Changing forest conditions behind the redwood curtain?

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

USGS
science for a changing world

STATE NOVEMBER 3, 2015

California gov. declares emergency over dead trees

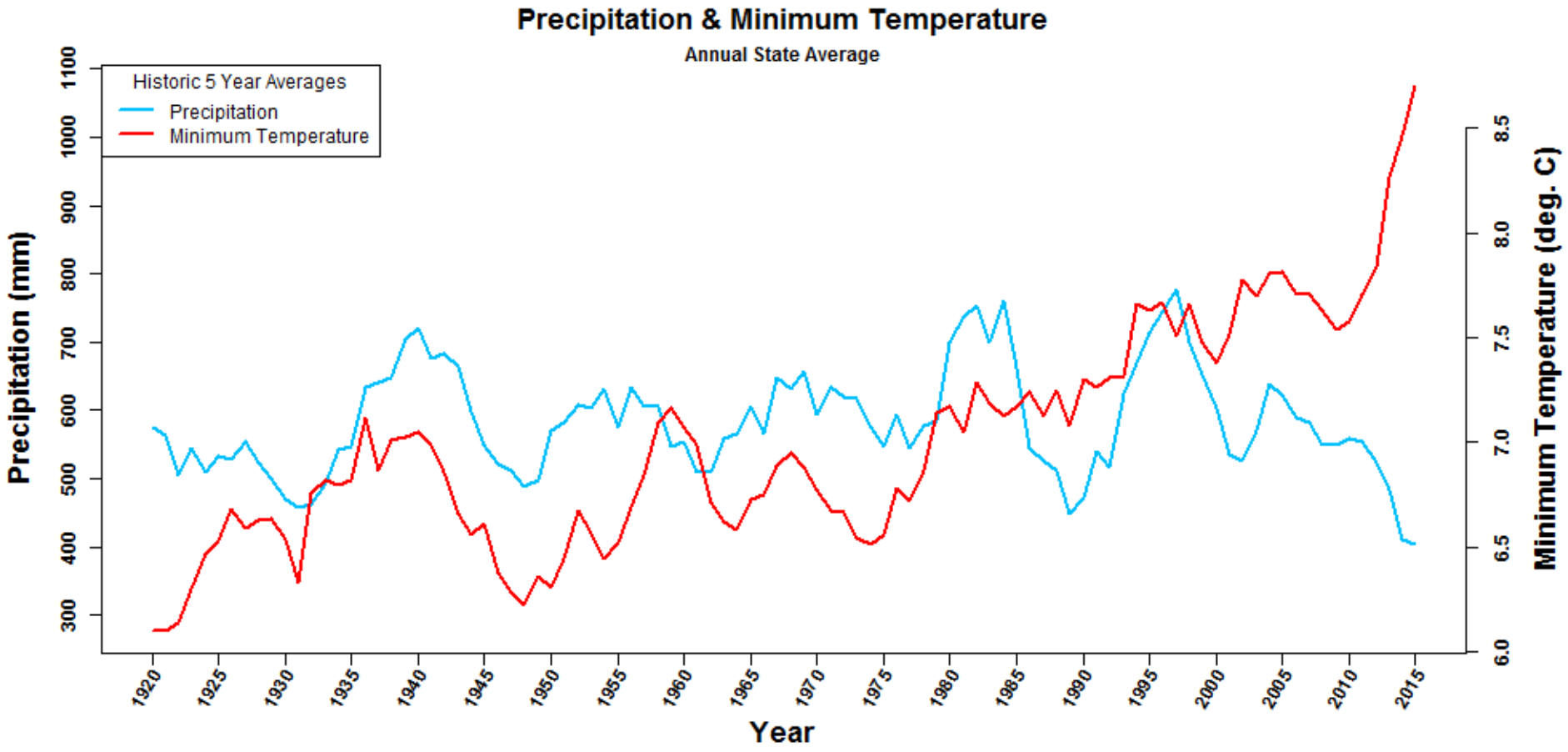
The Associated Press

A dead-tree census by the U.S. Forest Service found that 22 million trees have died during California's four-year drought, and tens of millions more are expected to follow.

USGS

Credit: N. Stephenson

Annual Average Precipitation and Temperature for California



Courtesy Jim Thorne UCD

USGS

The two components of drought are water supply and demand.

A leaky bucket analogy:

USGS

Credit: N. Stephenson

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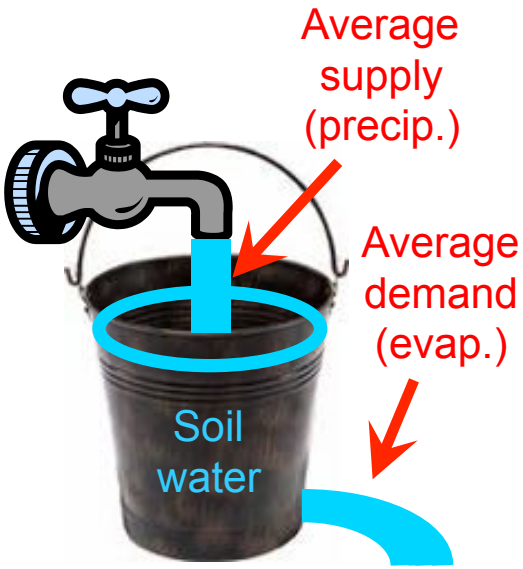
A leaky bucket analogy:

Average conditions



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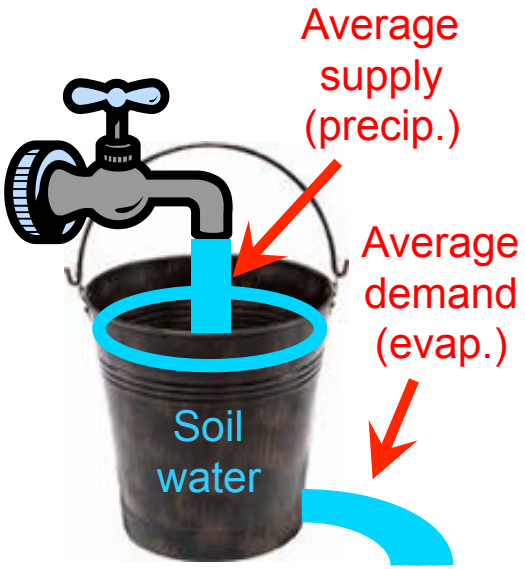
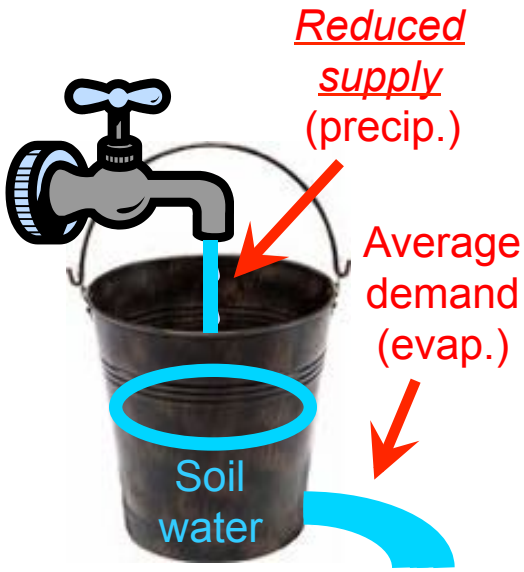
The two components of drought are water supply and demand.

A leaky bucket analogy:

Average conditions



"Normal" drought

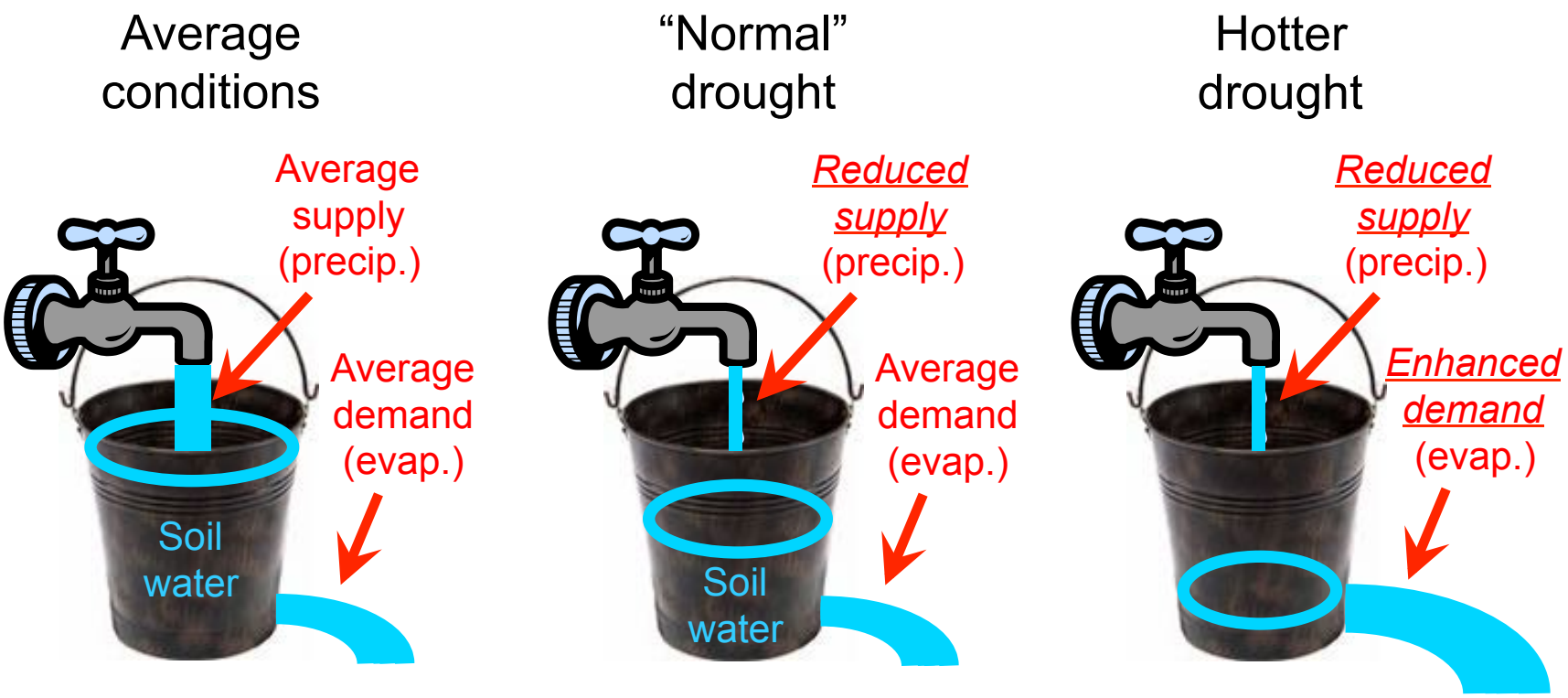


USGS

Credit: N. Stephenson

The two components of drought are water supply and demand.

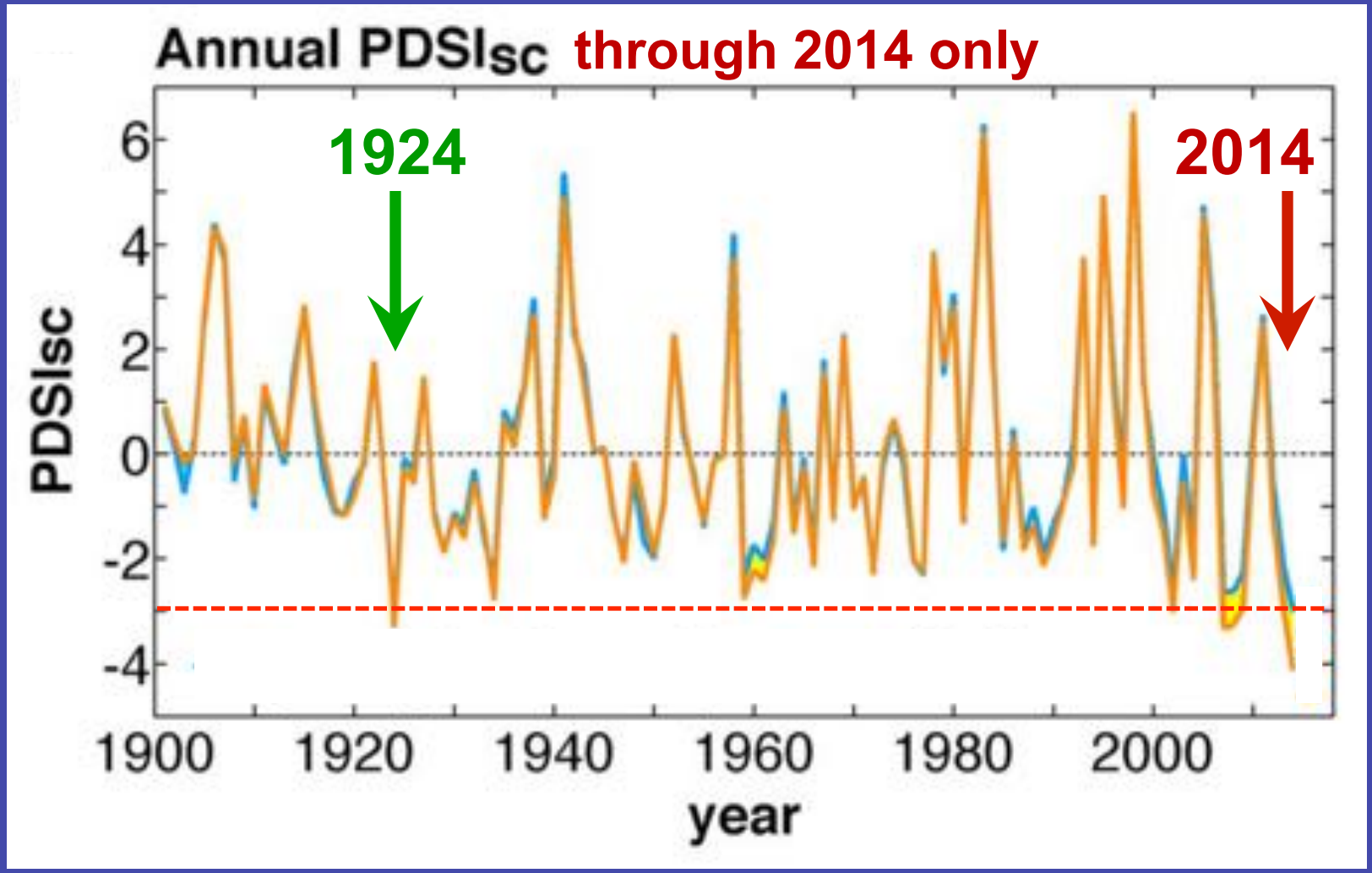
A leaky bucket analogy:



USGS

Credit: N. Stephenson

If all we had was a rain gauge, we'd think the current drought was comparable to the 1924 drought.

