Bark Beetles as Forest Disturbances

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Credit: Leslie Manning/Canadian Forest Service

April 2nd, 2014

Guest lecture:
Biogeography course

Tree mortality resulting from insect outbreaks

Southwestern US

Photo by Craig Allen - USGS

British Columbia

© Parks Canada/Ross MacDonald/KNP/2004

October 2004, Sylvan Pass, Yellowstone NP, photo by J. Hicke

Outline

Photo by J. Hicke

1. Life-cycle of bark beetles
2. Interactions with climate
3. Maps of tree mortality
4. Effects on the ecosystem
5. Conclusions

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Photo by J. Hicke

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Bark beetles

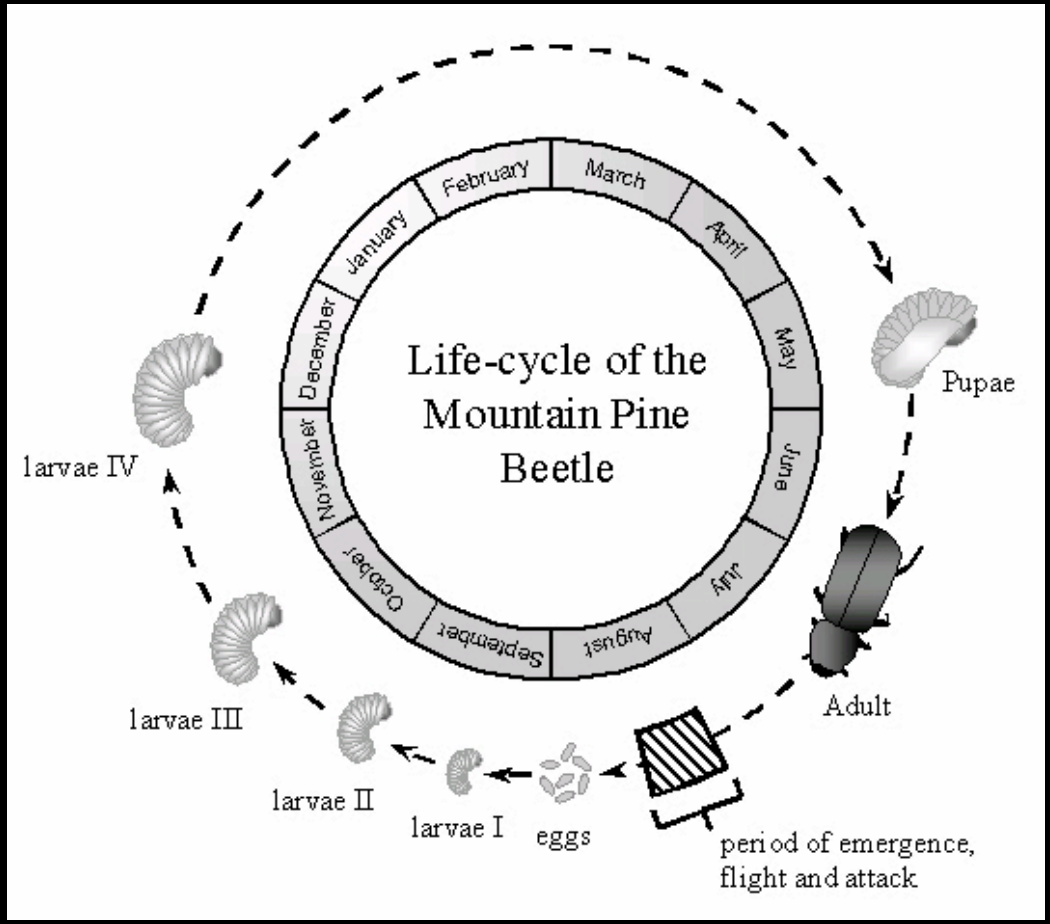
- Majority of life time in stem of tree
- Beetles emerge late-summer to mass attack healthy trees and carry blue stain fungi into tree
- Females deposit eggs in phloem of the tree

Illustration: USDA FS – Rocky Mountain Region Archive,

The Mountain pine beetle (*Dendroctonus ponderosae* Hopkins) size from 3.5 - 6.5mm in body length.

- Larvae feed on the phloem girdling the tree
- Preference for larger diameter trees
- Life stage development of bark beetles is affected by temperatures
- Outbreaks are favored by: abundance of large diameter host trees and favorable climate conditions

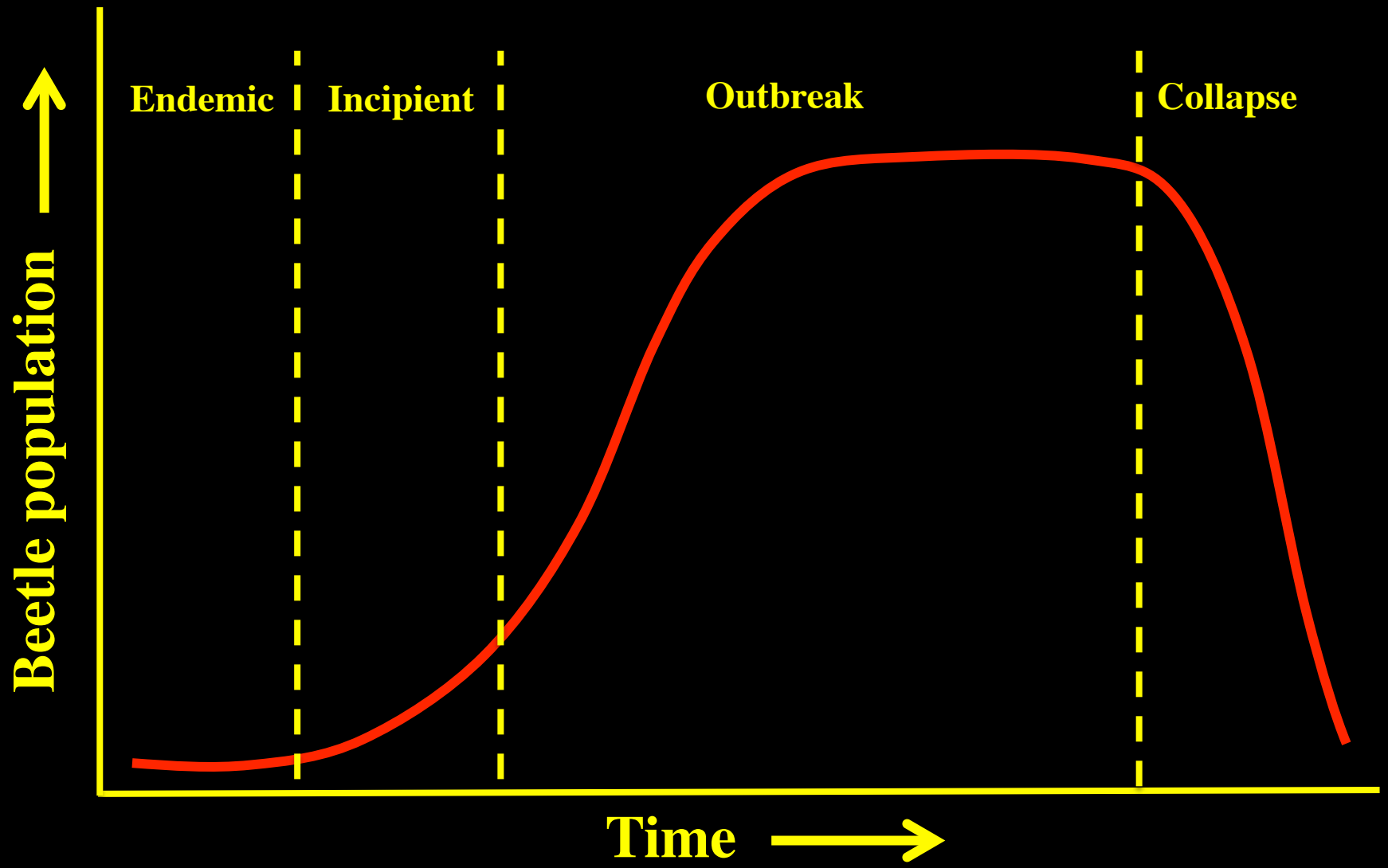
Life-cycle mountain pine beetle



Development (rate) is governed by temperature (increasing with warmer temperatures)

Adaptive seasonality: **life cycles of one year** (univoltism) which lead to **synchronous emergence** of adults from host trees at an appropriate time of year in order **to overwhelm tree defenses**

Stages of bark beetle outbreaks



Factors influencing mountain pine beetle epidemics

Factors related to trees:

- presence of host tree species
- stem density
- stand age
- drought stress on trees

stand structure

climate

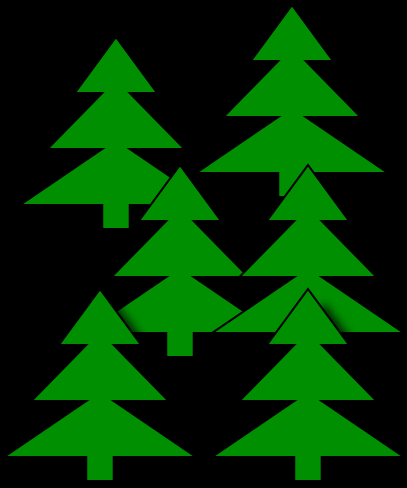


Photo courtesy USDA Forest Service, www.forestryimages.org

Safranyik et al. 1975; Shore and Safranyik 1992; Carroll et al. 2004; Logan and Powell 2001

