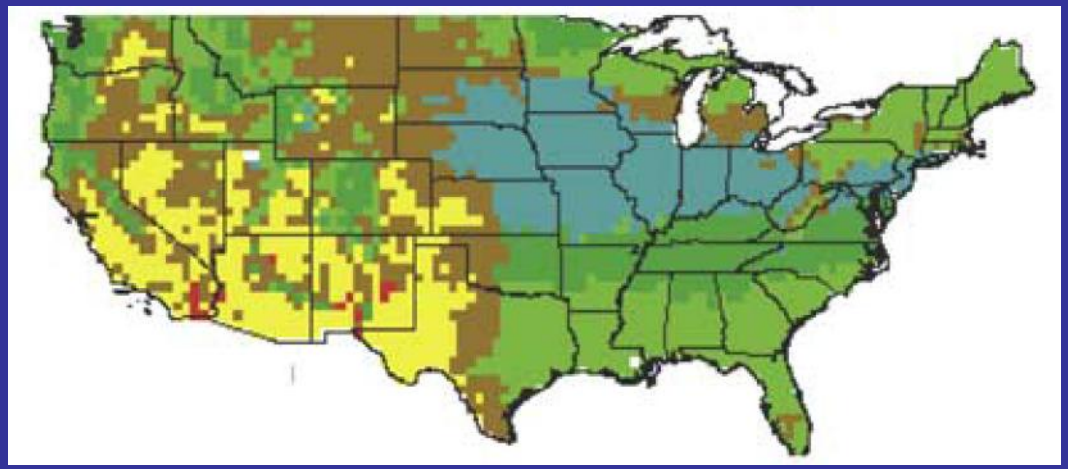
But these biotic changes will also be unpredictable.

Uncertainty in our climatic models will only be compounded by uncertainty in our biotic models.

MC1 model



LPJ model



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Bachelet et al. 2003, *Global Biogeochem. Cycles*

Agents of change

Climatic changes:

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- Thresholds and surprises

USGS

Climatic changes can lead to sudden and unexpected outbreaks of insects and pathogens ...

Credit: USGS

Rocky Mountain lodgepole pine die-back

USGS

… and to severe wildfires that kill local seed sources, resulting in soil loss and type conversions (e.g. forest to shrubland).

Credit: Craig Allen, USGS

Bandelier National Monument, August 2011

USGS

Climatic extremes will likely become more frequent and more extreme.

Credit: NPS

Mount Rainier National Park, November 2006

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Geoengineering is deliberate large-scale intervention in the Earth's climate to moderate global warming.
It is being seriously discussed.

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It is being seriously discussed.

Even if geoengineering moderates global warming, regional and local climates could still experience significant changes in both precipitation and temperature.

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Interactions with some other agents of change:

- Habitat fragmentation
- Air pollution
- Altered fire regimes
- Non-native invasive species

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Context: The population of the Sierra Nevada counties has roughly doubled over the last 30 years, and rapid growth is expected to continue.