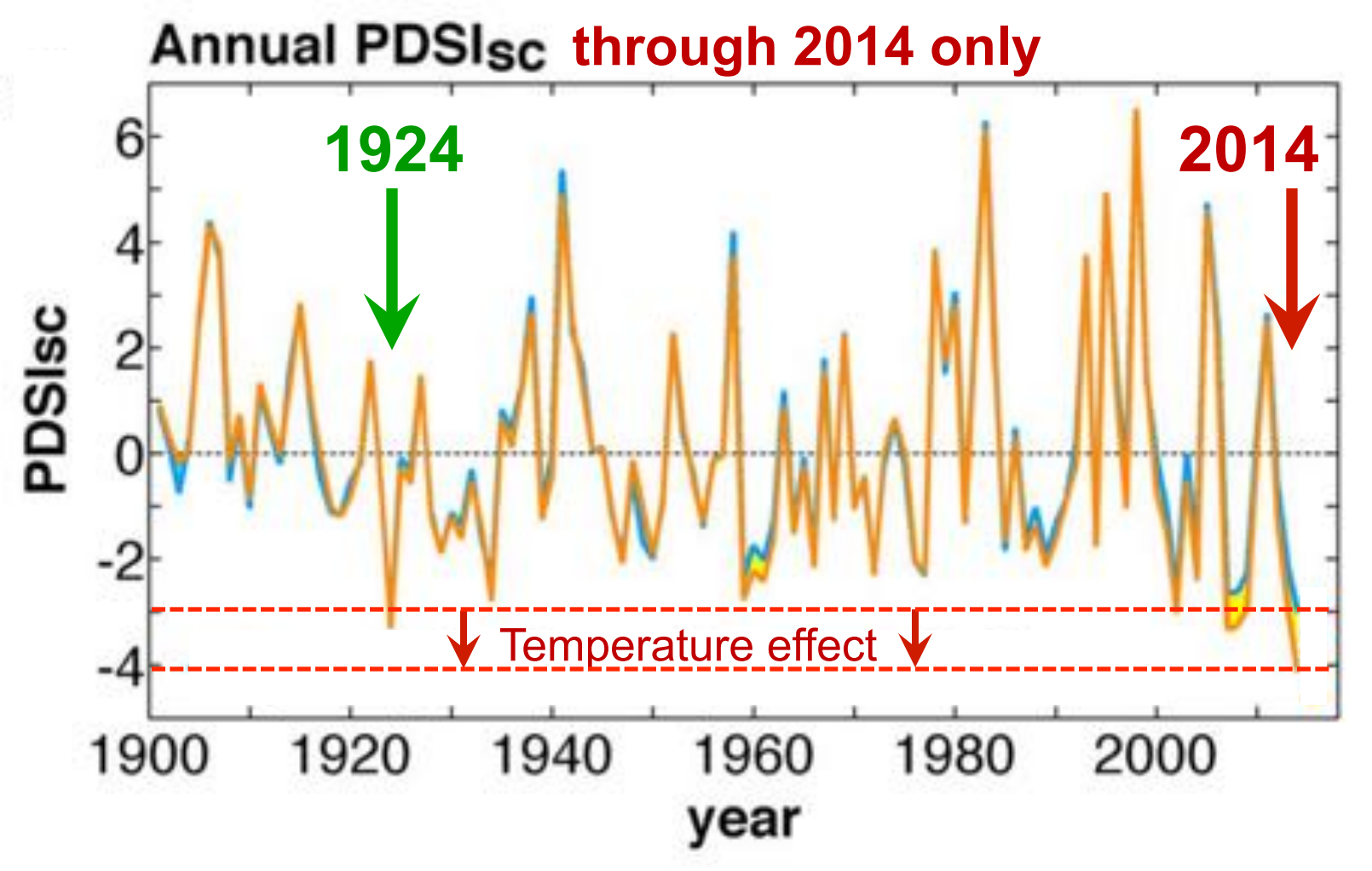


Williams et al. 2015, *Geophys. Res. Lett.*

USGS

Credit: N. Stephenson

But temperature-induced increases in evaporative demand have pushed the drought to historical extremes ...



Williams et al. 2015, *Geophys. Res. Lett.*

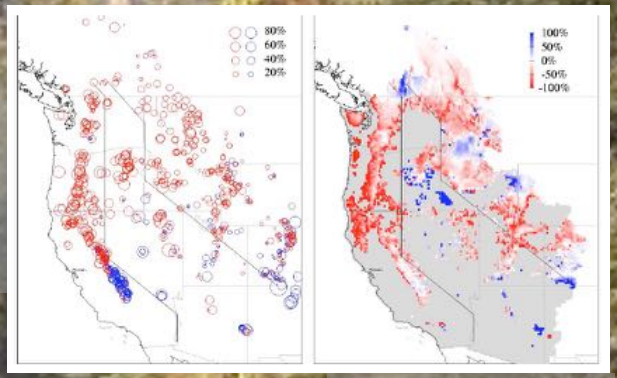
USGS

Credit: N. Stephenson

Changes in western North America

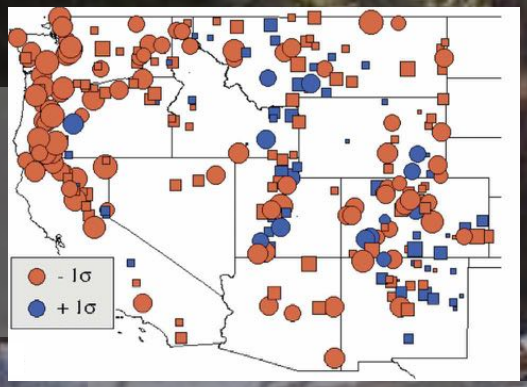
Hydrologic changes in the West

Snowpack has been decreasing



Mote *et al.* 2005

More precipitation falling as rain vs. snow

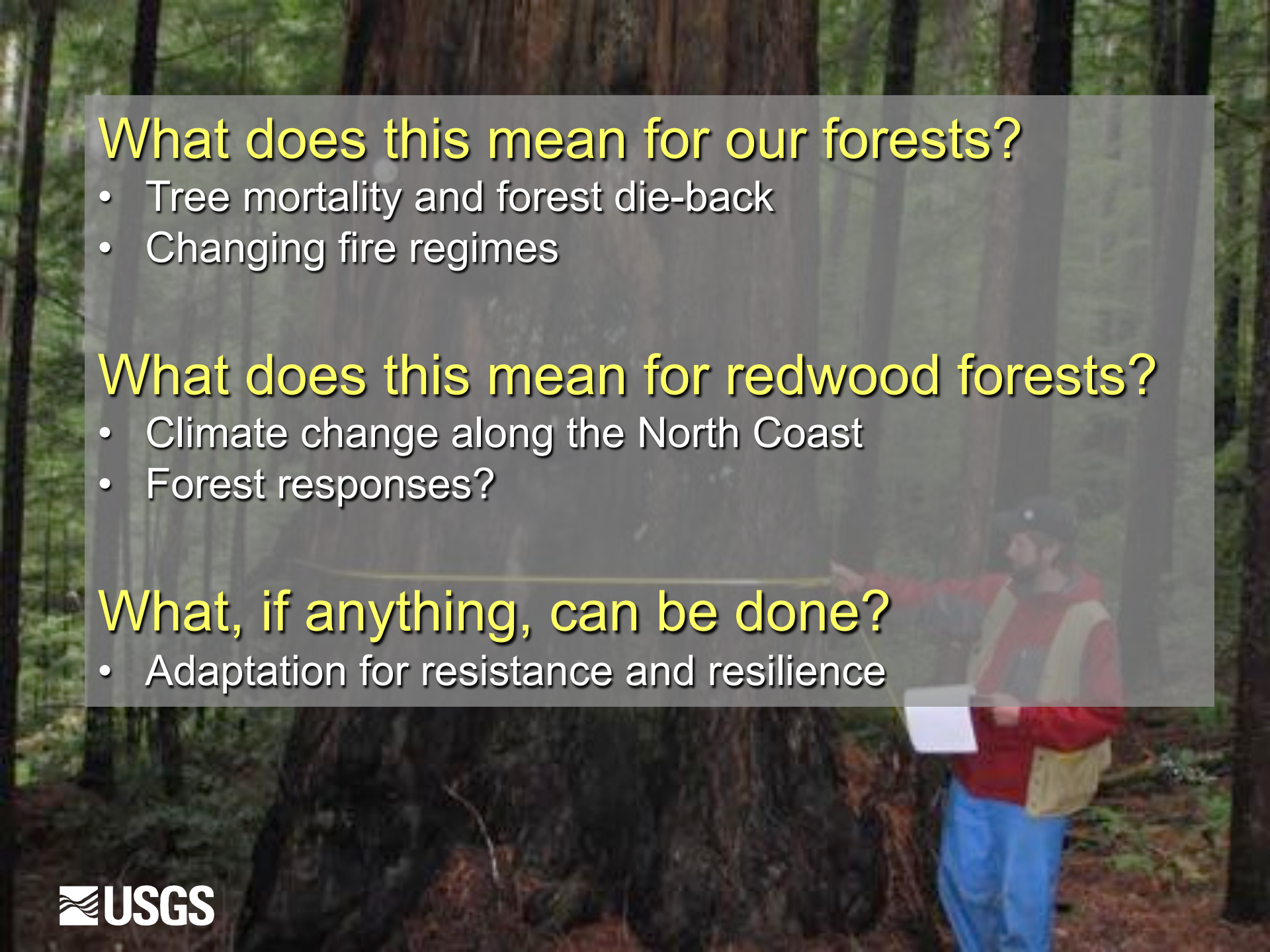


Knowles *et al.* 2006, *J. Clim.*

Spring streamflow has been arriving earlier

Stewart *et al.* 2004, *Clim. Change*

USGS



What does this mean for our forests?

- Tree mortality and forest die-back
- Changing fire regimes

What does this mean for redwood forests?

- Climate change along the North Coast
- Forest responses?

What, if anything, can be done?

- Adaptation for resistance and resilience

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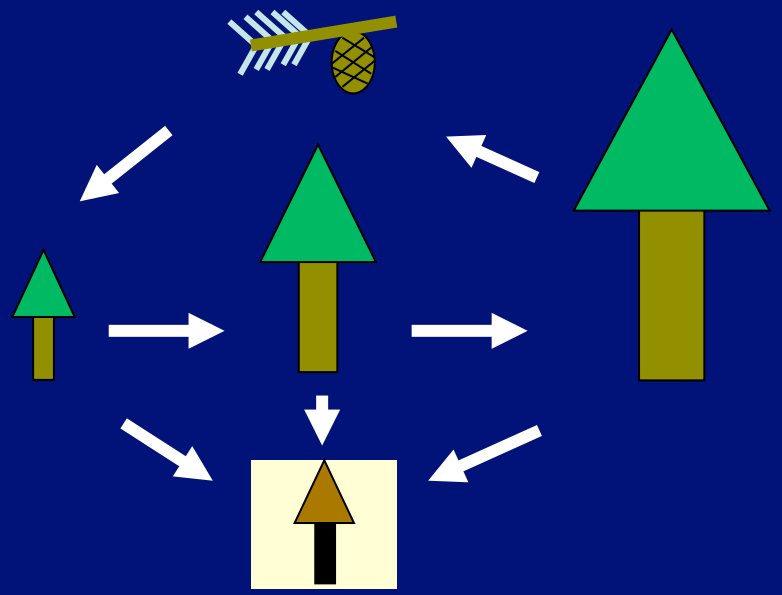
Why tree mortality?

Tree populations are highly sensitive to changes in mortality rate



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A growing body of evidence suggests that environment (particularly climate) affects forest demographic rates

Large-scale die-off

Background mortality

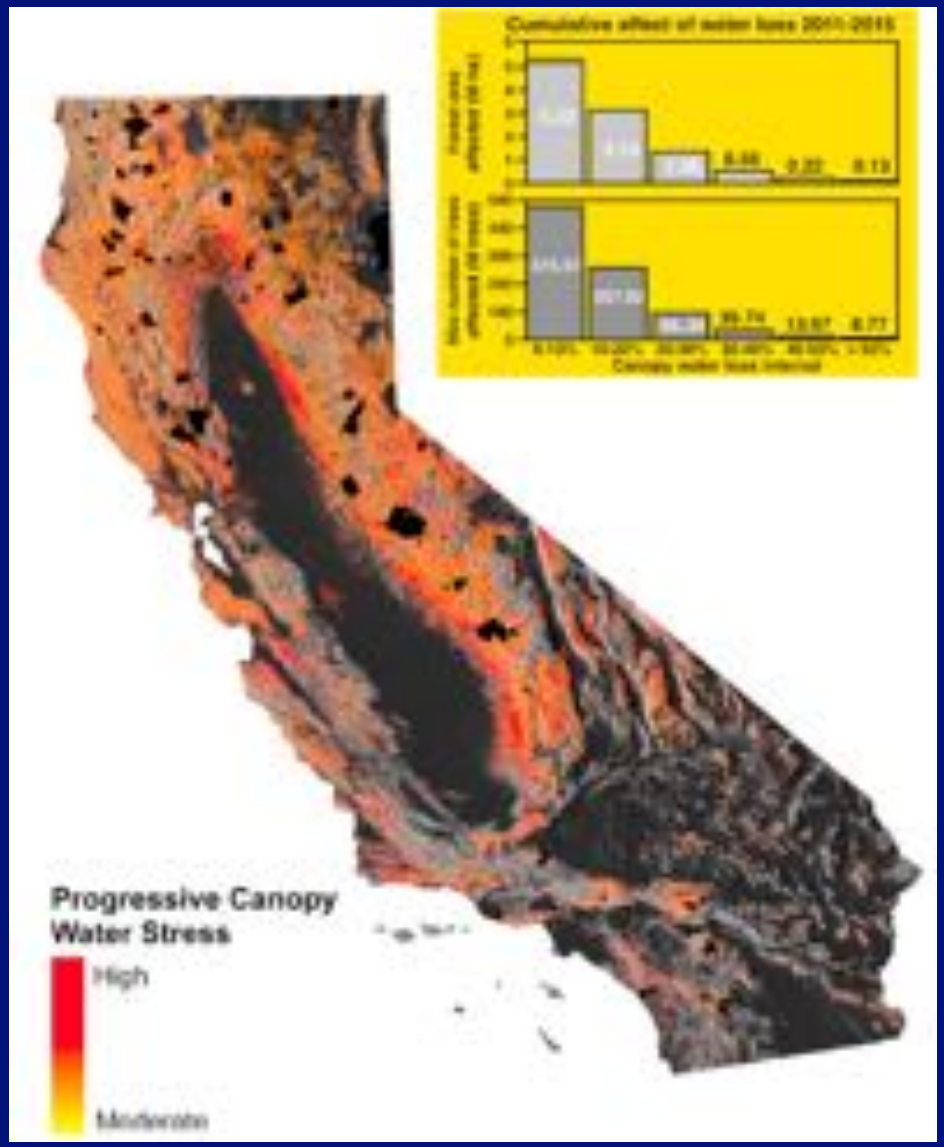
USGS

Southern Sierra Nevada die-back event of 2016

USFS Region 5 Aerial Detection Survey
Areas with mortality: 4.3 million acres
Estimated number of trees killed: 62 million (102 million since 2010)