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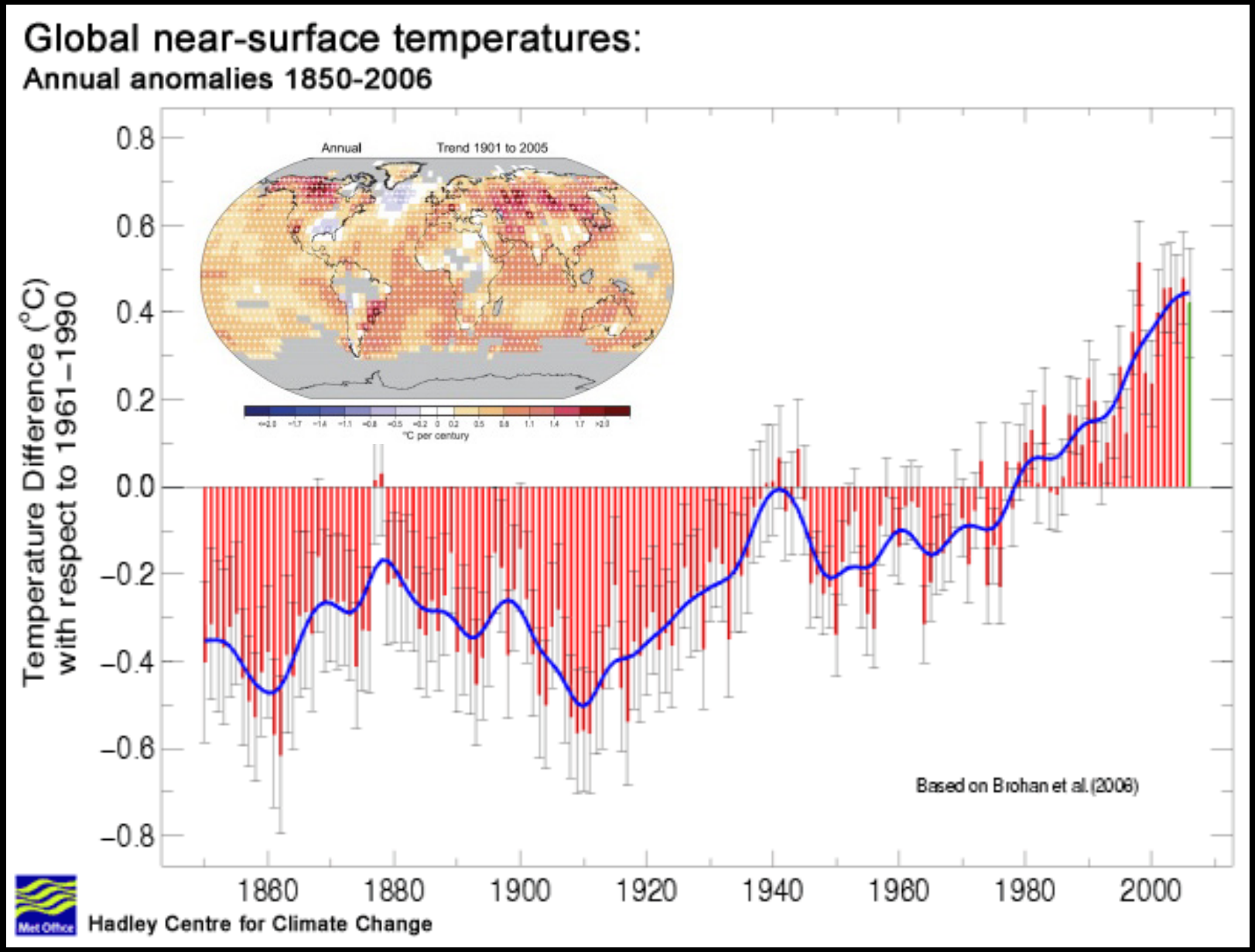
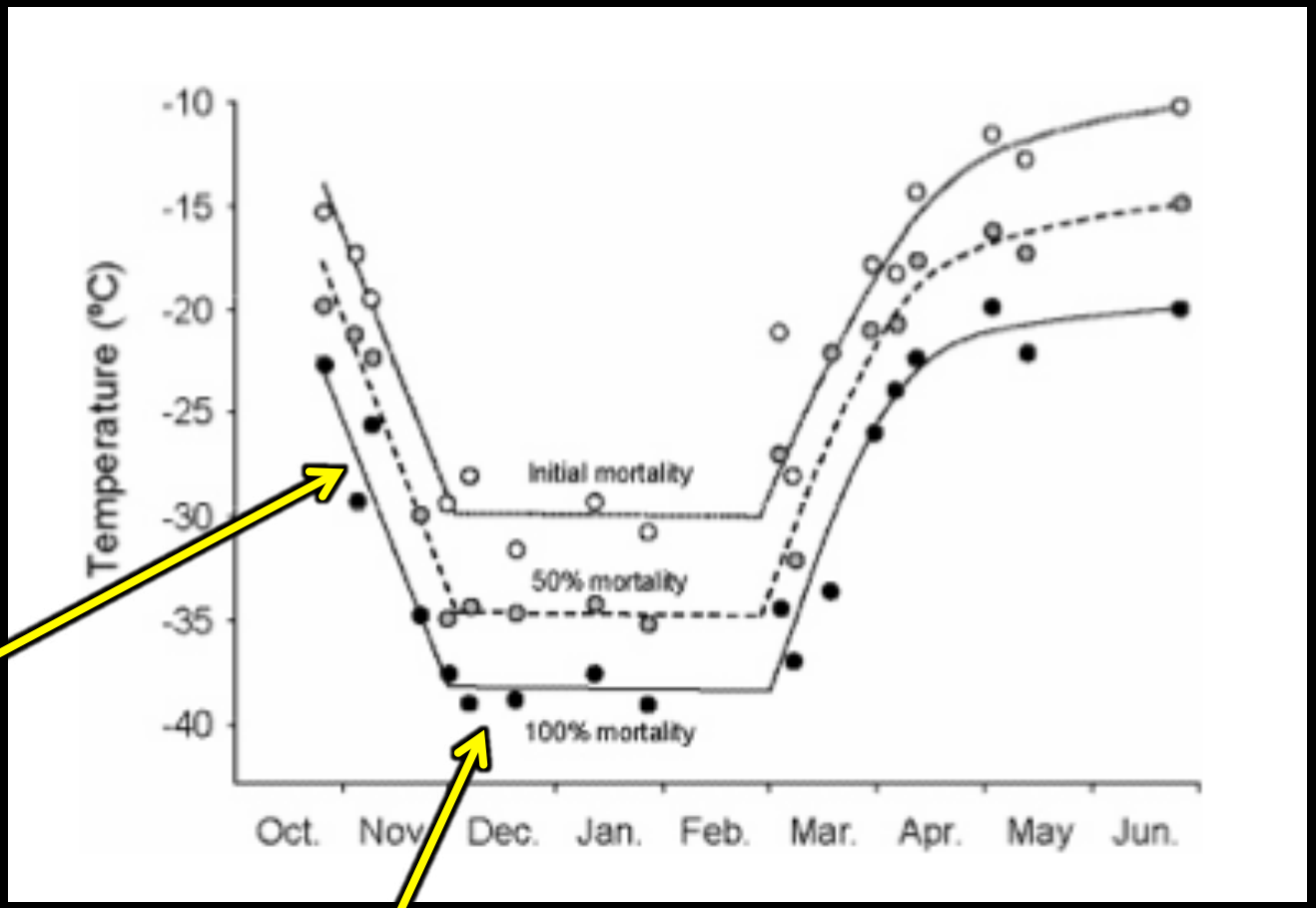
Change in temperature over last 150 years