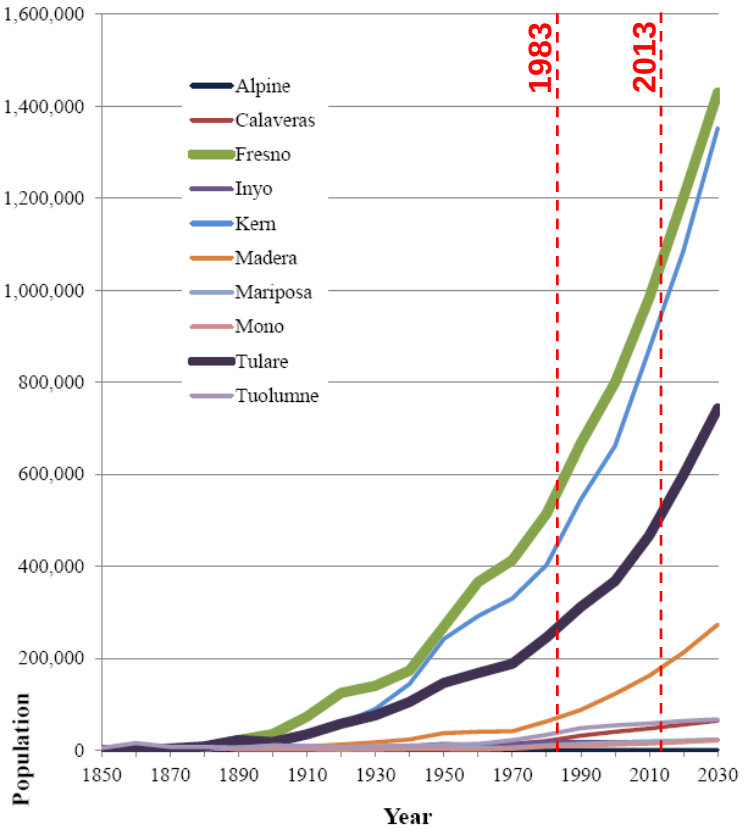

Figure 40. The trend and projected population for the ten counties in the PACE region. The two counties in which SEKI is found, Fresno and Tulare, are highlighted with bold-faced lines and represent two of the three counties with the largest populations and most rapidly growing populations.

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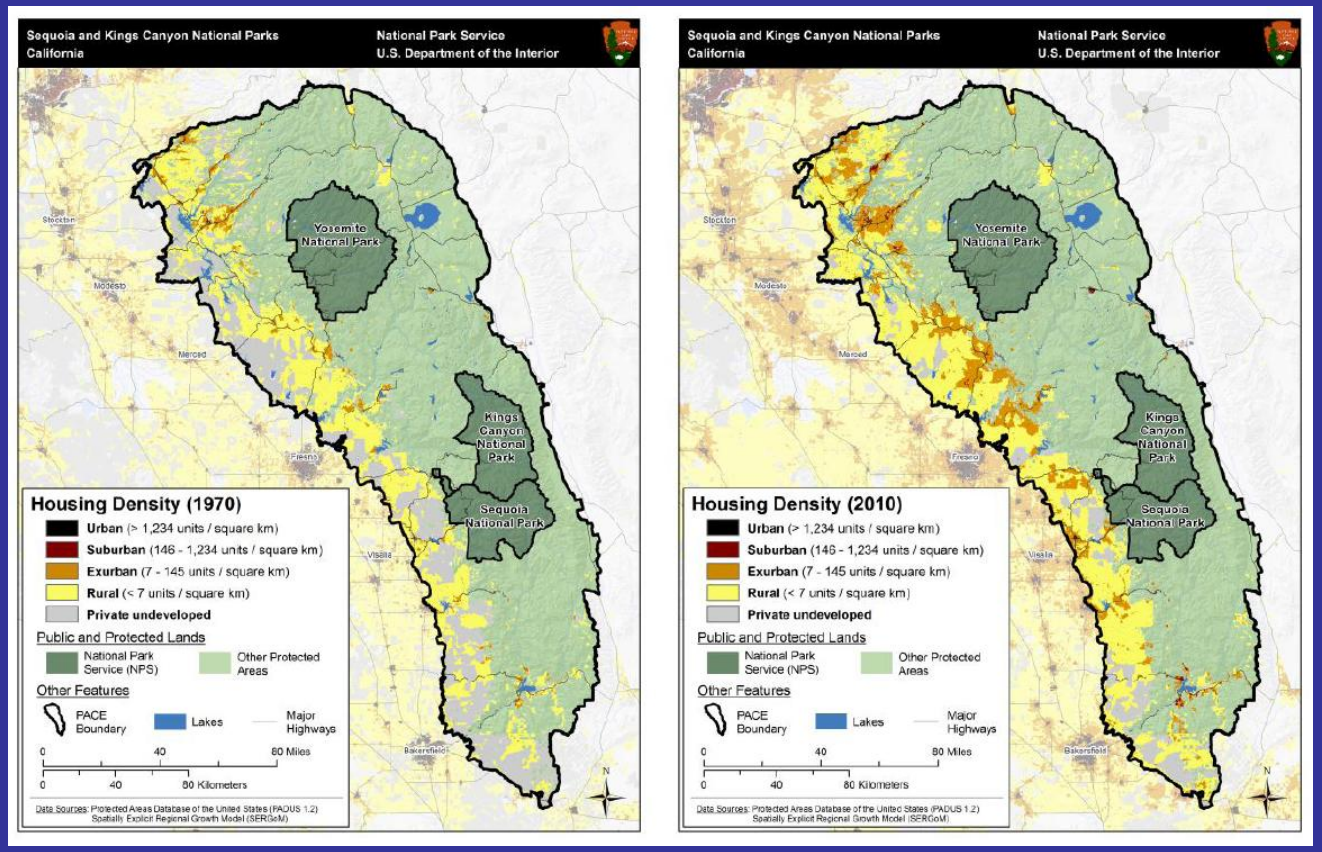
Thorne *et al*. 2013, *SEKI NRCA*