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd509278.pdf

USGS



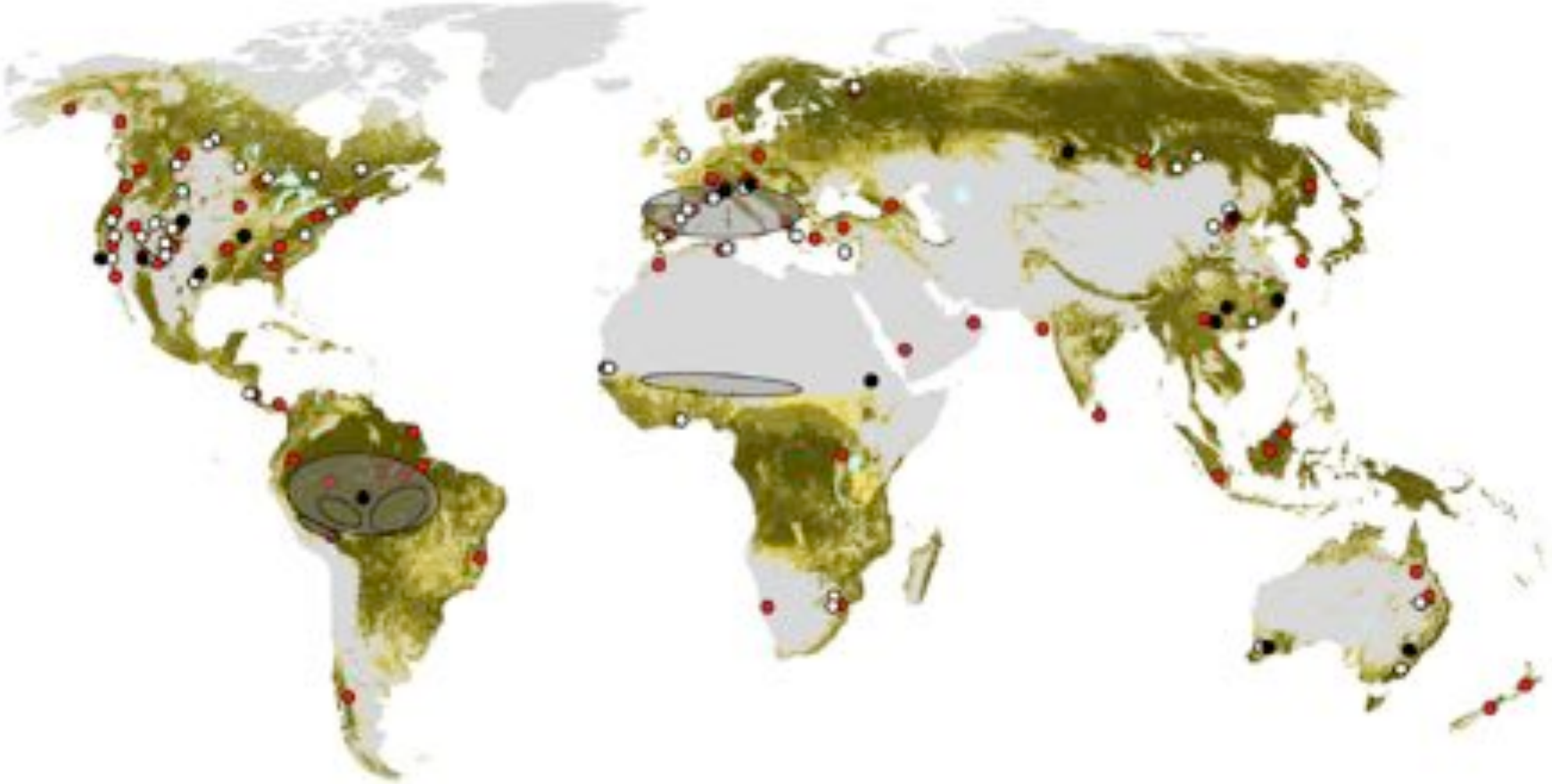
Approximately 10.6 million ha of forest containing up to 888 million large trees experienced measurable loss in canopy water content…

USGS

Asner et al. 2016 *PNAS*

Die-back events occurring during ‘hotter droughts’

Increasing incidence of forest die-back as an emerging global phenomenon



Locations of substantial drought- and heat-induced tree mortality around the globe since 1970 (Allen et al. 2015 *Ecosphere*)

USGS

Photo credit: C. Allen

A growing body of evidence suggests that environment (particularly climate) affects forest demographic rates

Large-scale die-off

Background mortality

(1) subtle, slow, neglected

(2) ... but important!

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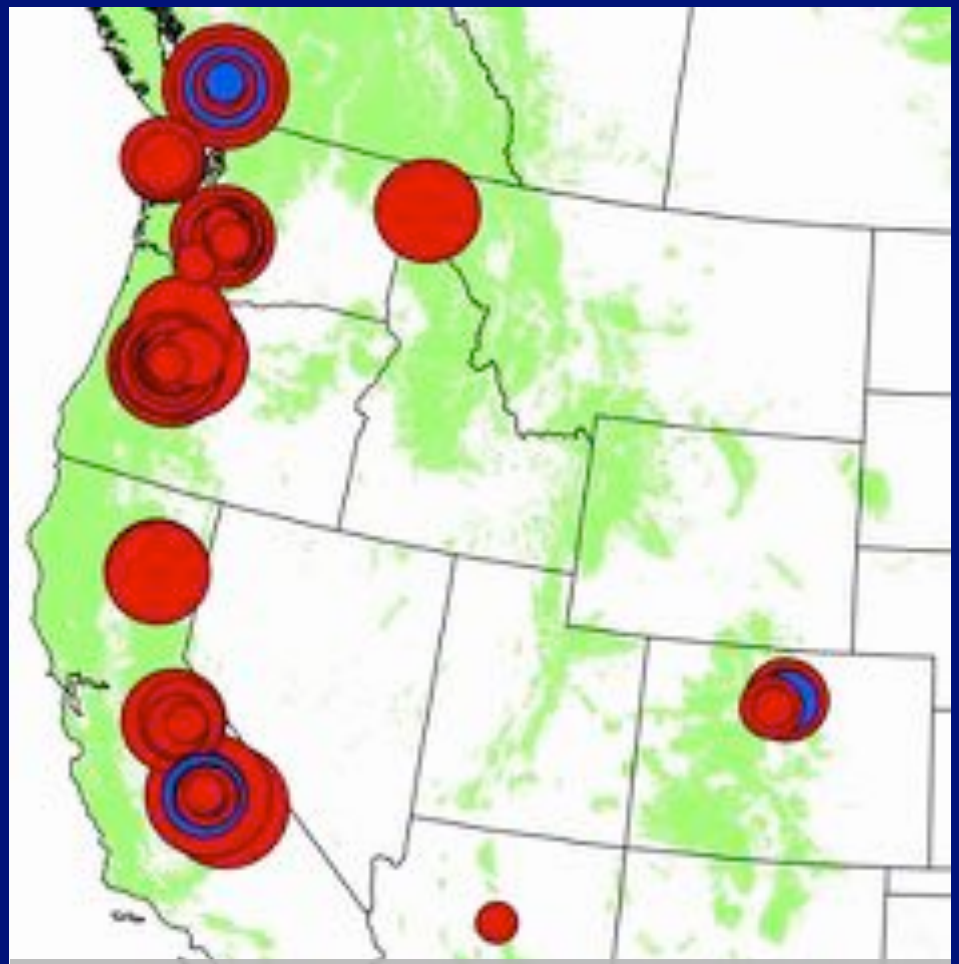
Tree mortality rates are increasing in the western US



Symbol size = magnitude of change
Red = increasing mortality
Blue = decreasing mortality

van Mantgem *et al.* 2009, *Science*

- 76 plots in undisturbed old forests
- observed from ~1981 to ~ 2004
- 87% of plots increasing mort. rate P <0.0001
- mort. rate ~18 yr DOUBLING period
- temporal trend, P <0.0001

USGS

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What, if anything, can be done?

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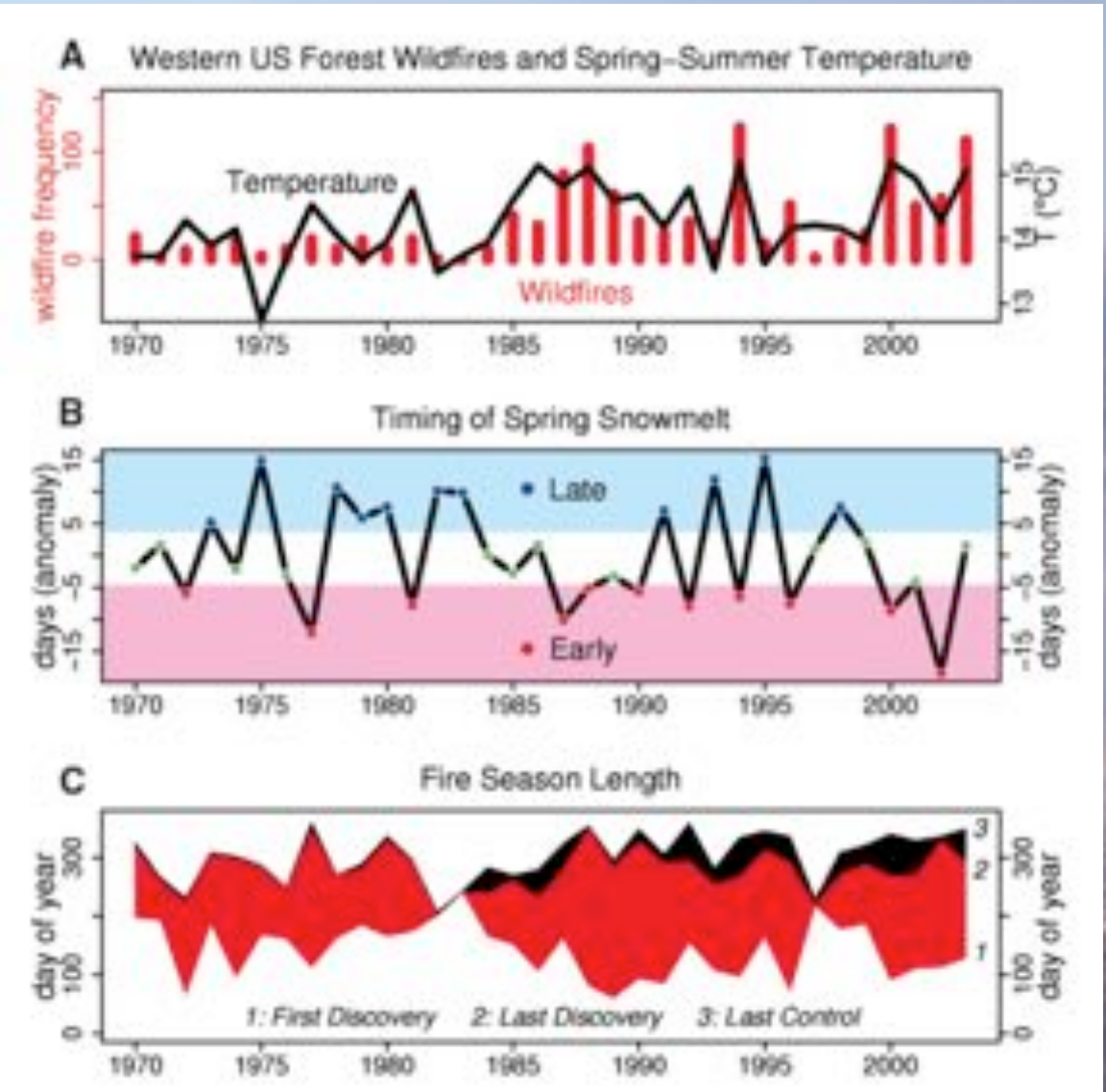
Credit: E. Knapp

Changing climate = changing fire regime



Westerling *et al.* 2006, *Science*

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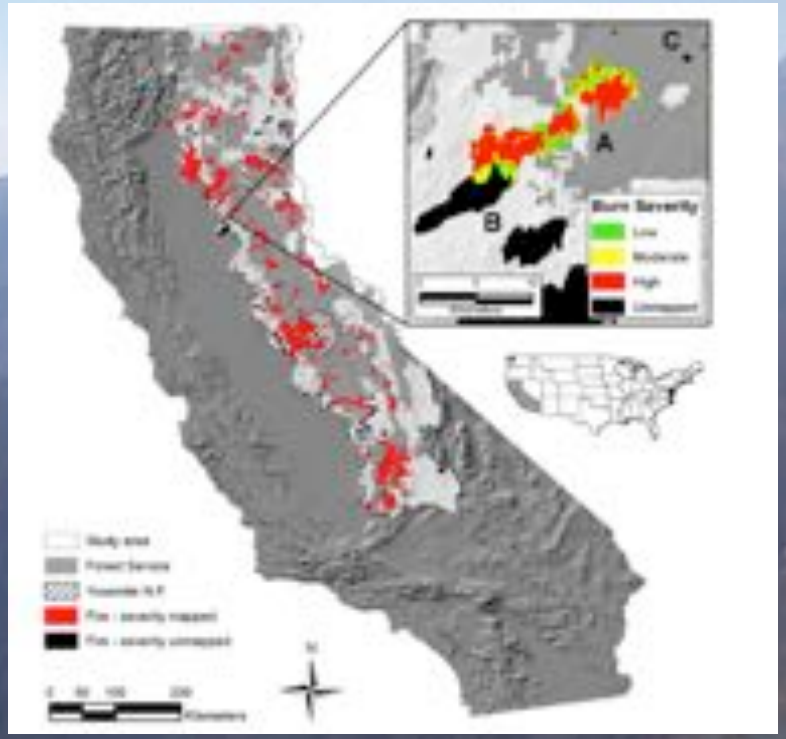
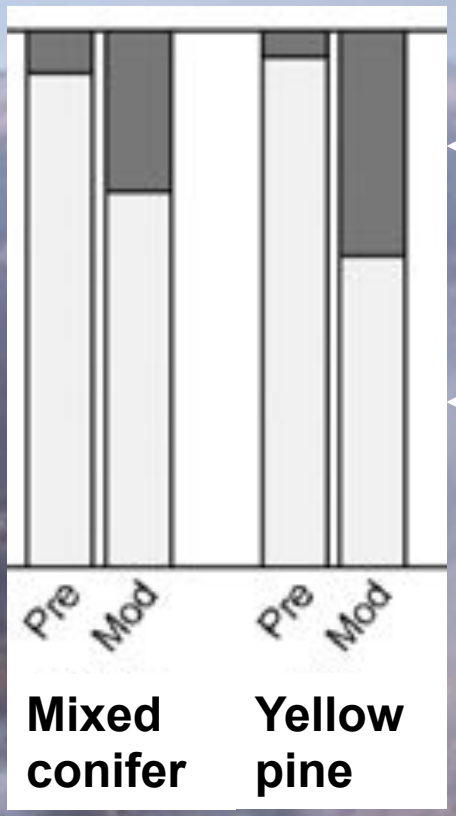
Credit: NPS