Cold tolerance in the mountain pine beetle

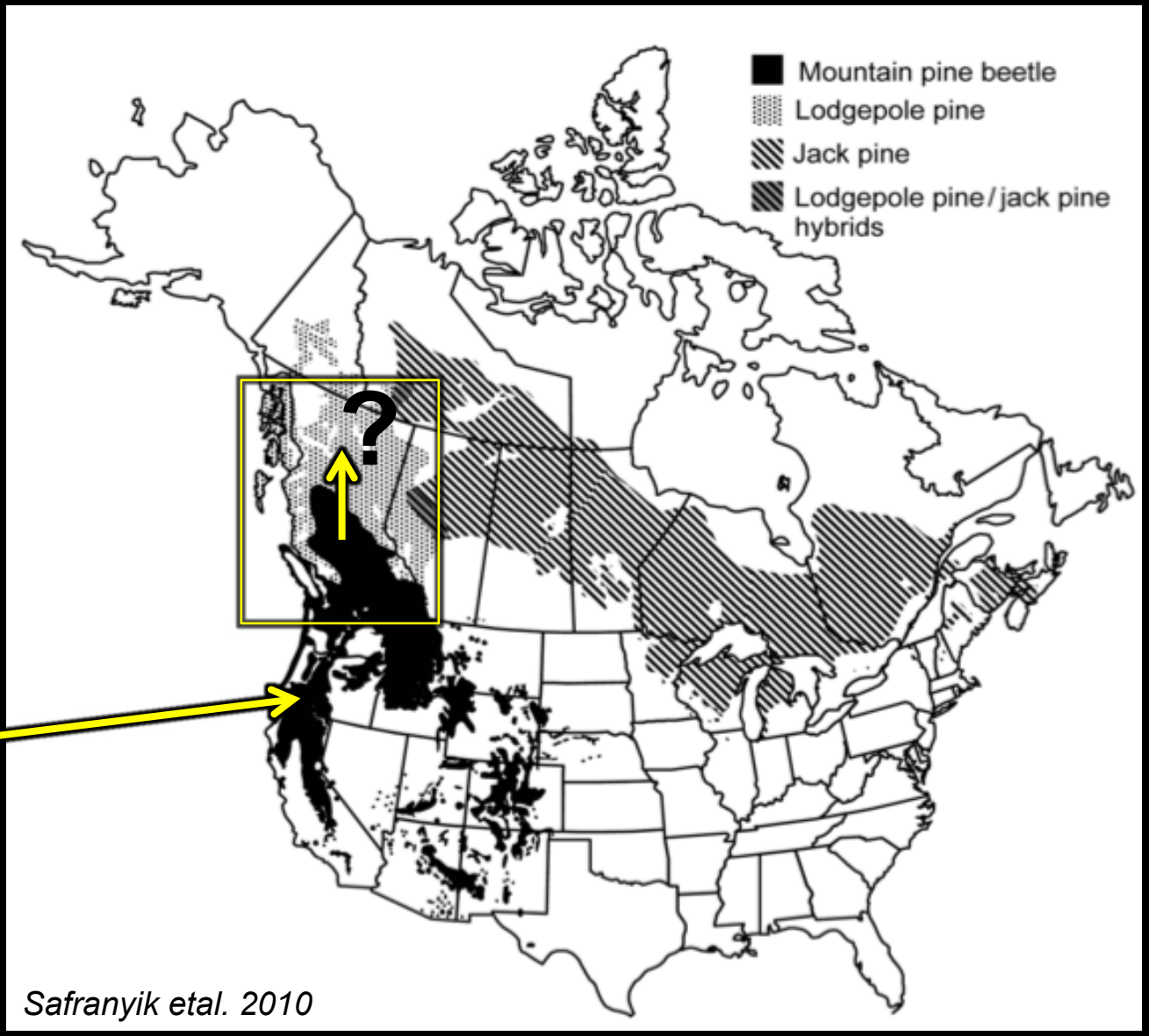
Safranyik & Wilson, 2005



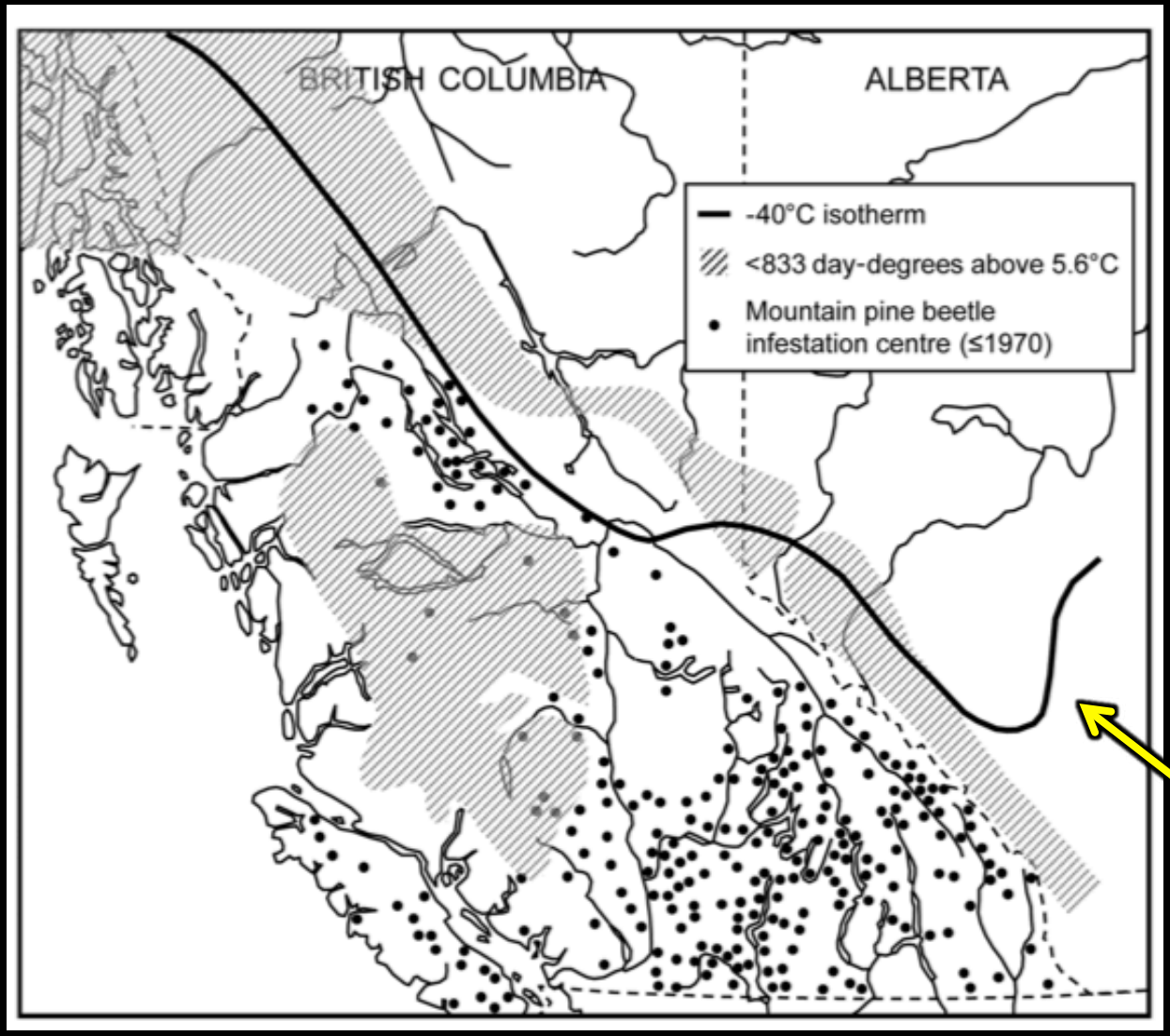
Cold-hardening

Complete winter mortality if temp. < -40°C

Potential range expansion of the mountain pine beetle



Potential range expansion of the mountain pine beetle



Warmer winter temperatures lead to shift in –40°C isotherm

Safranyik etal. 2010

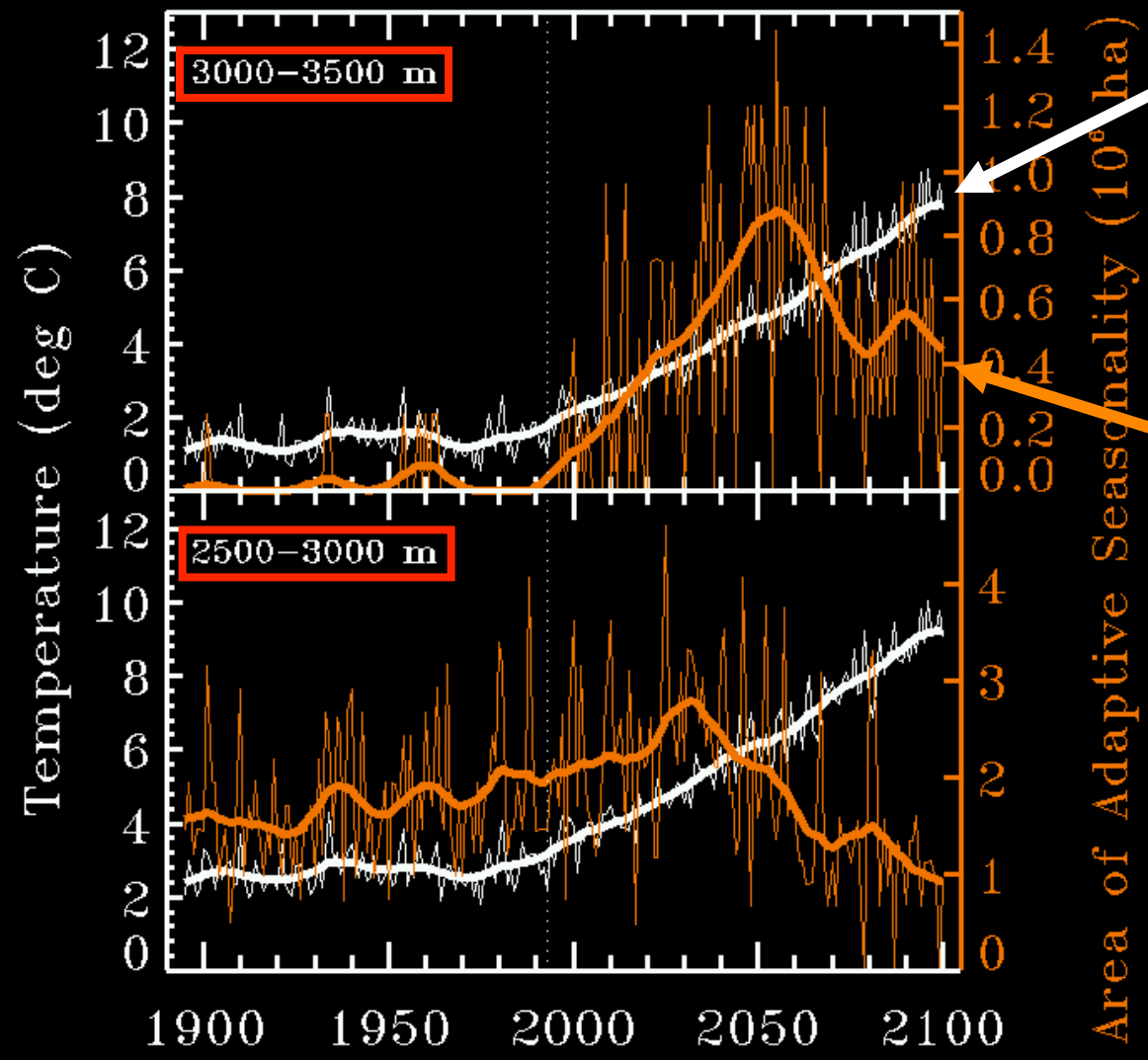
The whitebark pine

1. Five-needle pine
2. High (or highest)-elevation species
3. Provides food for:
    - Clack's nutcracker (caches)
    - Grizzly bears
4. Maintains snow pack (regulates spring runoff)