HABITAT FRAGMENTATION: In spite of this growth, the higher elevations of the southern Sierra remain largely intact. … Some exceptions include dams, some logged areas, areas of unnaturally large and severe wildfires, etc.



Thorne *et al*. 2013, *SEKI NRCA*

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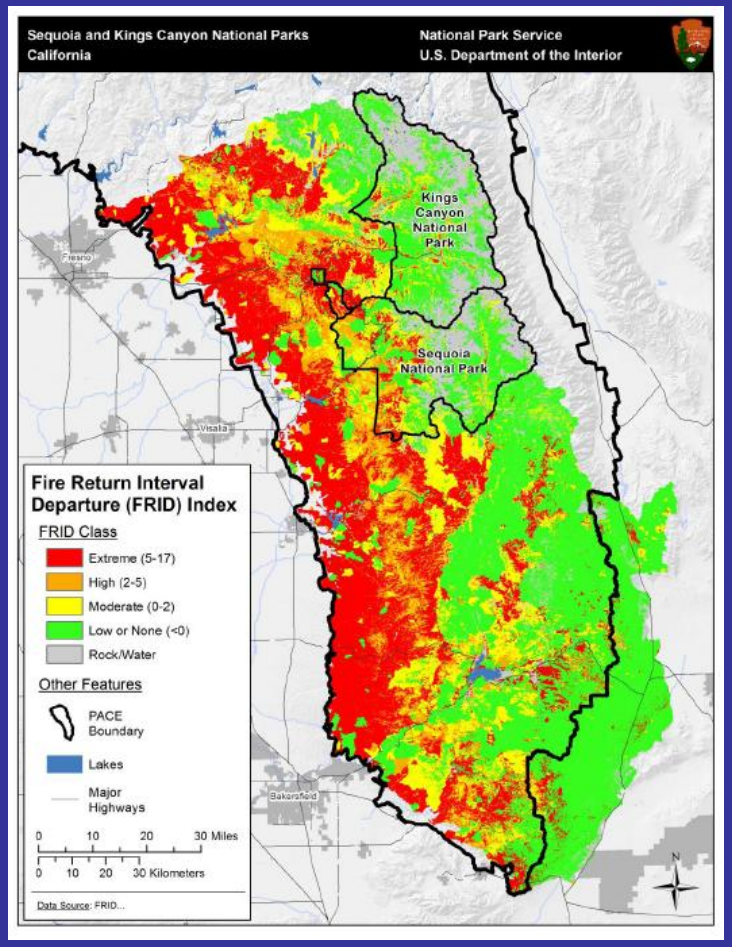
ALTERED FIRE REGIMES: At middle elevations, long-term fire exclusion has in many cases led to dense forests that are now more susceptible to fire, insects, and climatic changes.