Changing climate = changing fire regime

High severity fire is increasing in low elevation forests in the Sierra Nevada of California





Severe fire %

Low/mod fire %

Mallek et al. 2013 *Ecosphere*
Miller *et al.* 2009, *Ecosystems*
Miller & Safford 2012, *Fire Ecol.*
(but see Miller *et al.* 2012, *Ecol. Appl.*)

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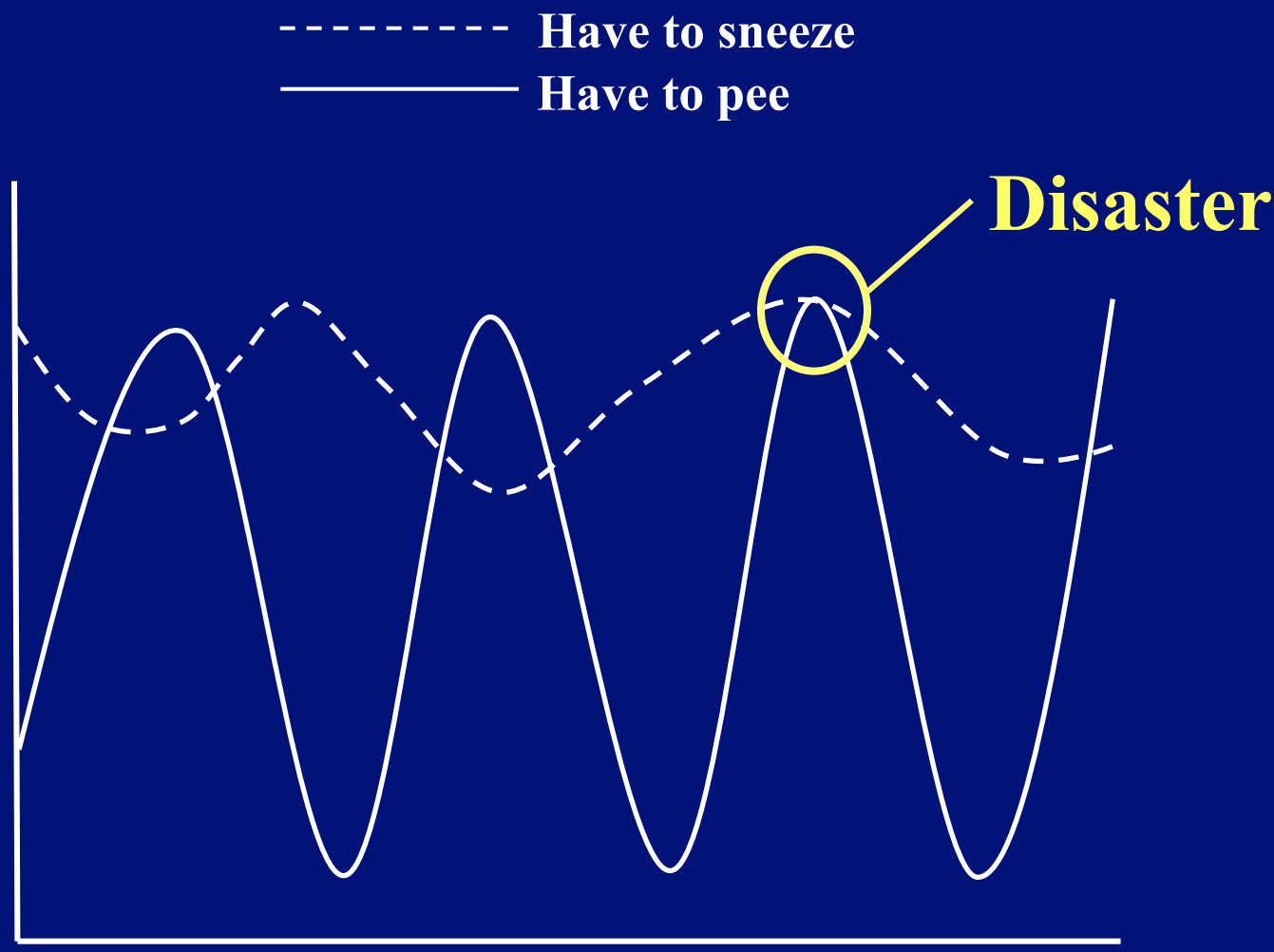
Interactions of stressors



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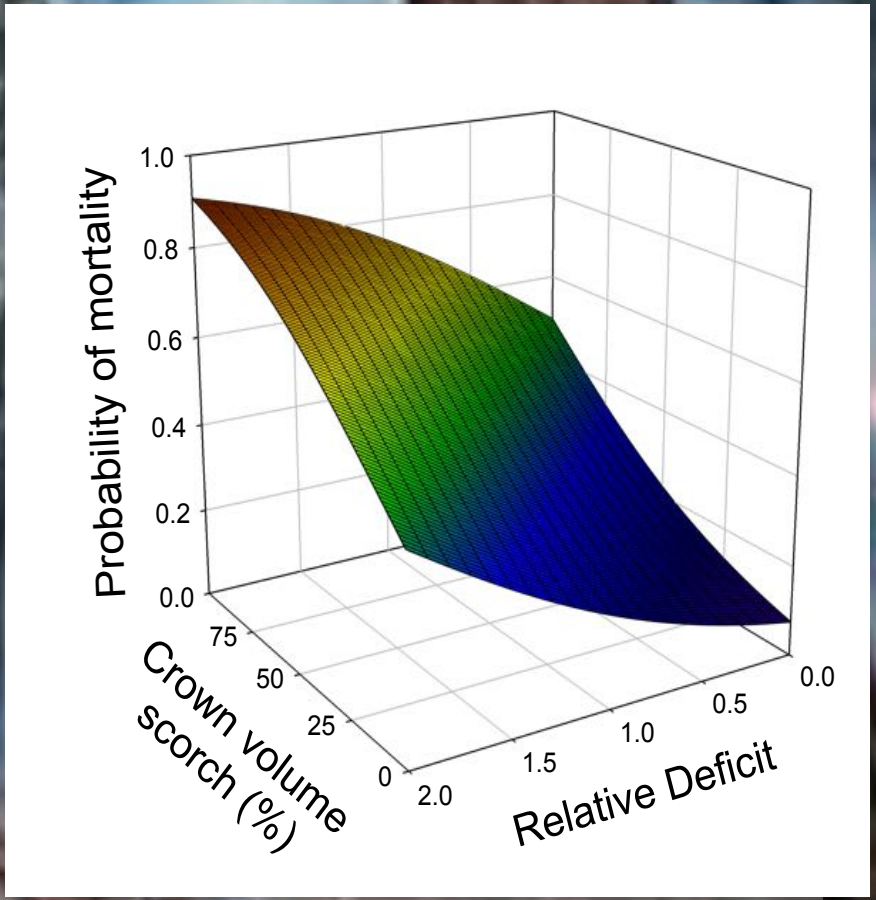
from Martin 2012, *This is a Book*

Climatic stress increases forest fire severity across the western United States

- Data from NPS and USFS
- 18 sites
- >250 plots
- >7000 trees
- dominated by *P. ponderosa* and *A. concolor*

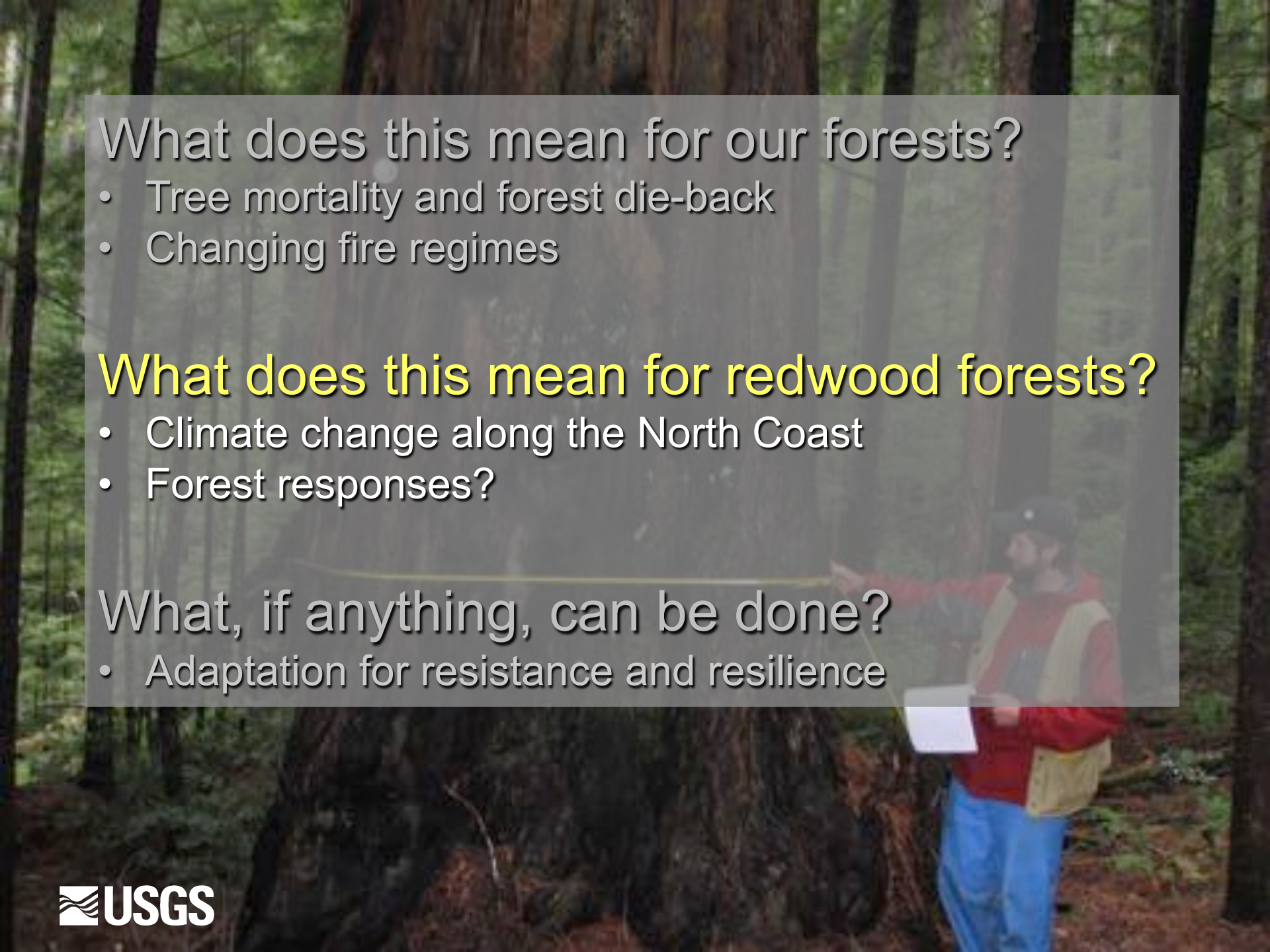
(also *Pseudotsuga menziesii*, *Calocedrus decurrens* and *P. lambertiana*)



van Mantgem *et al.* 2013, *Ecol. Lett.*

USGS

Credit: N. Stephenson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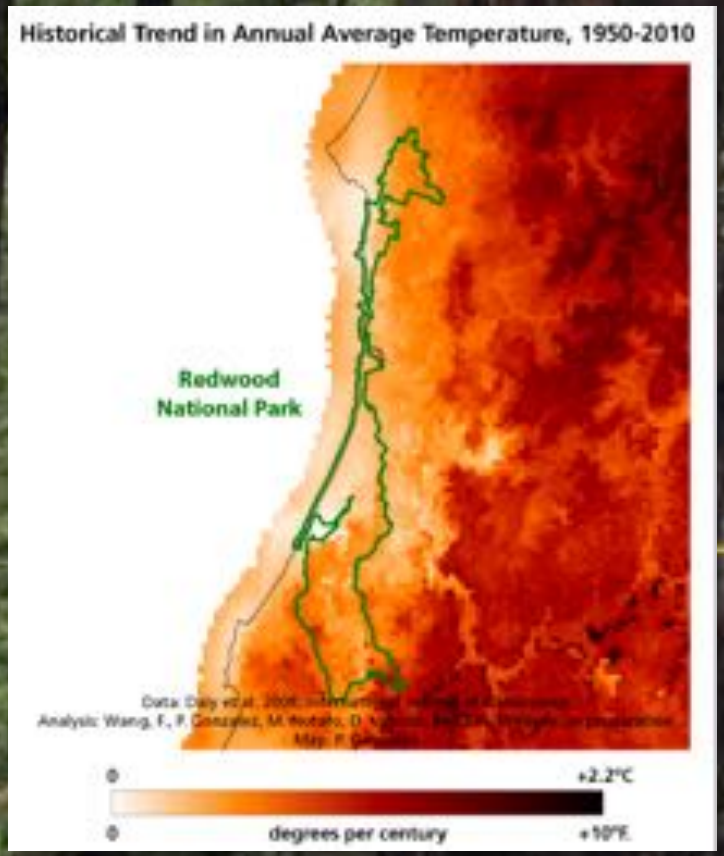
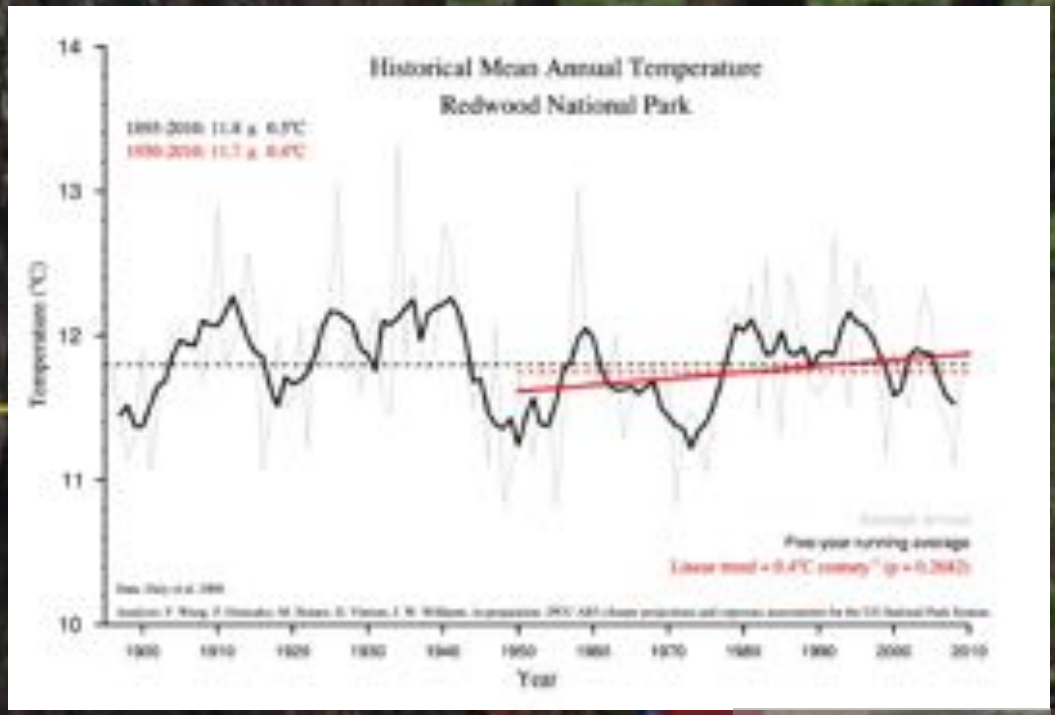
What does the future hold?
Temperature trends at RNSP