Threats:

1. Mountain pine beetle
2. Blister rust
3. Fire suppression

Warming will lead to susceptibility of high-elevation forests across the West

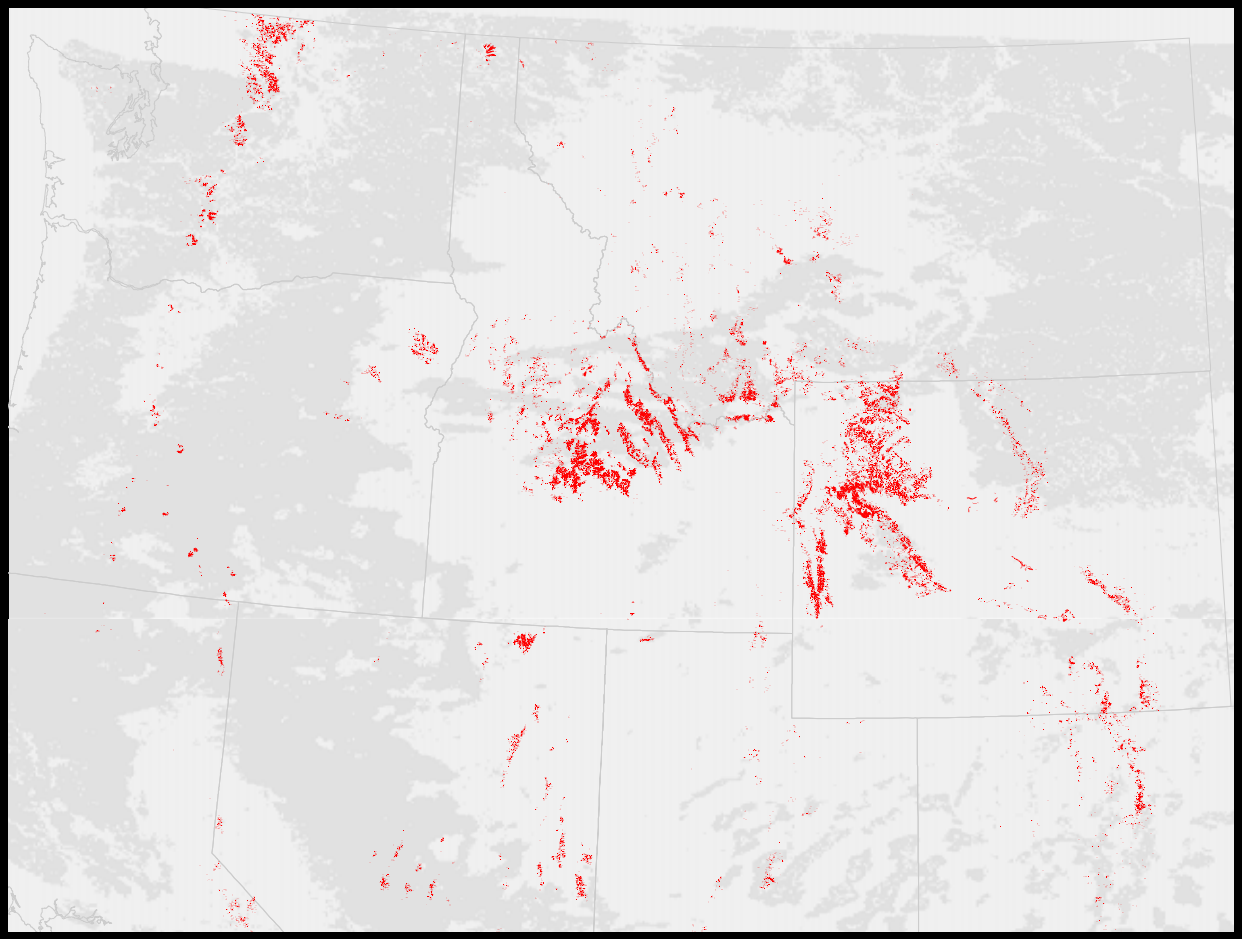


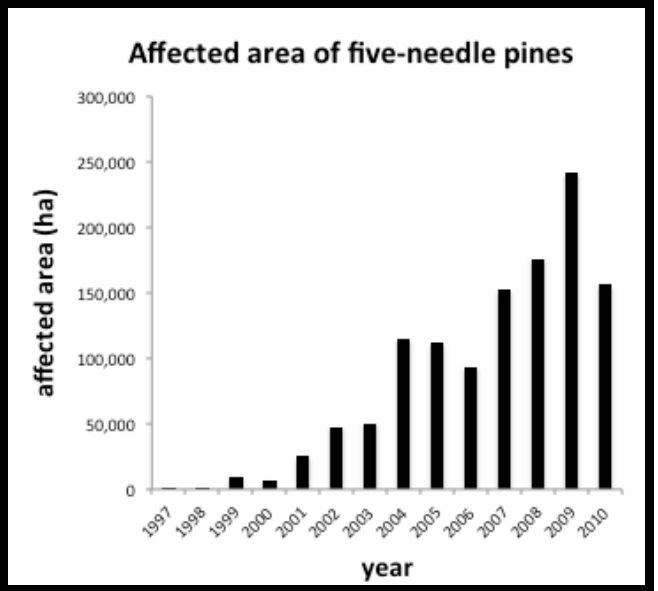
Predicted to be continuously warmer

Area of climate suitability projected to increase at highest elevations

Hicke et al., JGR, 2006

Insect outbreaks: Mountain pine beetle in whitebark pine



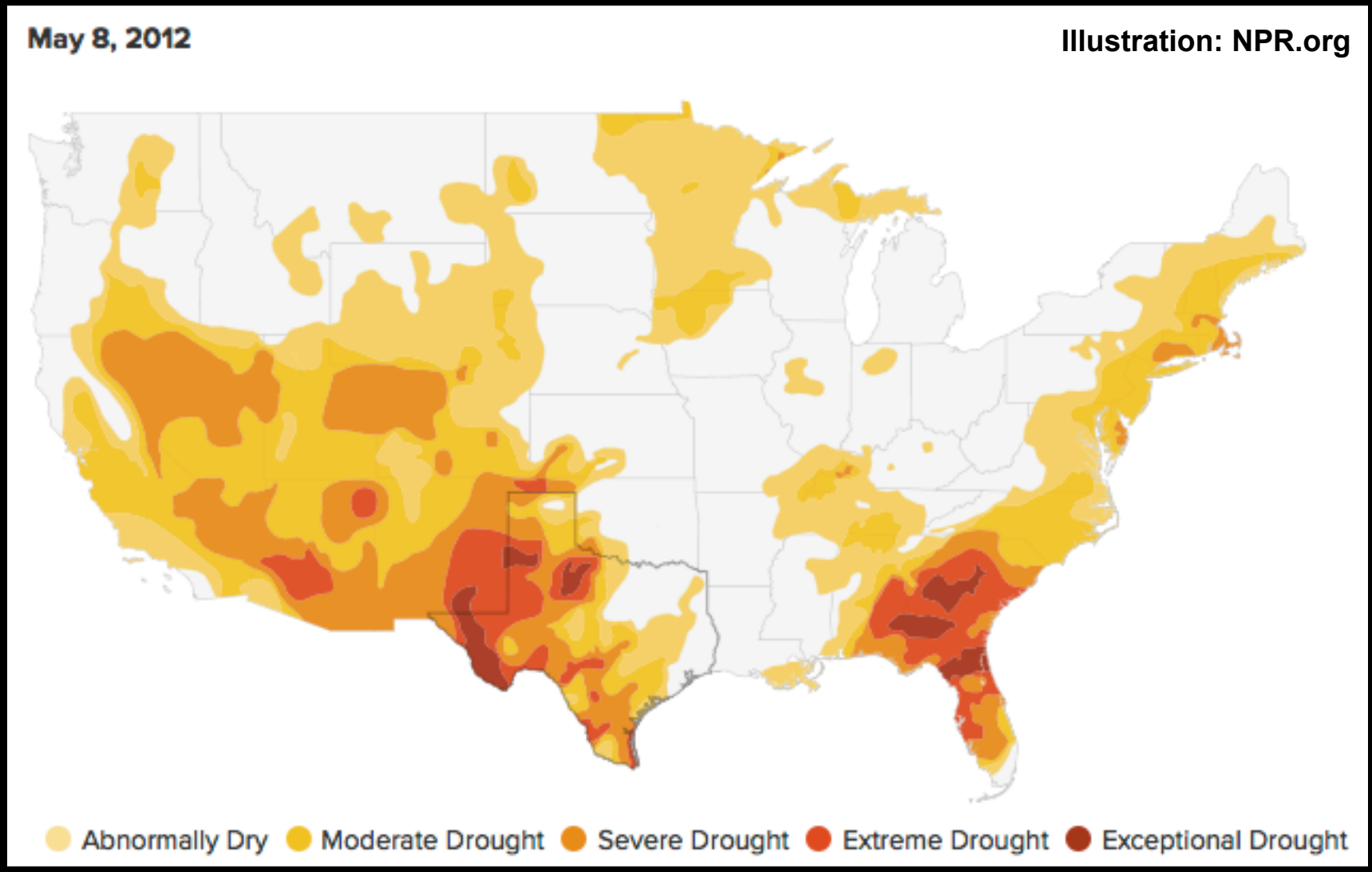


Now bark beetle outbreaks are occurring in whitebark pine ecosystems:

"where outbreaks either did not previously occur or were limited in scale" (Logan et al. 2010)

Video: treefight.org

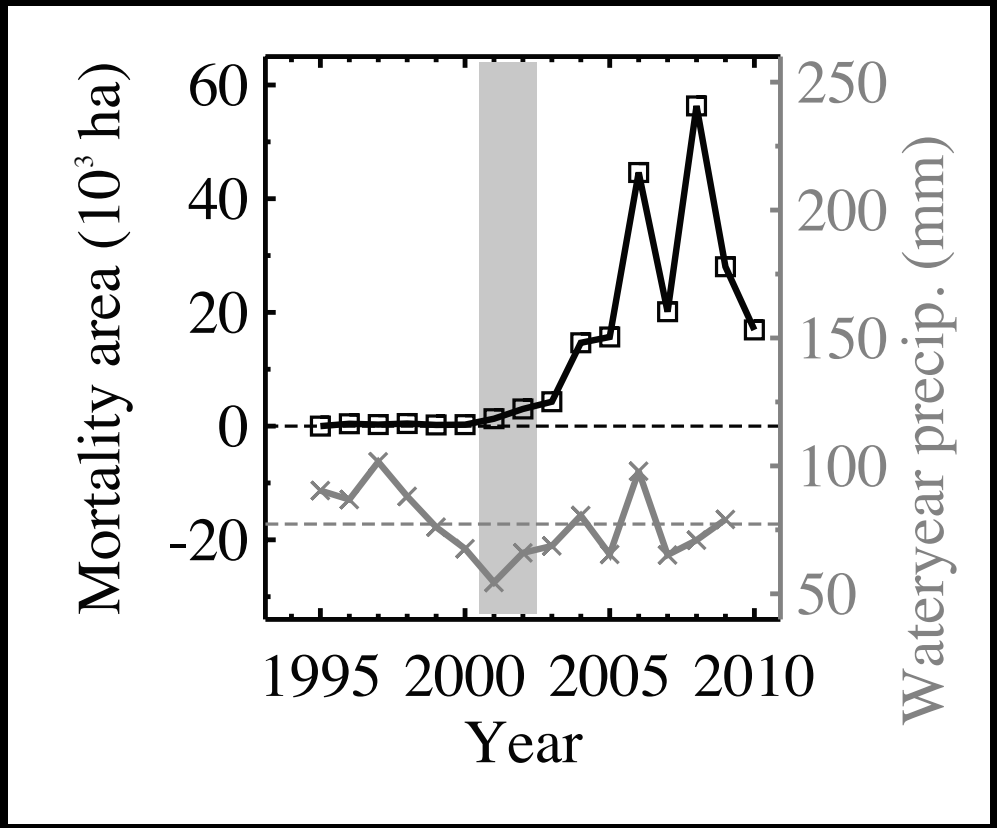
Drought in the US



Mountain pine beetle outbreaks in Colorado enhanced by:

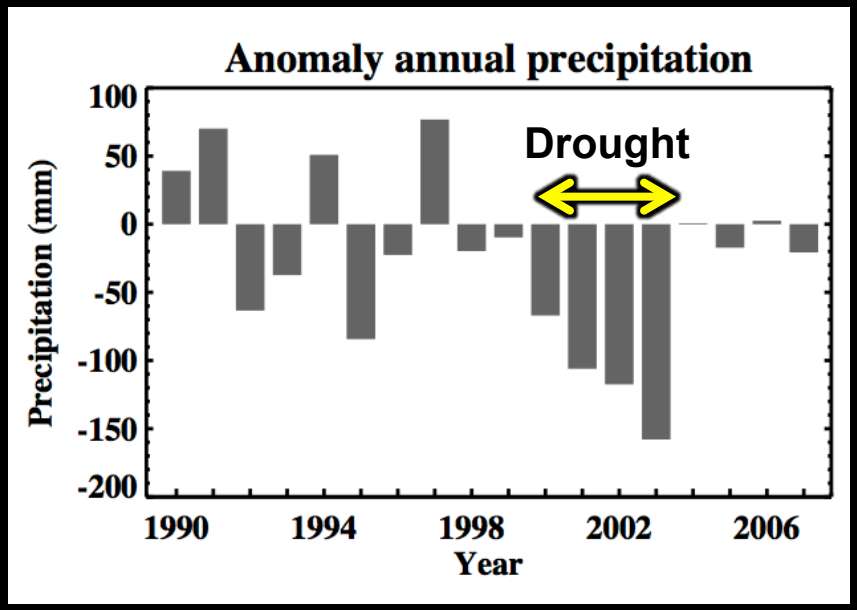
a. **Low diversity in age and tree species (logging and fire)**

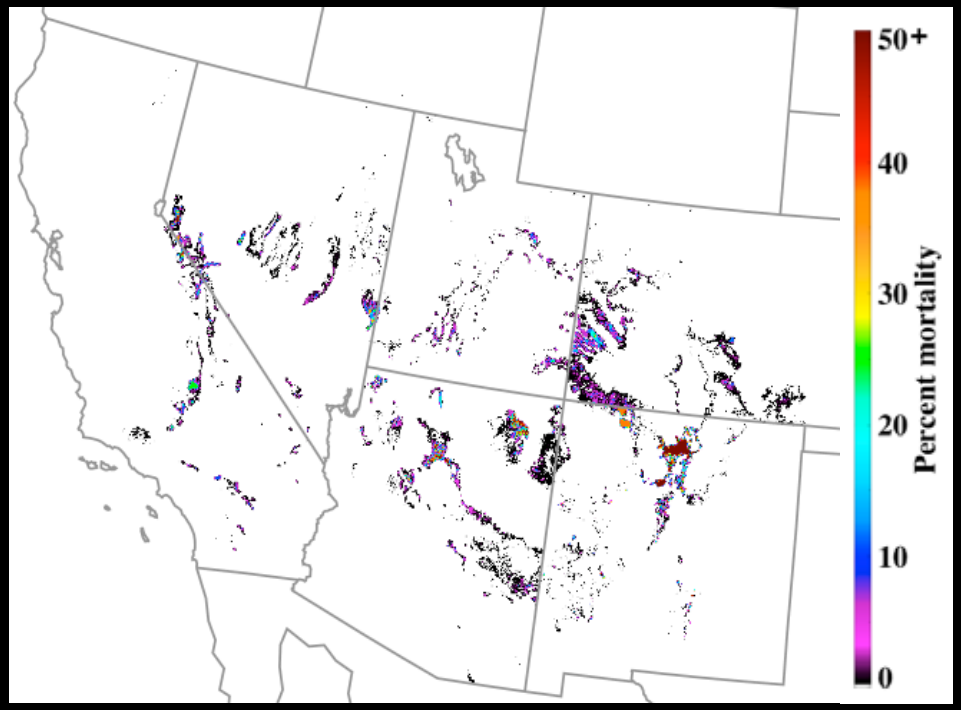
b. **Drought (e.g., 2002 drought in Colorado)**



Piñon pine die-off in the Southwest

- Extent: 1.2 million ha
- Cause: extreme drought, warming, piñon ips

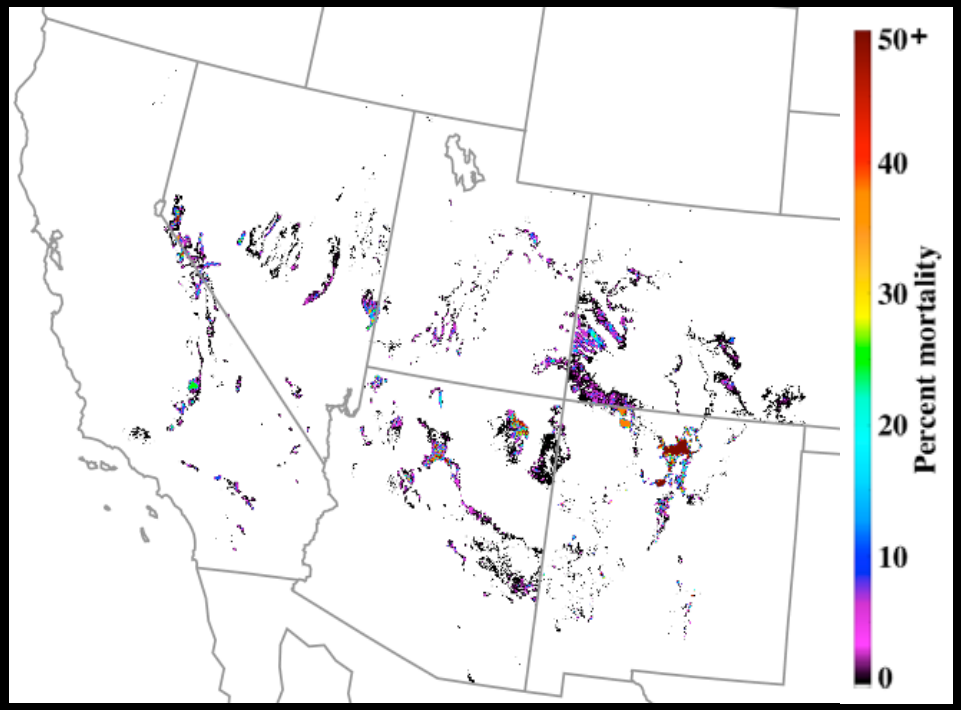




Cumulative piñon pine mortality from drought and bark beetles (1997-2010)