Thorne *et al*. 2013, *SEKI NRCA*

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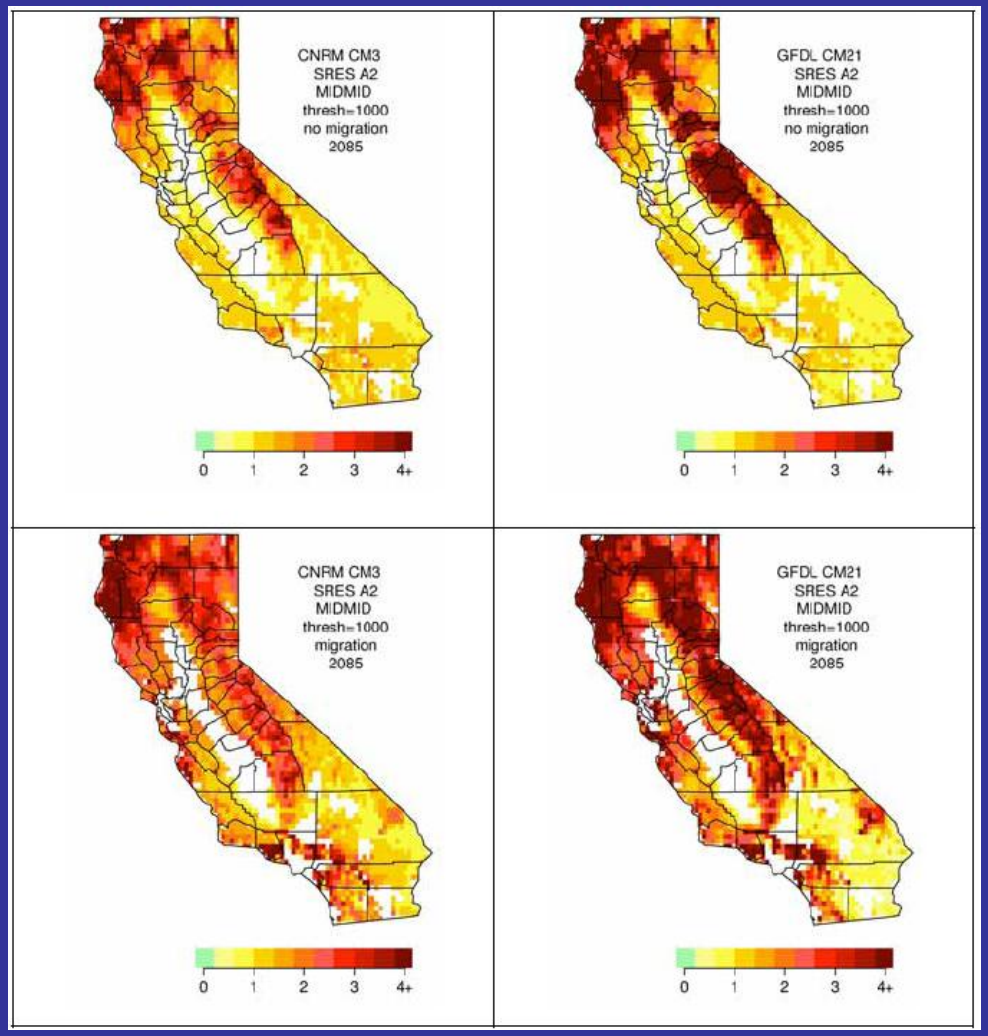
With a longer summer and warmer temperatures, fire season is expected to lengthen, escapes will be more common, and area burned will increase.



Westerling et al. 2009, Calif. Climate Change Center report

AIR POLLUTION: Pollution in the southern Sierra comes in several forms:

Photo credits: NPS

- Nitrogen deposition
- Pesticides & contaminants
- Particulates
- Ozone

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Ozone pollution is greatest in the foothills and at middle elevations ...