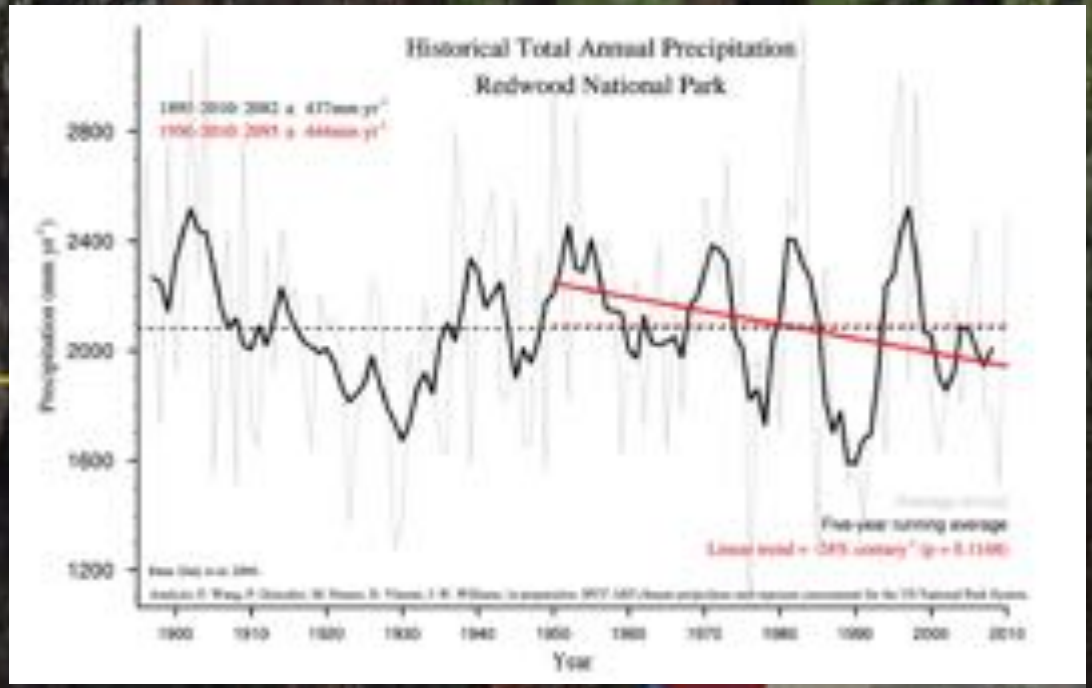




Wang et al., *in prep*

USGS

What does the future hold?
Precipitation trends at RNSP

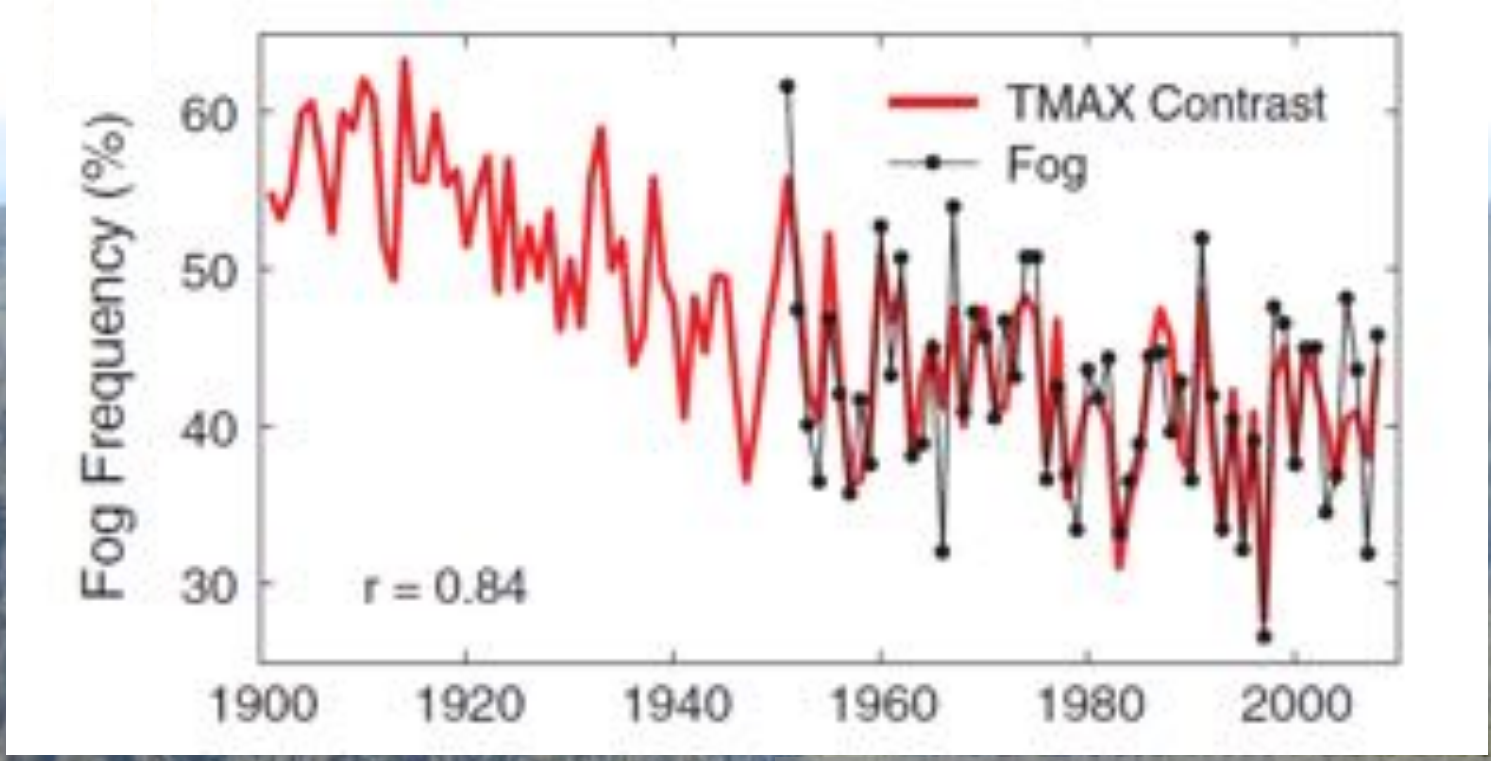


Wang et al., *in prep*

USGS

Changing coastal fog?

33% reduction in (*high altitude*) fog frequency since the early 20th century

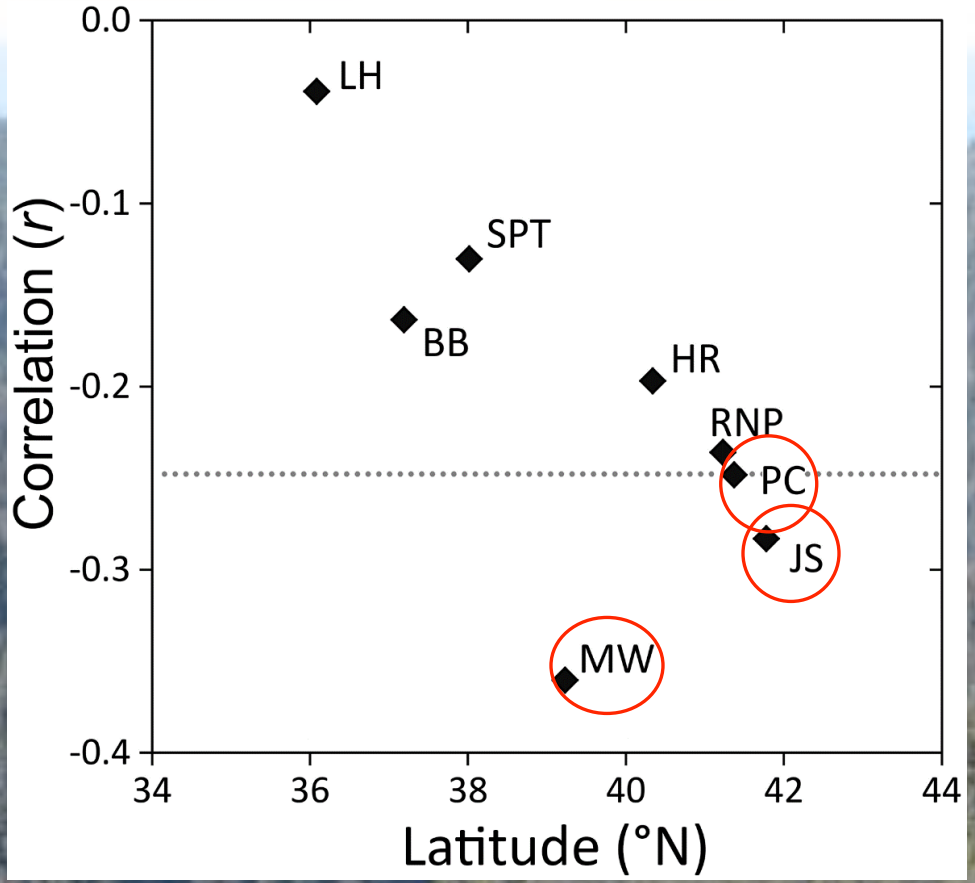


Johnstone & Dawson 2010, *Proc. Nat. Acad. Sci.*

USGS

Redwood growth increasing?

- redwood radial growth increased with decreasing summer cloudiness (i.e., airport fog)
- significant (P<0.01) at three locations in northern California



Carroll *et al.* 2014, *PloS one*

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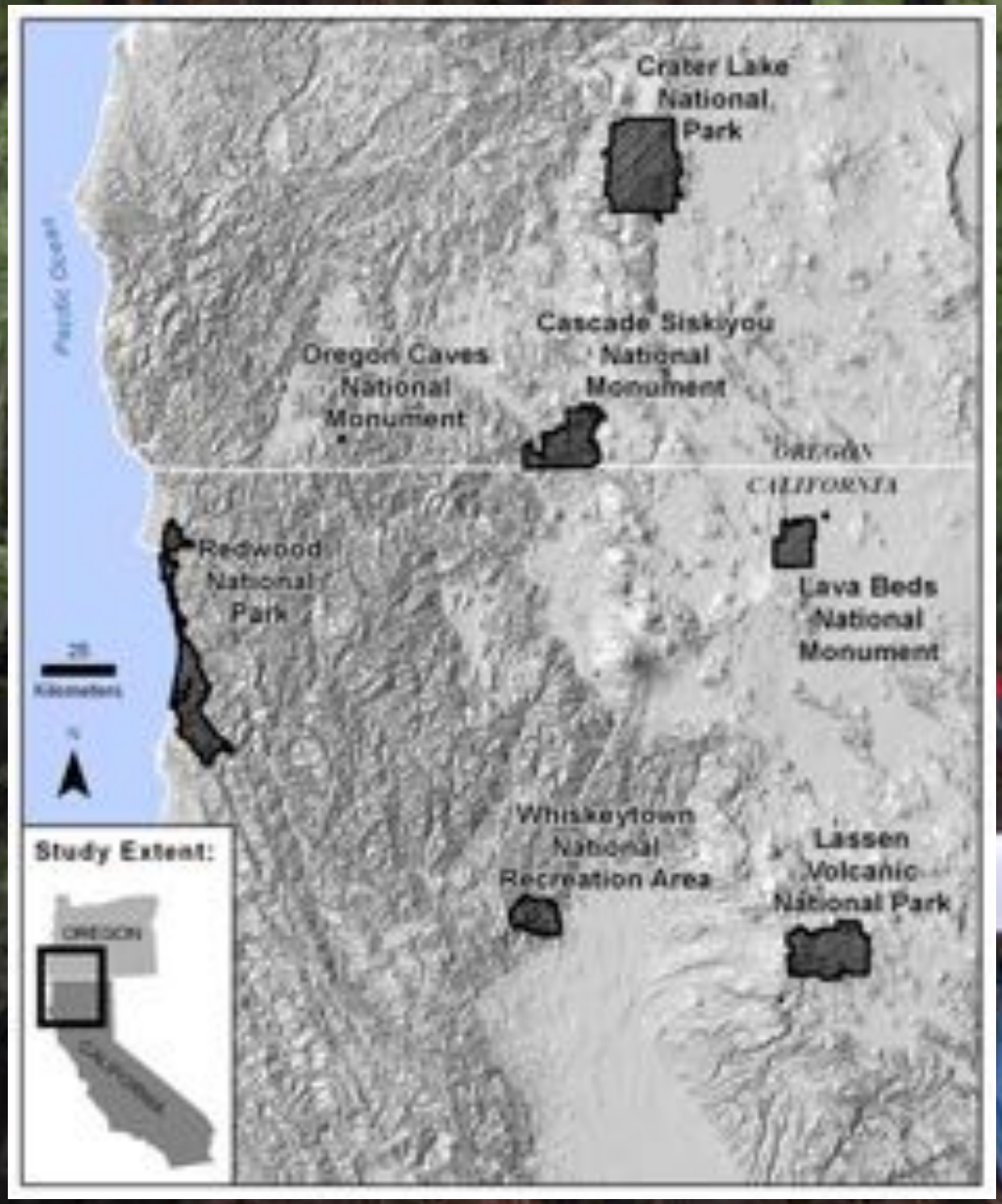
The Klamath Inventory and Monitoring Network