Piñon pine die-off in the Southwest

- Extent: 1.2 million ha
- Cause: extreme drought, warming, piñon ips (needs drought to kill trees)



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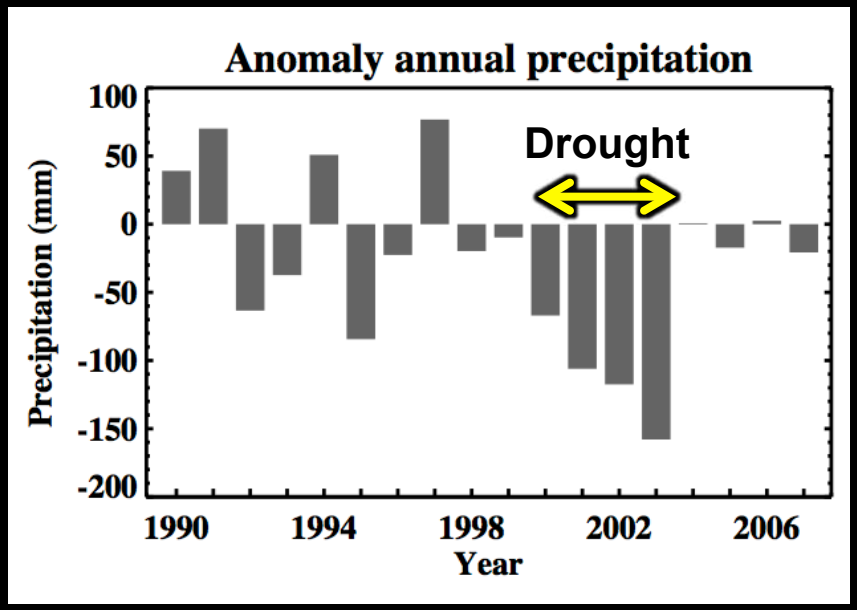
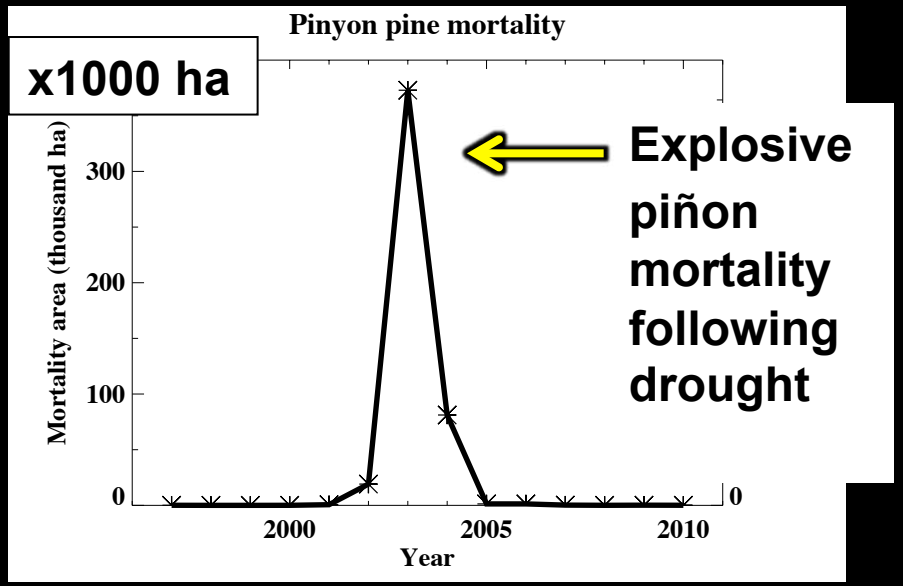
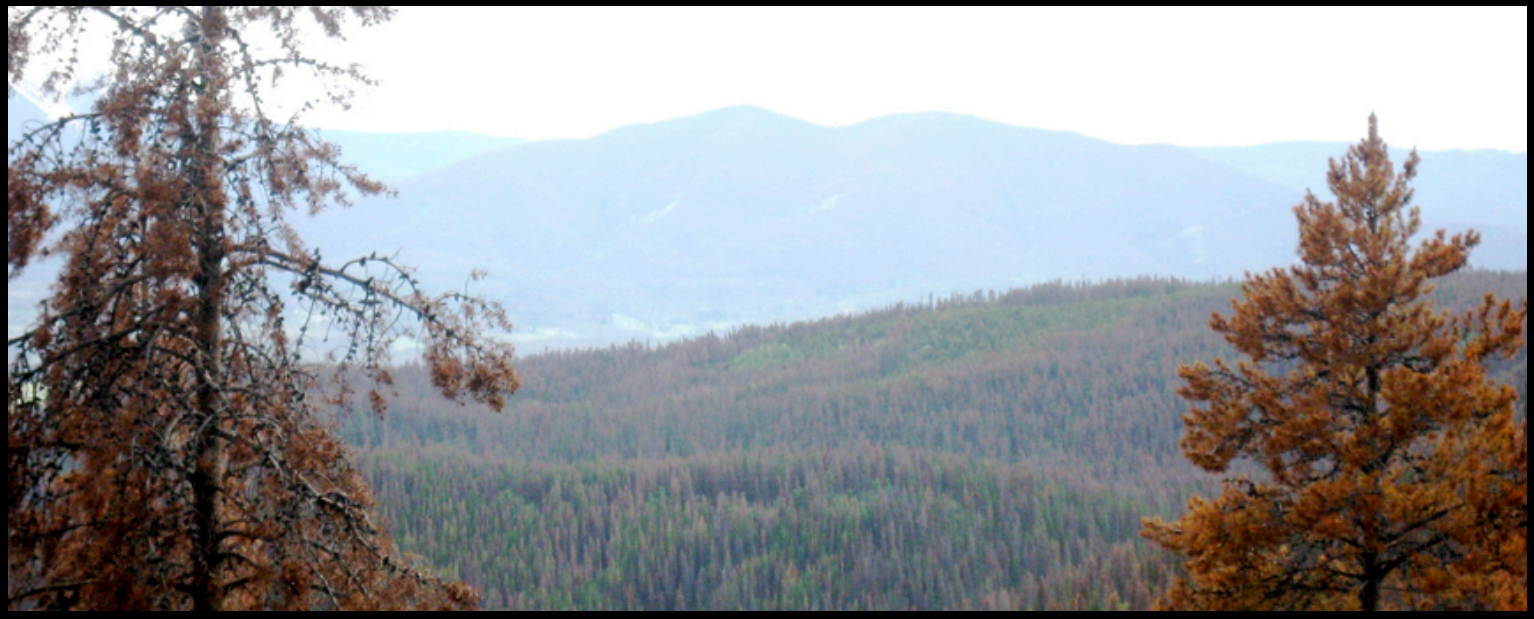




Note that:

1. Insect populations responsive to climate change:
    - physiological sensitivity to temperature
    - high mobility
    - short generation times
    - explosive reproductive potential

2. Tree health is related to climate changes with less favorable conditions:
    - At higher temperatures
    - At lower precipitation/moisture



Outline

Photo by J. Hicke

1. Live cycle of bark beetles
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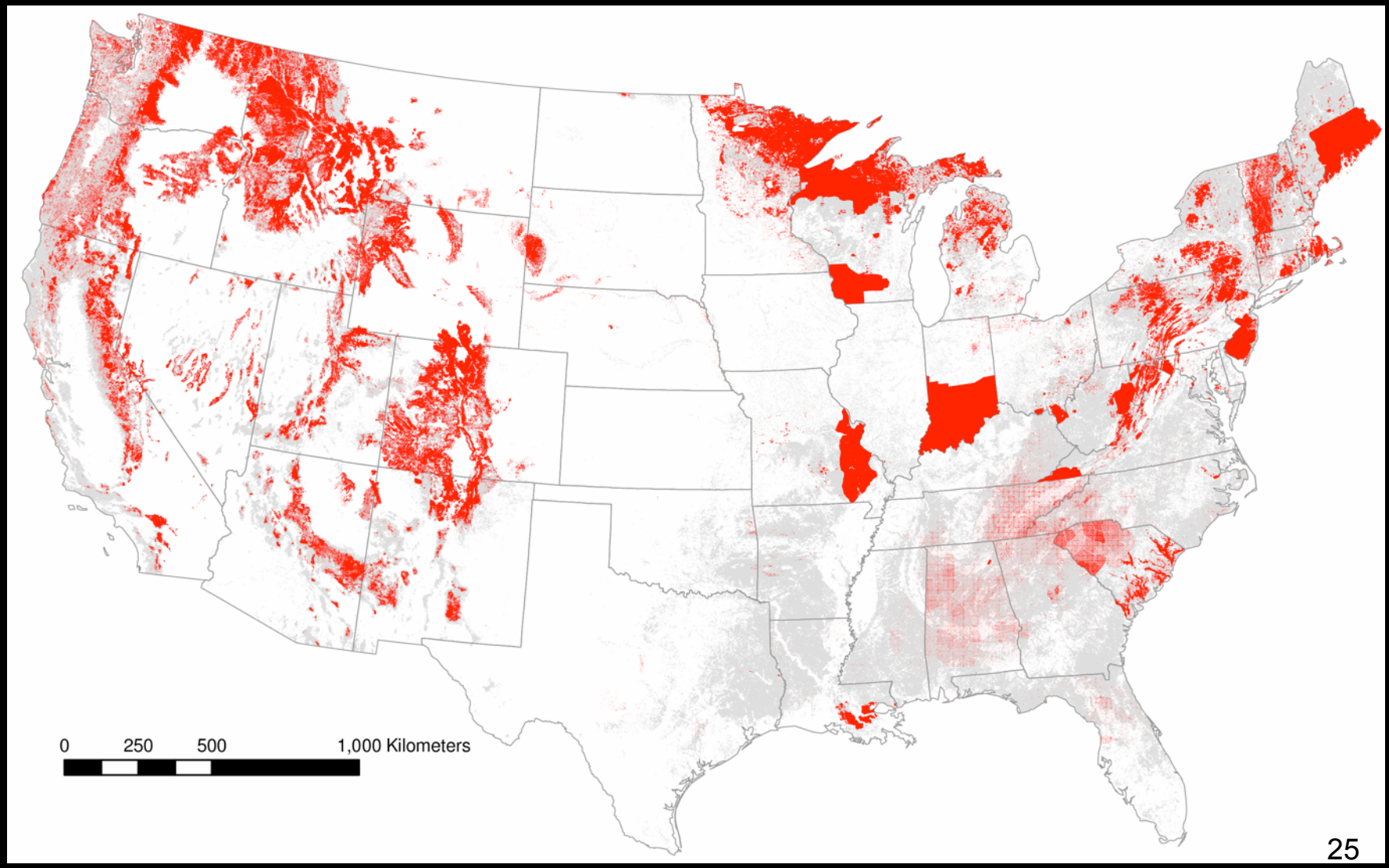
Stages of trees after beetle attack