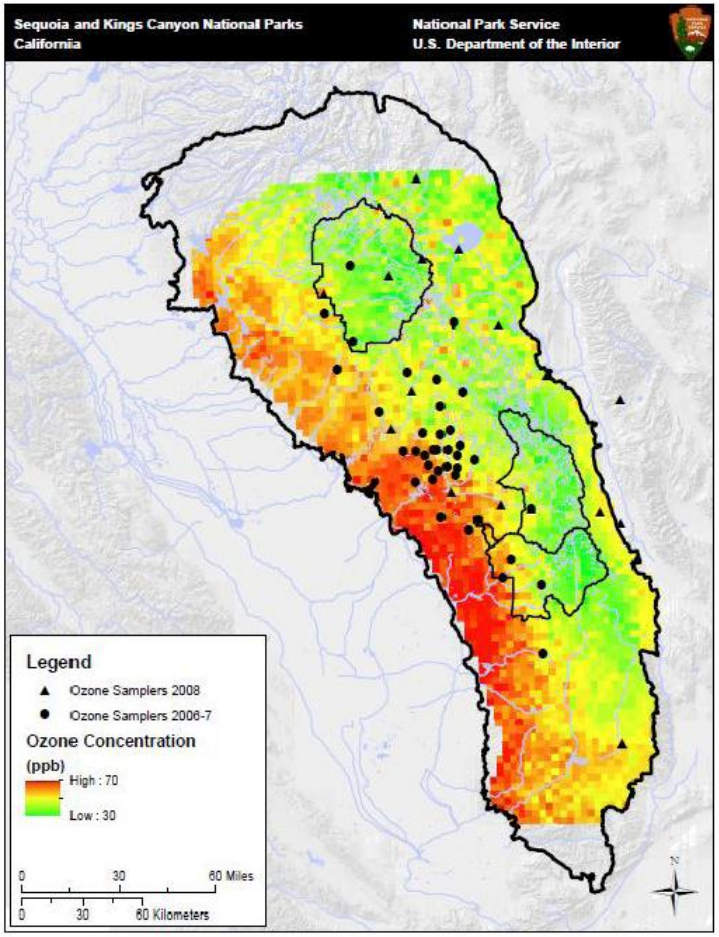

Figure 2. Average ozone concentration for the PACE region, from a geographically weighted regression analysis of passive ozone monitors sampled over the summer and early fall months (June-October) in 2006, 2007 and 2008. Grid size is 3500m. Yosemite, Sequoia and Kings Canyon National Parks boundaries are outlined within the PACE.

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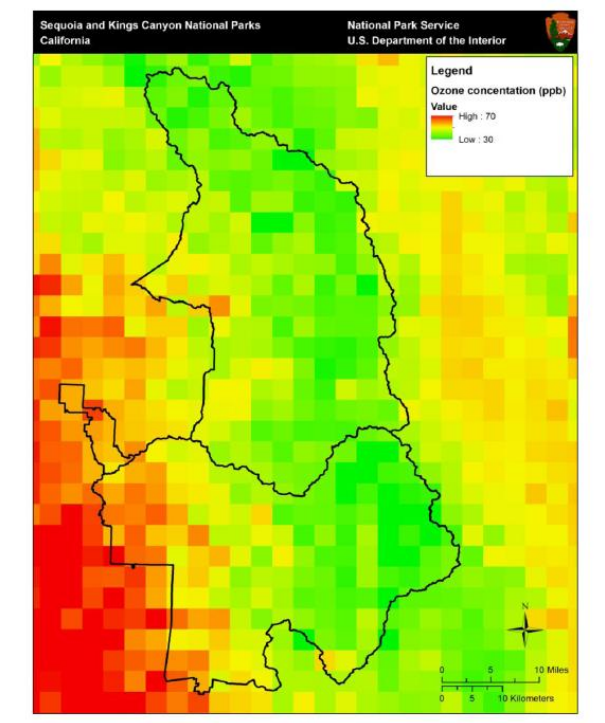
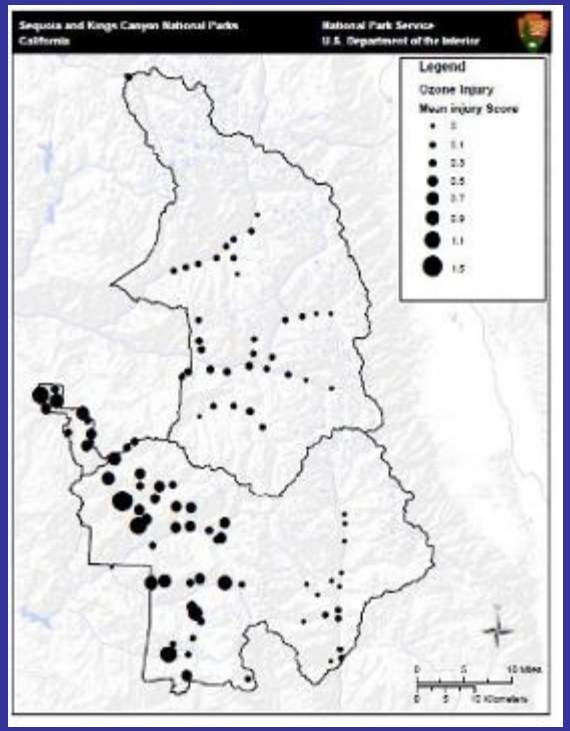
Panek, Saah, & Esperanza 2013,
SEKI NRCA

… causing needle injury to ponderosa and Jeffrey pines.