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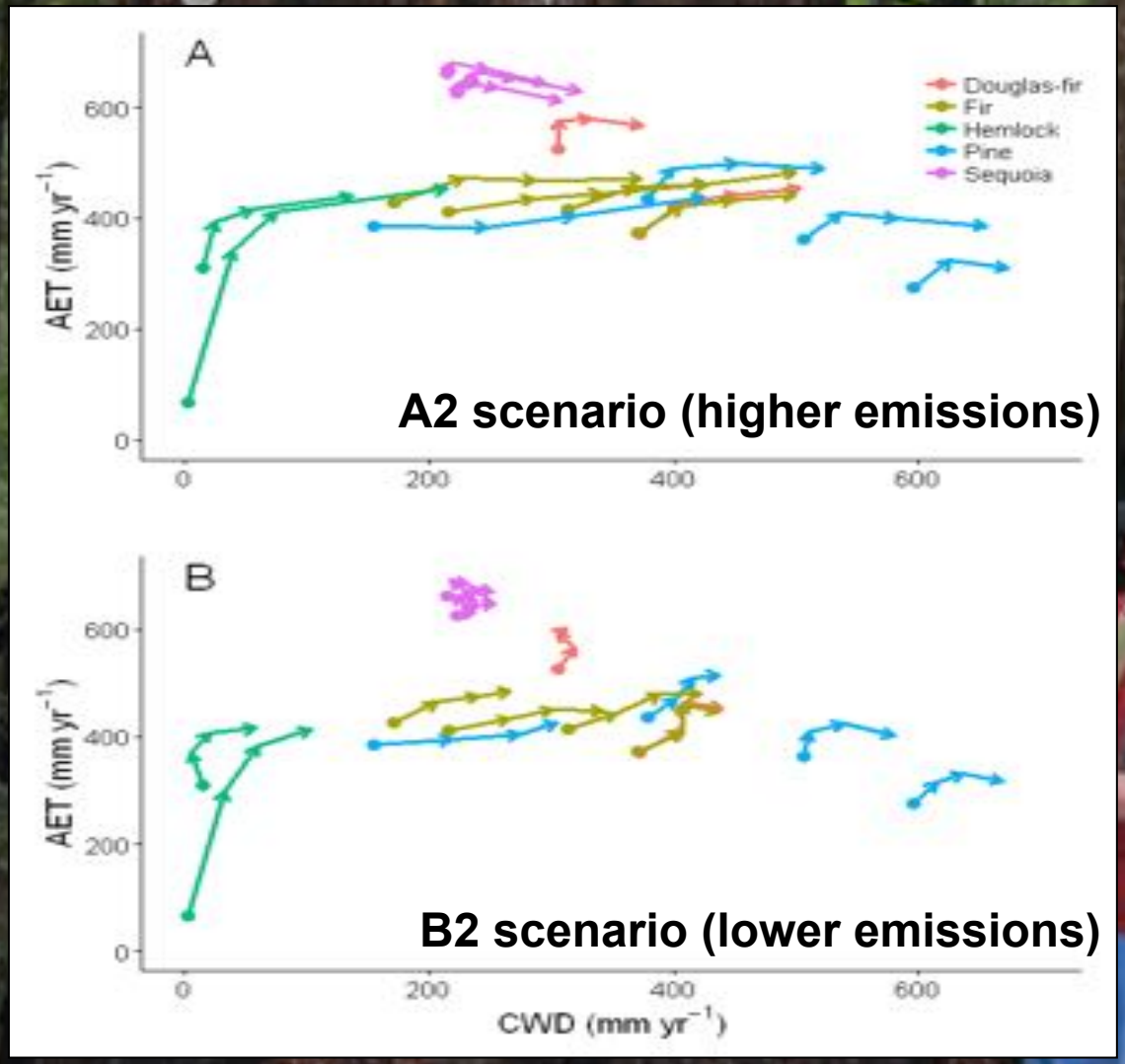
The KLMN forest plots

Climatic velocity: modeled changes in actual evapotranspiration (AET) and climatic water deficit (CWD)



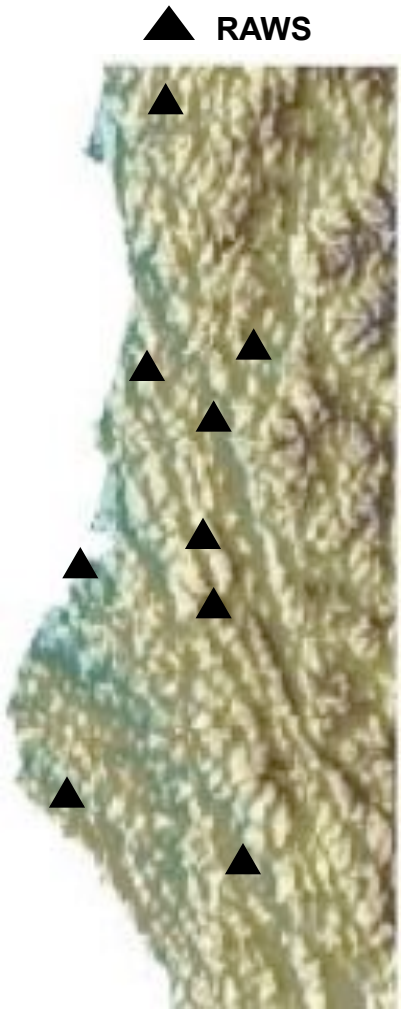
van Mantgem & Sarr 2015, *Northwest Sci.*

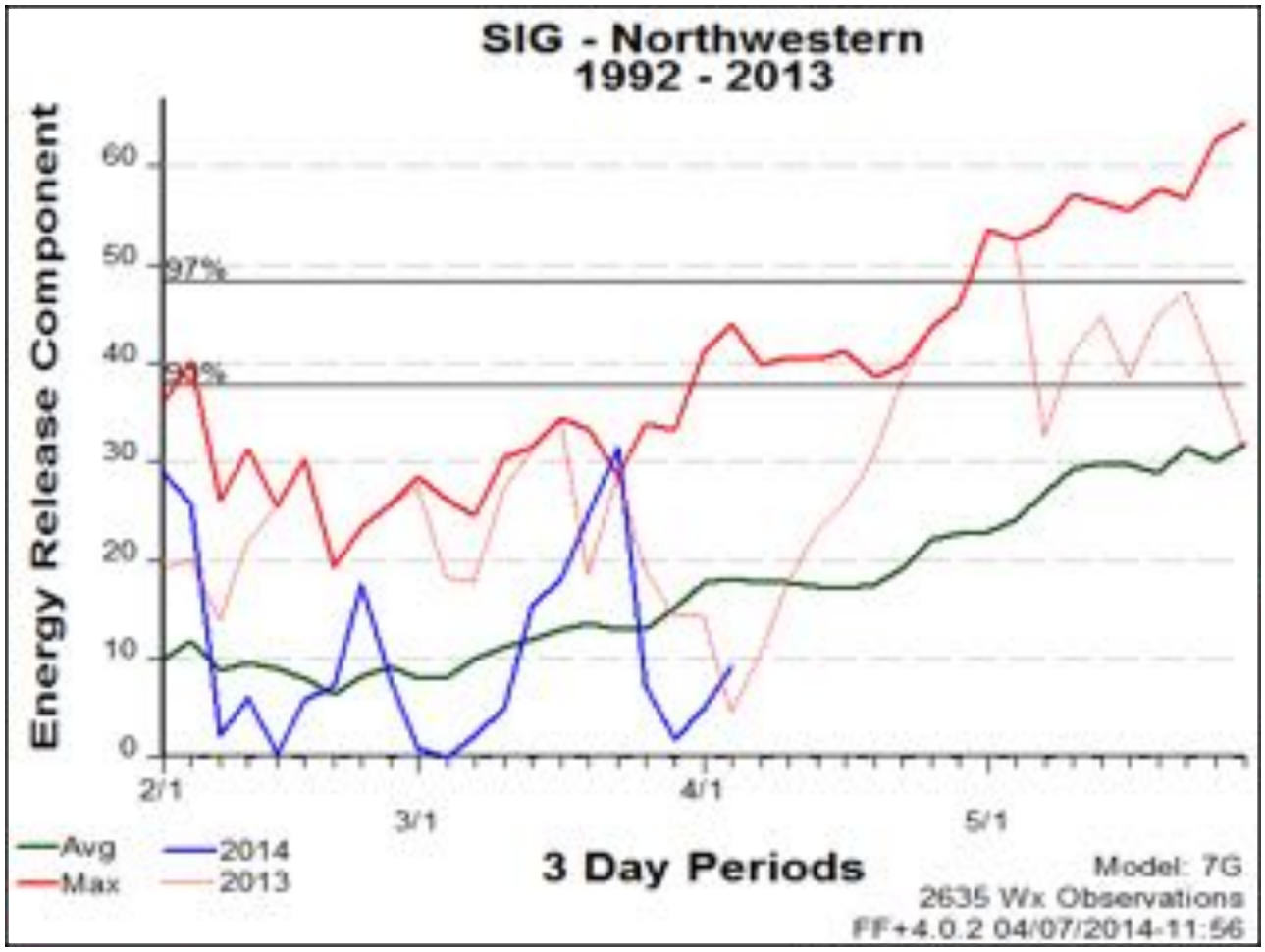
USGS

Courtesy of J. LENIHAN

NORTH COAST PREDICTIVE SERVICES AREA (PSA)

ENERGY RELEASE COMPONENT (ERC) CHART
FUEL MODEL G SHORT NEEDLE (HEAVY DEAD)





http://gacc.nifc.gov/oncc/predictive/fuels_fire-danger/psac/erc/

Courtesy of J. LENIHAN

MEAN ANNUAL MAX MONTHLY TEMPERATURE (ºF)

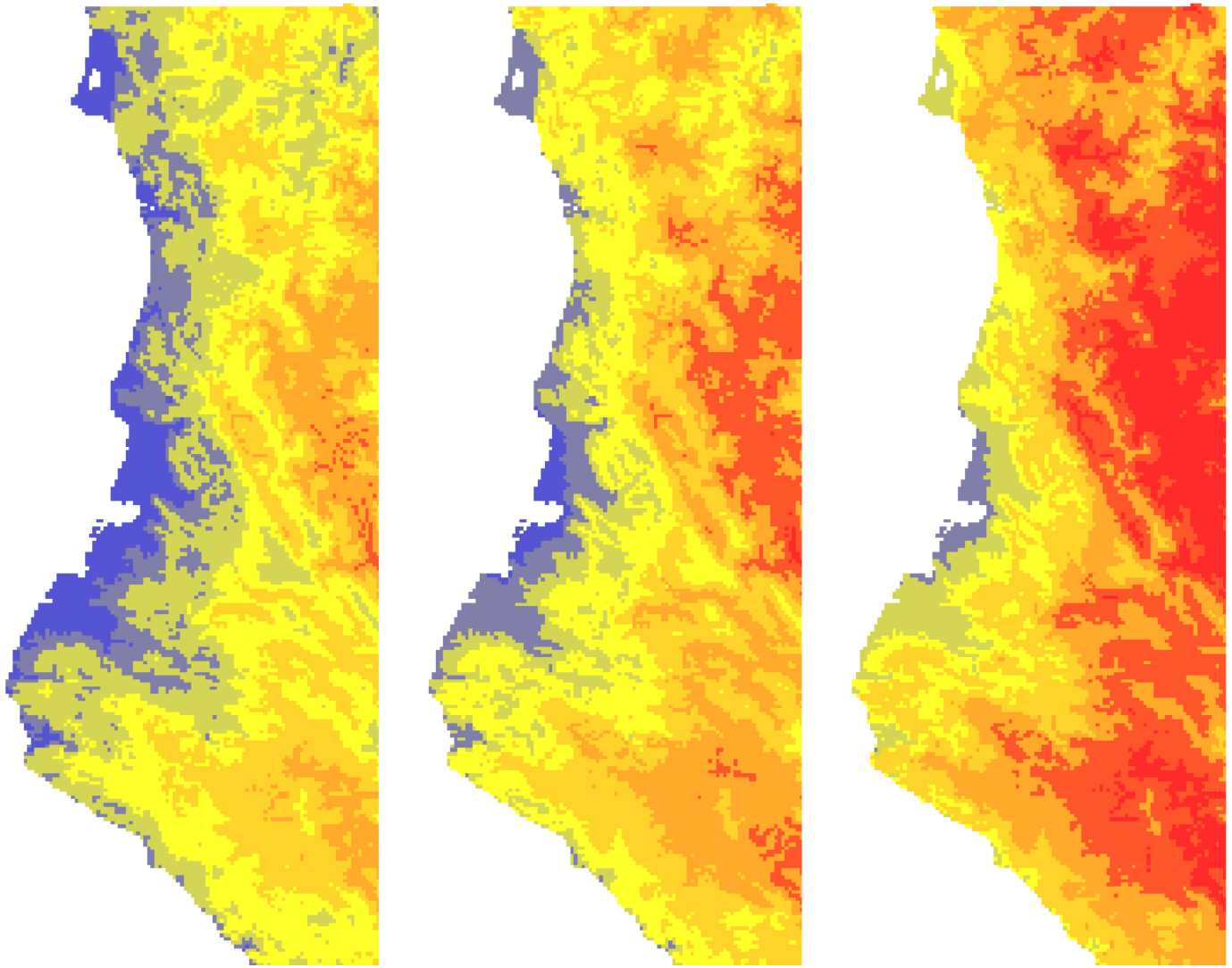
NORTH COAST PSA

OBSERVED HISTORICAL *1972-2006*

HADLEY A2 MID CENTURY *2007-2041*

HADLEY A2 LATE CENTURY *2042-2076*

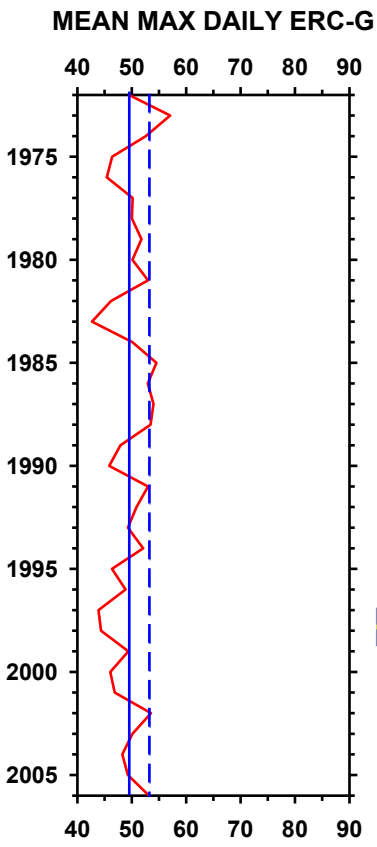
< 70
70–75
75–80
80–85
85–90
90–95
95–100
> 100