			
Postattack stage	Green trees	Red attack stage	Gray attack stage
Timing	Before beetle attack	1 to 3 years after attack	3 to 5 years after attack

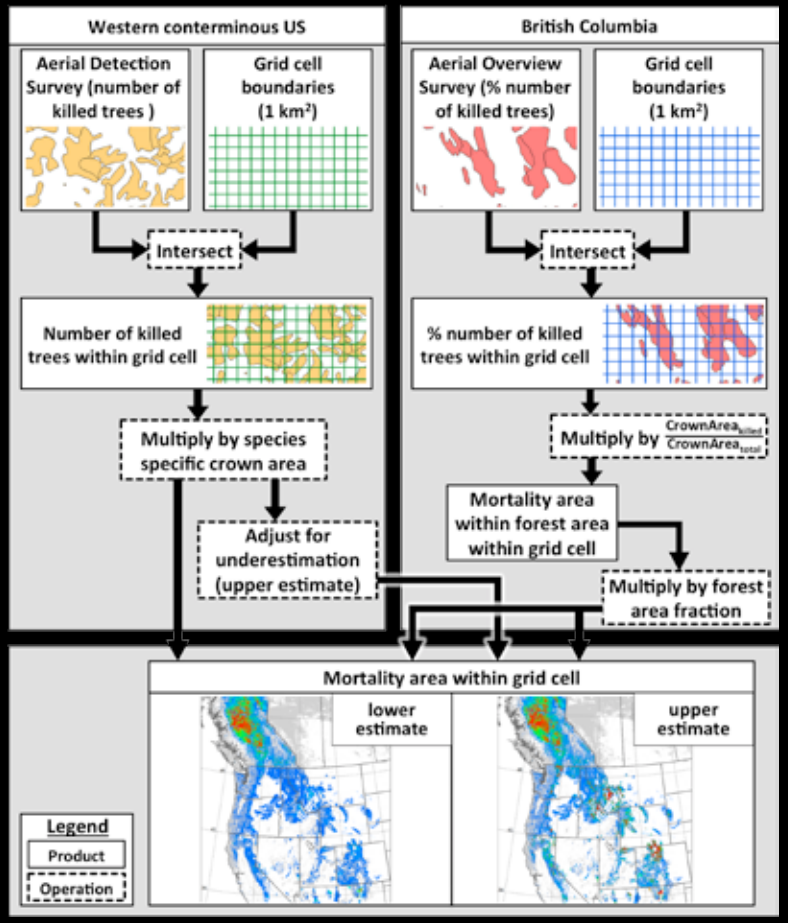
Insect outbreaks are major forest disturbances in North America

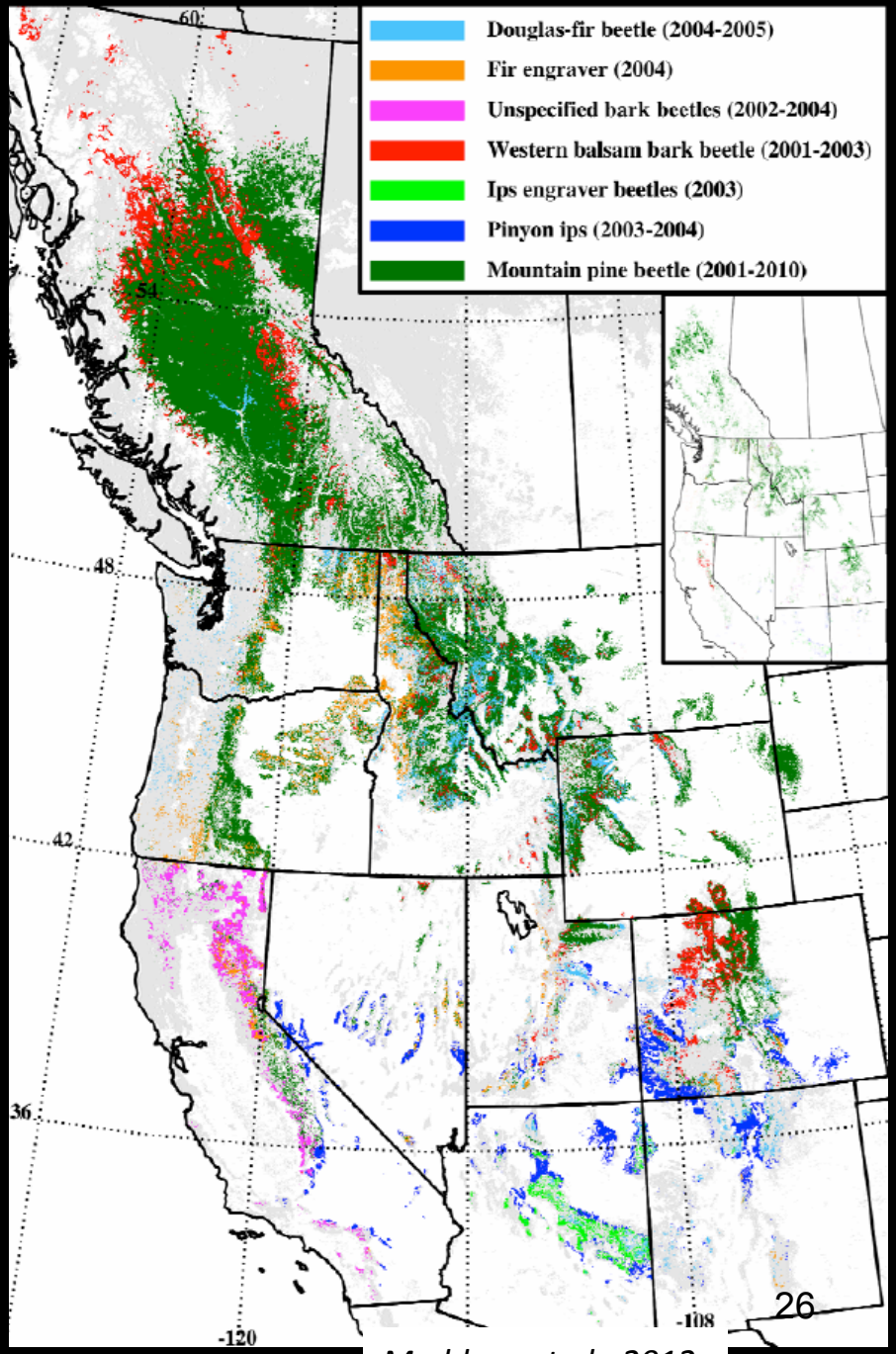
affected area reported by aerial surveys, 1997-2010