Ozone concentrations



Needle injury



Panek, Saah, & Esperanza 2013,
SEKI NRCA

Credit: Mark Fenn, USFS

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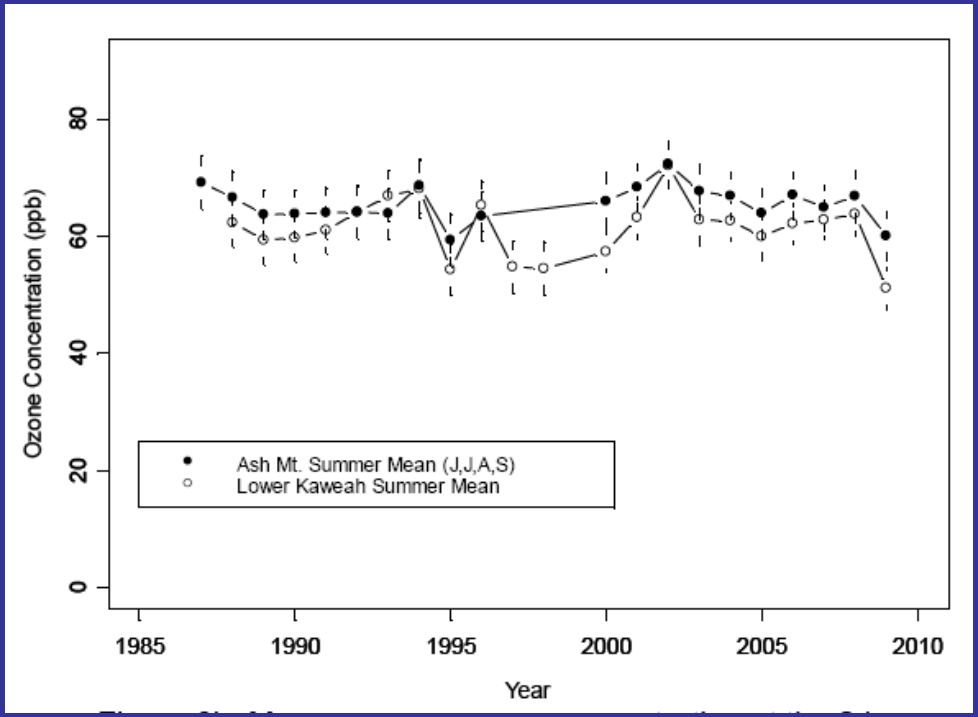
Cup half full: In spite of a nearly doubled population, ozone concentrations have remained relatively flat.

Cup half empty: Current levels may reduce some species' resilience to climatic changes.



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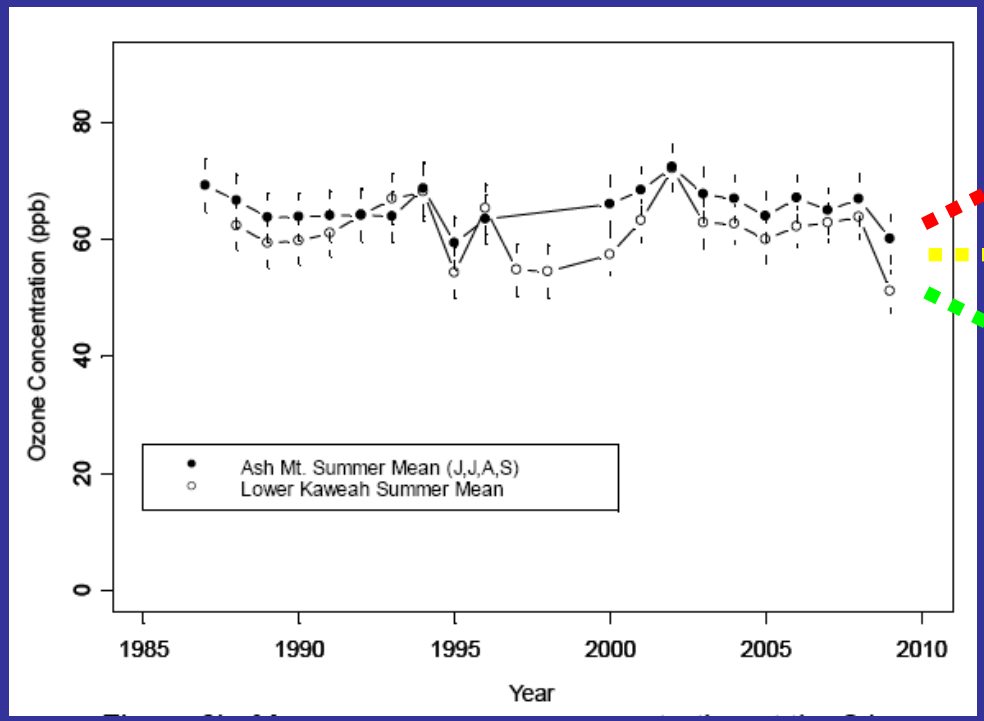