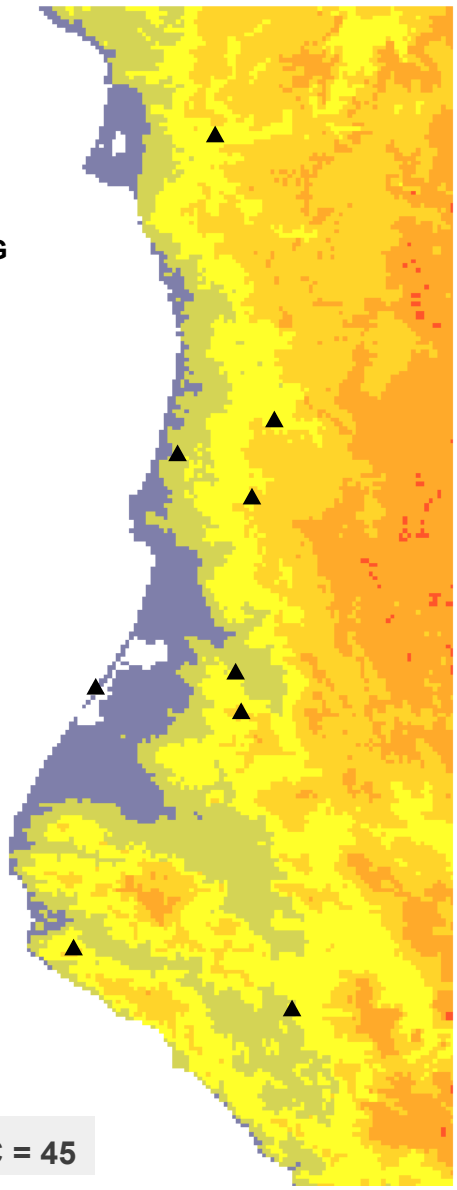


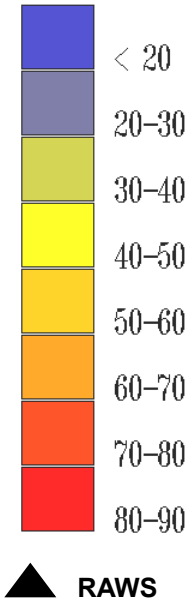
Courtesy of J. LENIHAN

HISTORICAL → MID-CENTURY

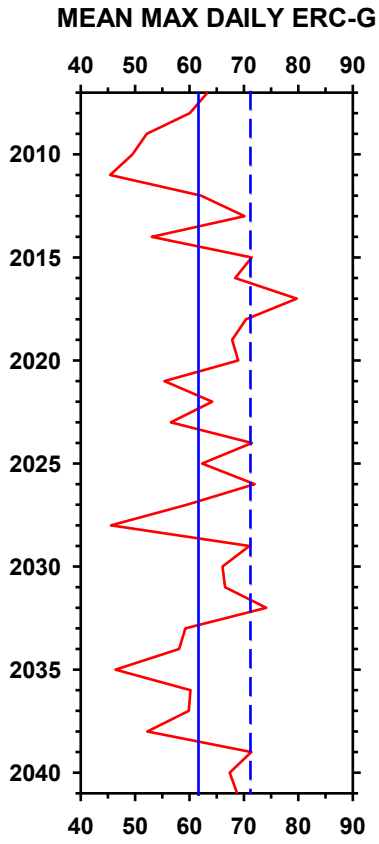
1972-2006







2007-2041 HADLEY A2



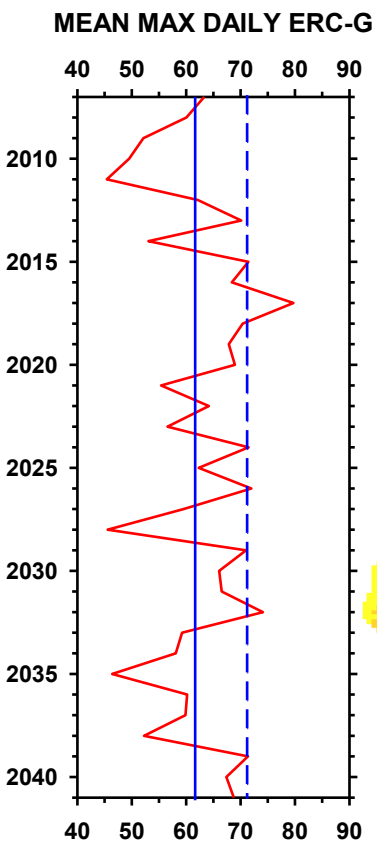
RAWS MEAN MAX ERC = 45

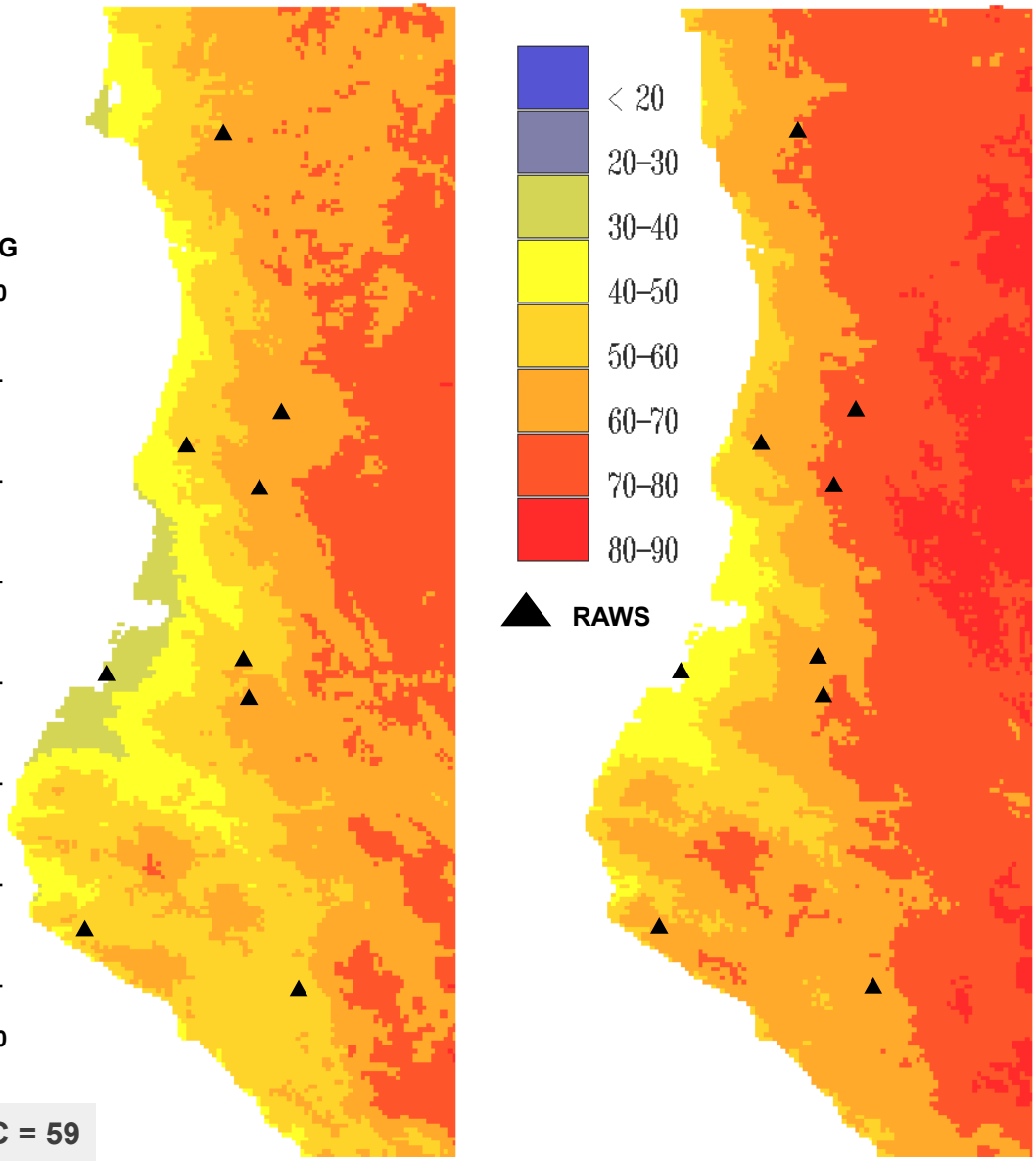
RAWS MEAN MAX ERC = 59

Courtesy of J. LENIHAN

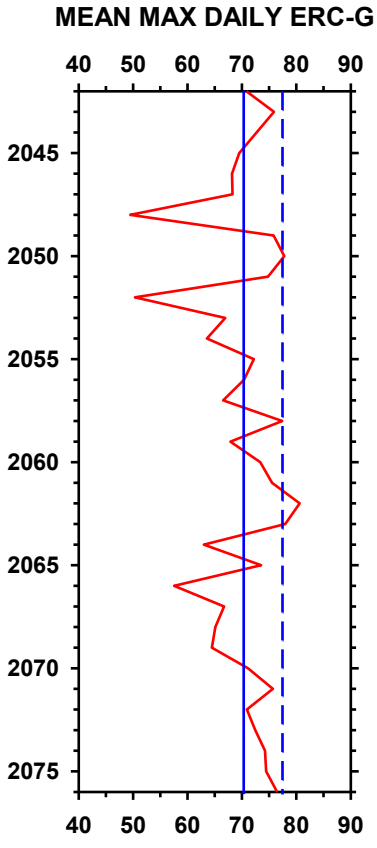
MID-CENTURY → LATE-CENTURY

2007-2041 HADLEY A2





2042-2076 HADLEY A2

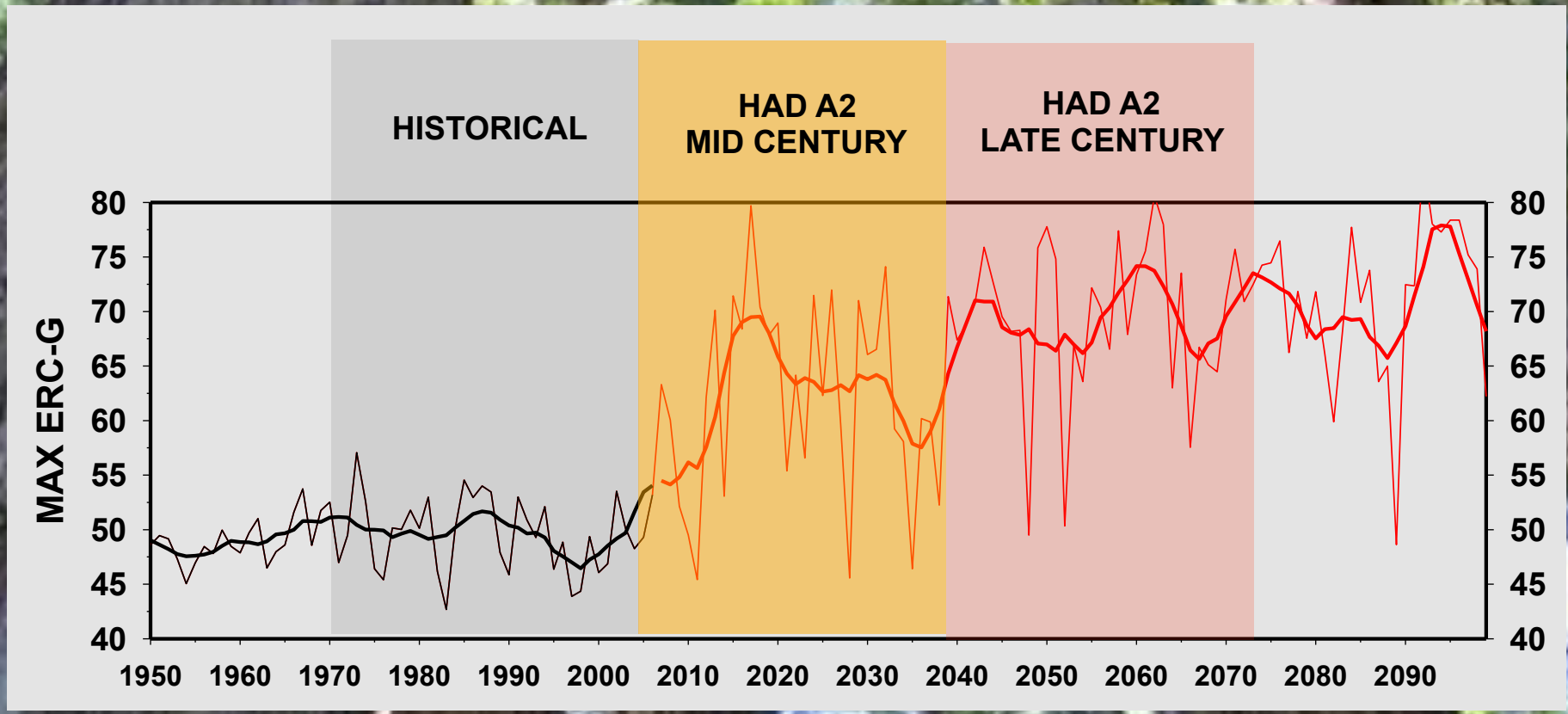


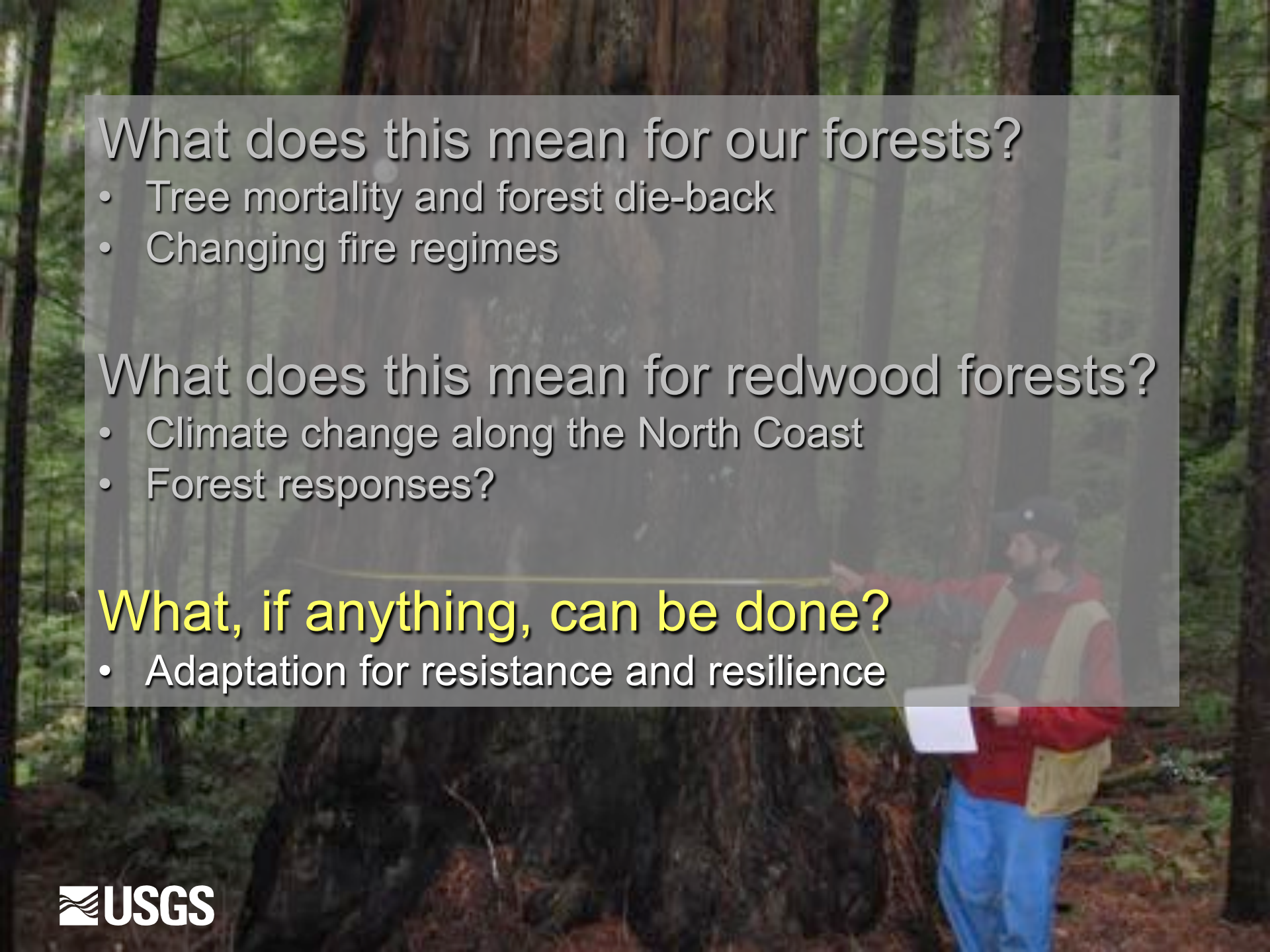
RAWS MEAN MAX ERC = 59

RAWS MEAN MAX ERC = 67

Courtesy of J. LENIHAN

NORTHERN COASTAL CALIFORNIA: ON THE BRINK OF A PHASE CHANGE IN FIRE BEHAVIOR?

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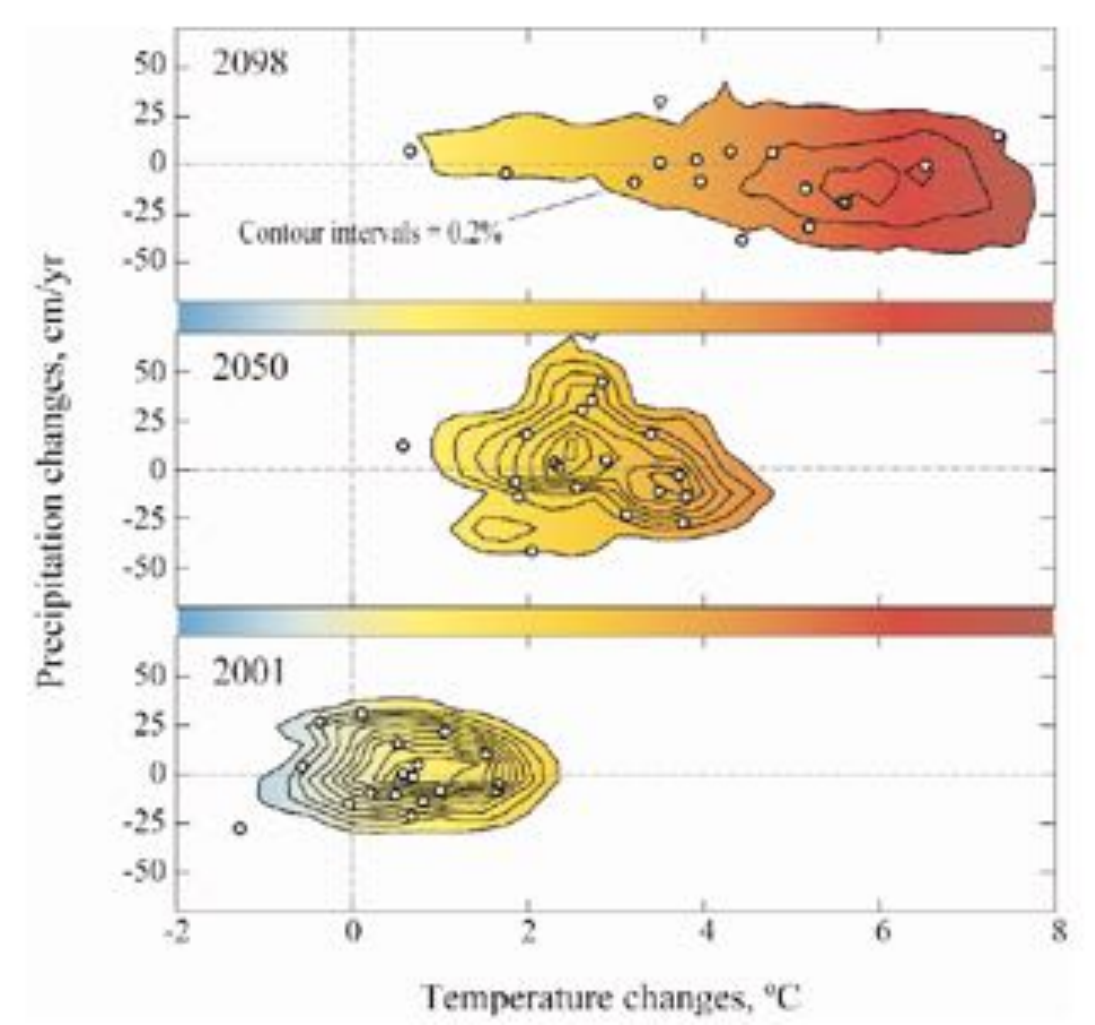
USGS

Past forest conditions no longer *automatically* provide us with management targets!

AND

The future is highly uncertain



Dettinger 2005

USGS

What are “natural” conditions?

Current NPS natural resources policy:

-- When possible, restore and maintain naturally-functioning ecosystems.

-- When this is not possible, “maintain the closest approximation of the natural condition.”

USGS

Credit: N. Stephenson

What, if anything, can be done?

Adaptation strategies

Resistance: ability to remain essentially unchanged following disturbance

Resilience: ability to recover quickly from disturbance

USGS

Credit: N. Stephenson

Adaptation:

Can forest management increase resistance/resilience to drought?

USGS

Millar and Stephenson, 2015 *Science*

Can prescribed fire increase forest resistance to drought?

- Long-term forest plot data
- Surveys in 2014

- Ponderosa pine – mixed conifer forests (mostly *A. concolor*)
- 28 plots (28 burned, 13 unburned)
- ≥ 6 years post-fire
- >5000 trees

van Mantgem *et al.* in review.

USGS

Credit: N. Stephenson

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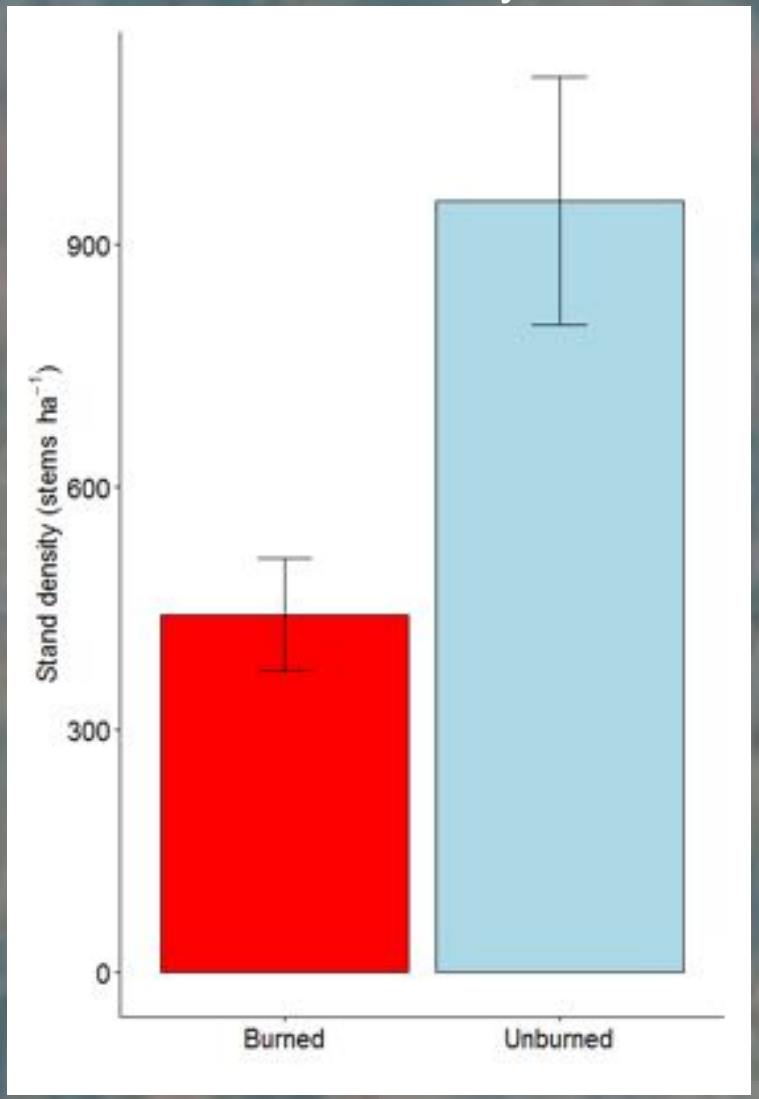
Stand density



van Mantgem *et al.* in review.

USGS

Credit: N. Stephenson

Can prescribed fire increase forest resistance to drought?

Findings

Probability of death lower in burned stands in 2013, 2014 (after accounting for tree size and taxonomic group).

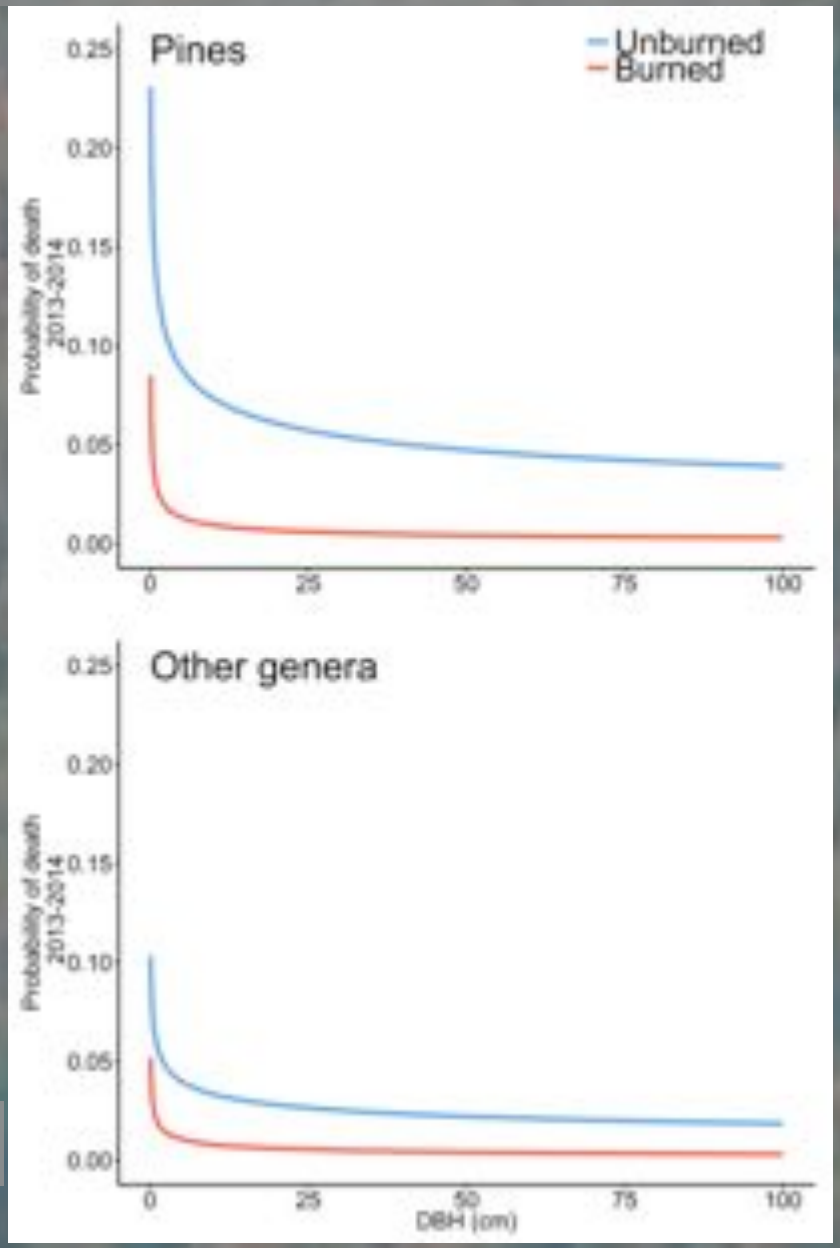
What is the impact of continued drought in 2015?

Can we explicitly identify the mechanisms of tree mortality??
i.e., roles of competition, pathogens, insects?

Other species, other regions???

www.werc.usgs.gov/DroughtForestFire

USGS



van Mantgem *et al.* in review.

Credit: N. Stephenson

Adaptation:
Can forest management increase resistance/resilience to drought?

Old-growth

Second-growth

Second-growth: thin

USGS


Prescribed fire as a thinning tool
in coastal redwood forests
-- Lower Airstrip Expansion site
USGS
Credit: E. Engber

Ponderosa pine stand, repeatedly treated with prescribed fire, Lava Beds NM, California

Barriers to implementation

Prescribed fire funding, air quality, burning windows, site accessibility

Prescribed fire may not be sufficiently severe *(Higgins IJWF 2015)*

Hotter droughts may produce stresses that exceed potential management responses

www.werc.usgs.gov/DroughtForestFire

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Thanks!

Countless field crews, and data managers…
Laura Lalemand & Jon Hollis

National Park Service, USGS, Joint Fire Sciences Program

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