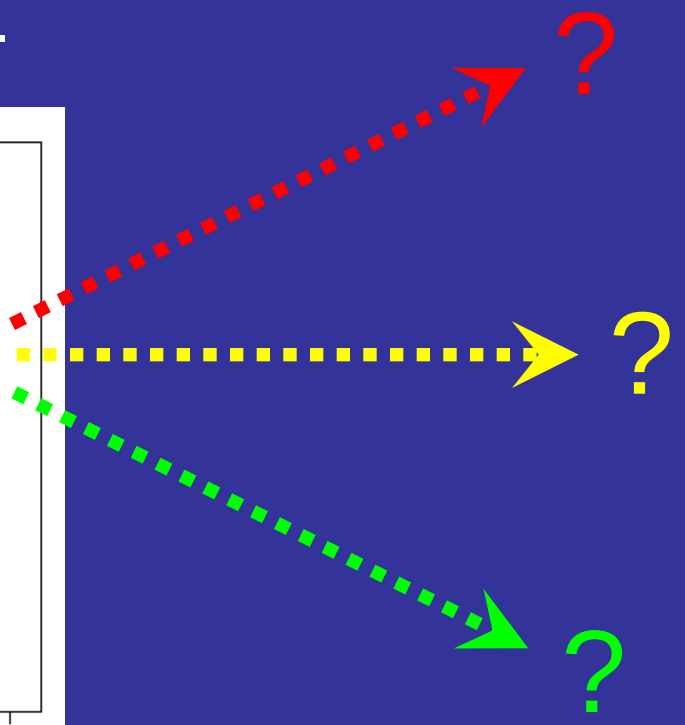

Panek, Saah, & Esperanza 2013,
SEKI NRCA

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NON-NATIVE INVASIVE SPECIES: … can alter fire regimes,

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NON-NATIVE INVASIVE SPECIES: … can alter fire regimes, can eat native species,

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NON-NATIVE INVASIVE SPECIES: … can alter fire regimes, can eat native species, and can outcompete native species.

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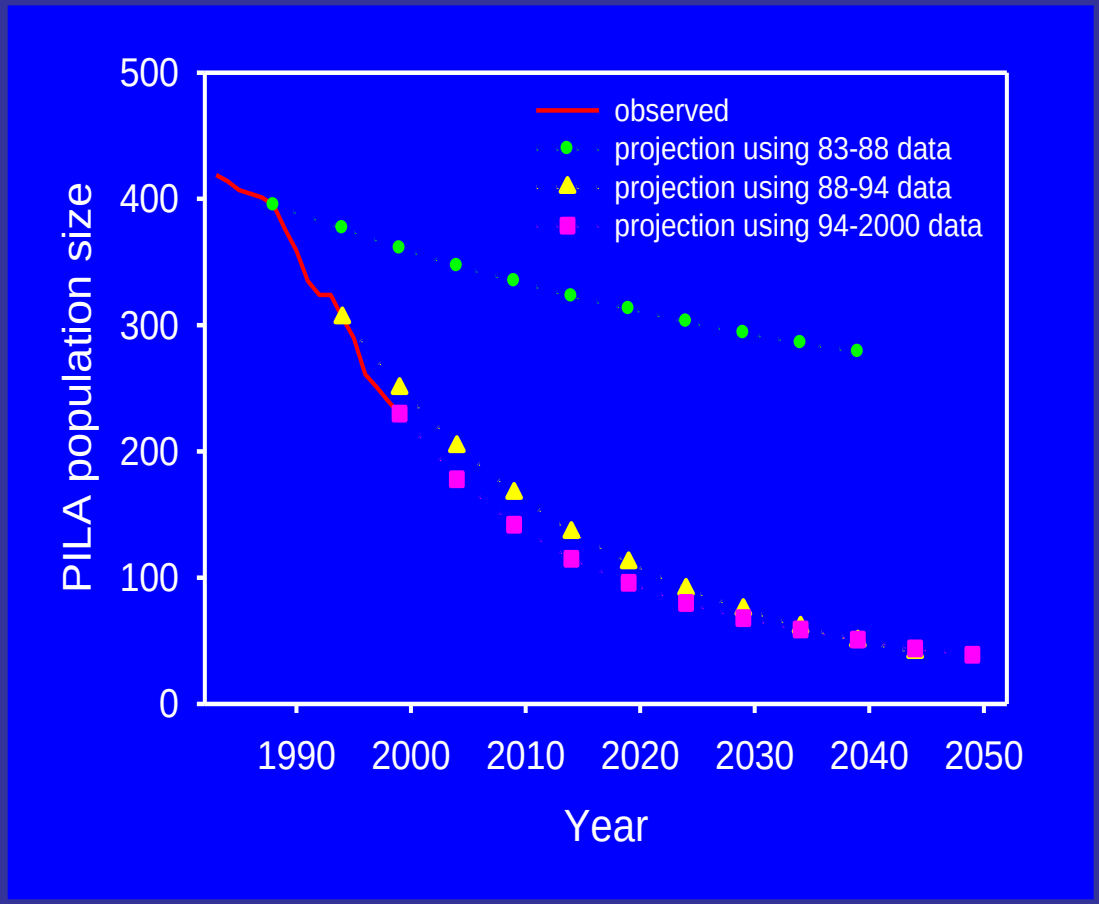
And non-native pathogens (like white pine blister rust) can contribute to the loss of iconic and valuable native species.



van Mantgem et al. *Ecol. Appl.* 2004

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Interactions among all these agents of change conspire to give us an unprecedented and unpredictable future.

How can we possibly respond?

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Strategies for shooting at a moving target:

- Restraint
- Resistance
- Resilience
- Realignment

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Strategies for shooting at a moving target:

- Restraint -- Near- and long-term strategy
- Resistance, Resilience } Near-term strategies
- Realignment -- Long-term strategy

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Restraint means leaving some areas alone, accepting the consequences of climate change there.

Could constraints imposed by limited funds, limited staffing, and law mean that this will be the default condition over most of the landscape?

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Resistance here refers to management actions aimed at temporarily slowing or stopping change, such as to protect an endangered species while seeking a long-term solution.

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Examples of actions:

-- Control an insect outbreak threatening critical habitat.

-- Irrigate a population of endangered plants.

-- Create fuel breaks to protect populations from fire.

Resistance!

USGS

Resilience is the ability of an ecosystem to absorb stresses without suddenly changing to a new (and often unwanted) state.

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An example of a non-resilient ecosystem:

Non-native invasive grasses → fires → loss of native shrubs

Credit: Todd Esque, USGS

USGS

Another example of a non-resilient ecosystem: The massive piñon pine die-off in southwestern USA

Credit: Craig Allen & NSF

USGS

Resilience is the ability of an ecosystem to absorb stresses without suddenly changing to a new (and often unwanted) state.

Examples of actions to increase resilience:

-- Control a destabilizing invasive species.

-- Thin sections of forest to increase resilience against fire, drought, and insect outbreaks.

USGS

Realignment means facilitating change.

In the long term, it often will be the best (or only) way to maintain regional native biodiversity and key ecosystem functions.

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Examples:

-- Mix gene pools to improve adaptive potential?

-- Assisted species migration?

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The task before us: Craft strategies for an unprecedented and unpredictable future!


Thank you for your attention!