Hicke et al., Global Change Biology, 2012

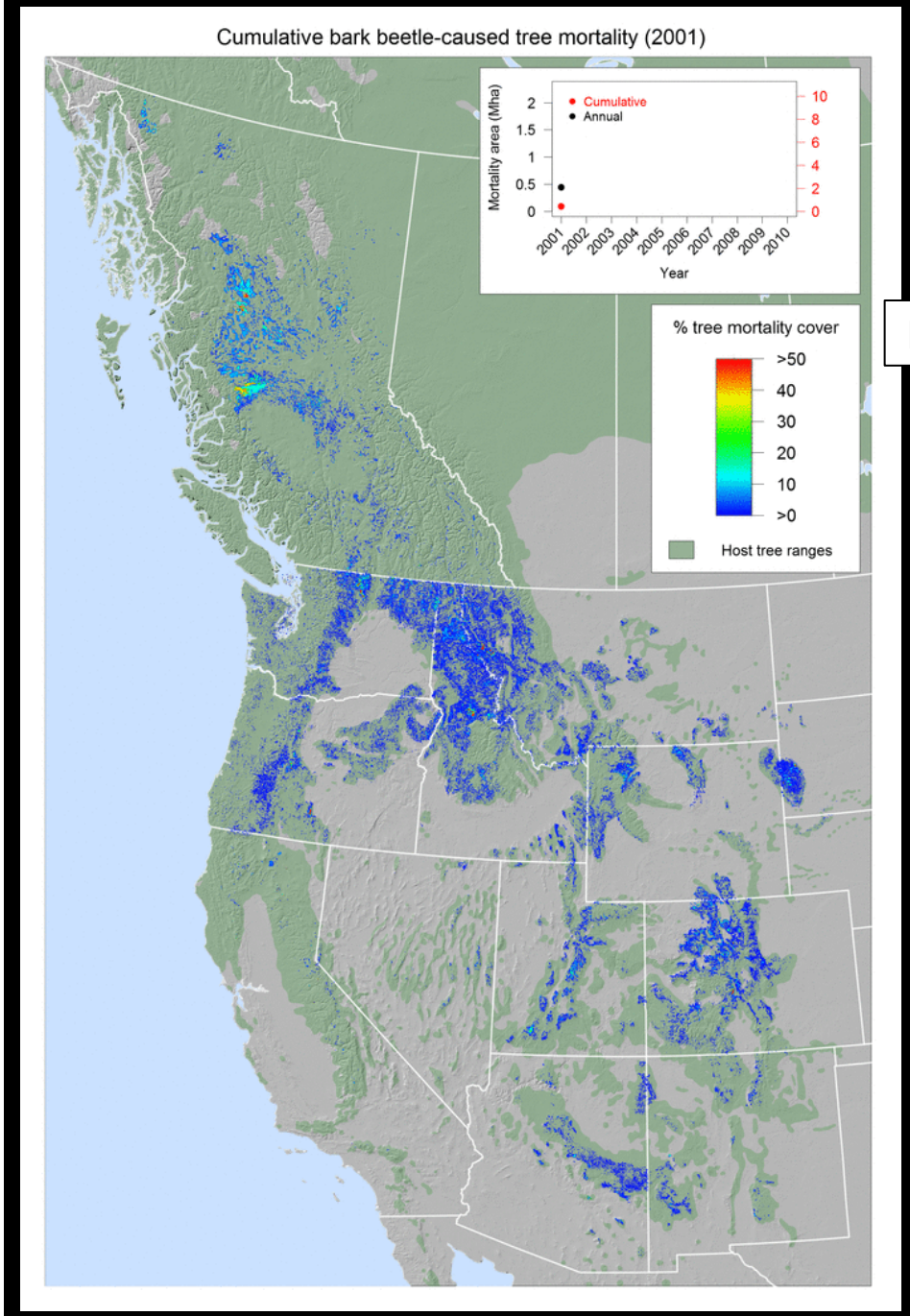
Aerial detection surveys

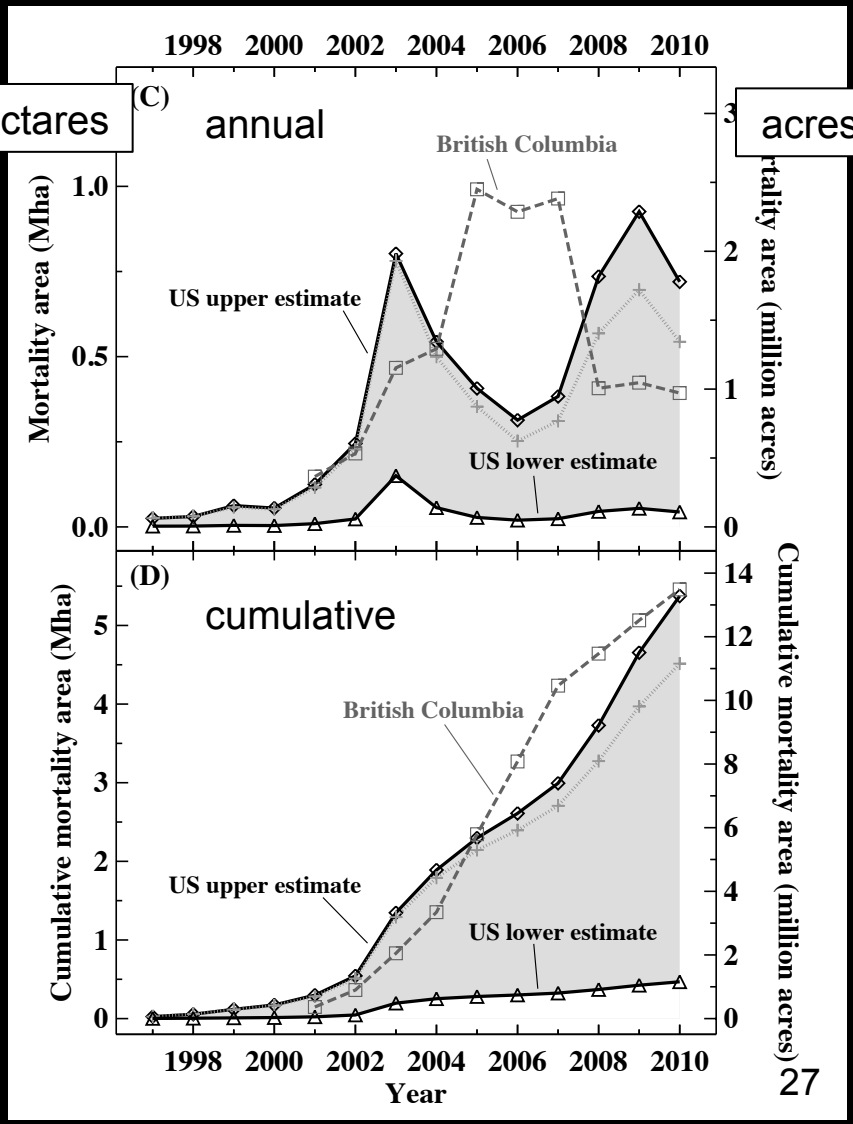




Meddens et al., 2012

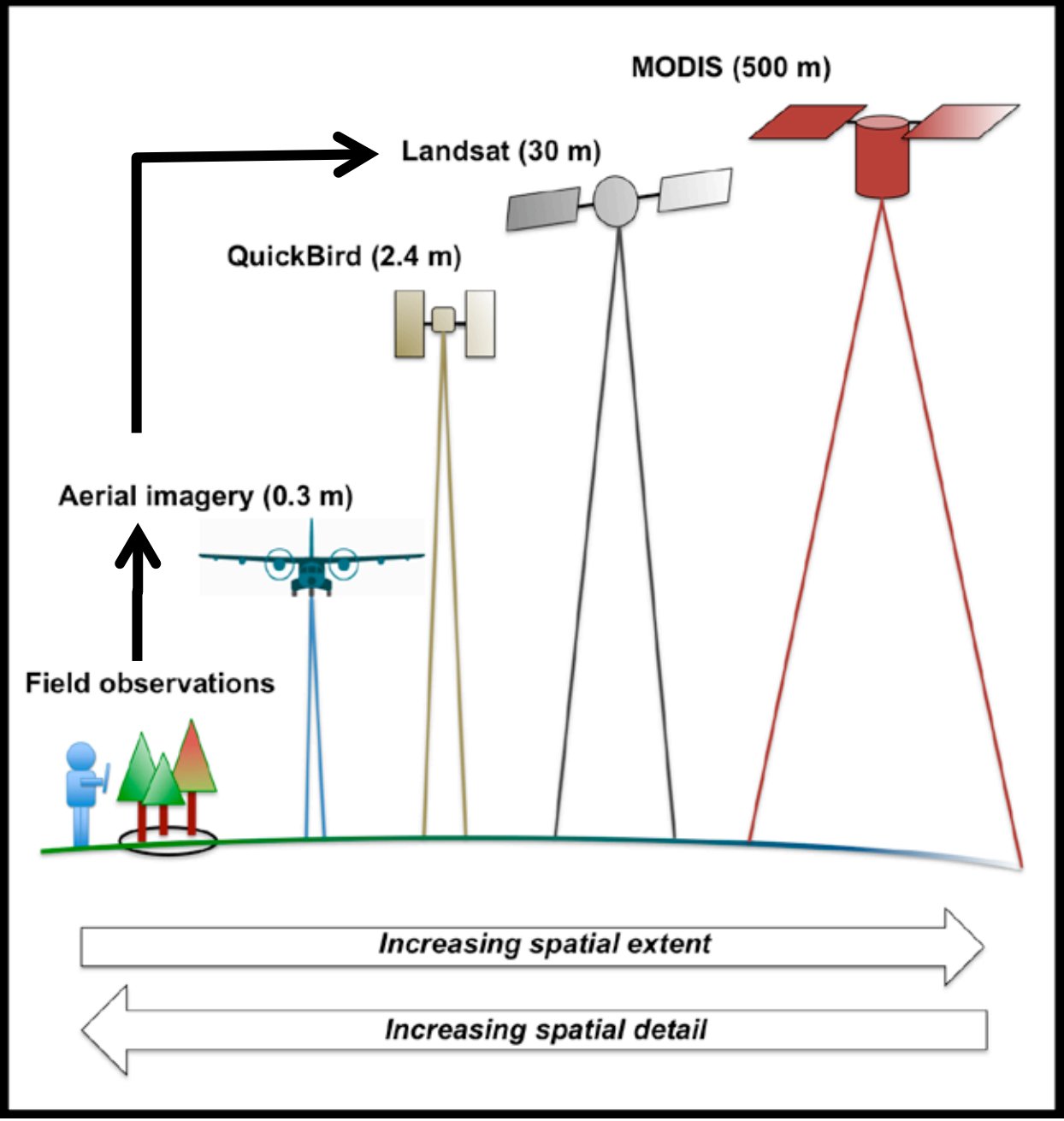
Bark beetle outbreaks are widespread and extensive in western North America



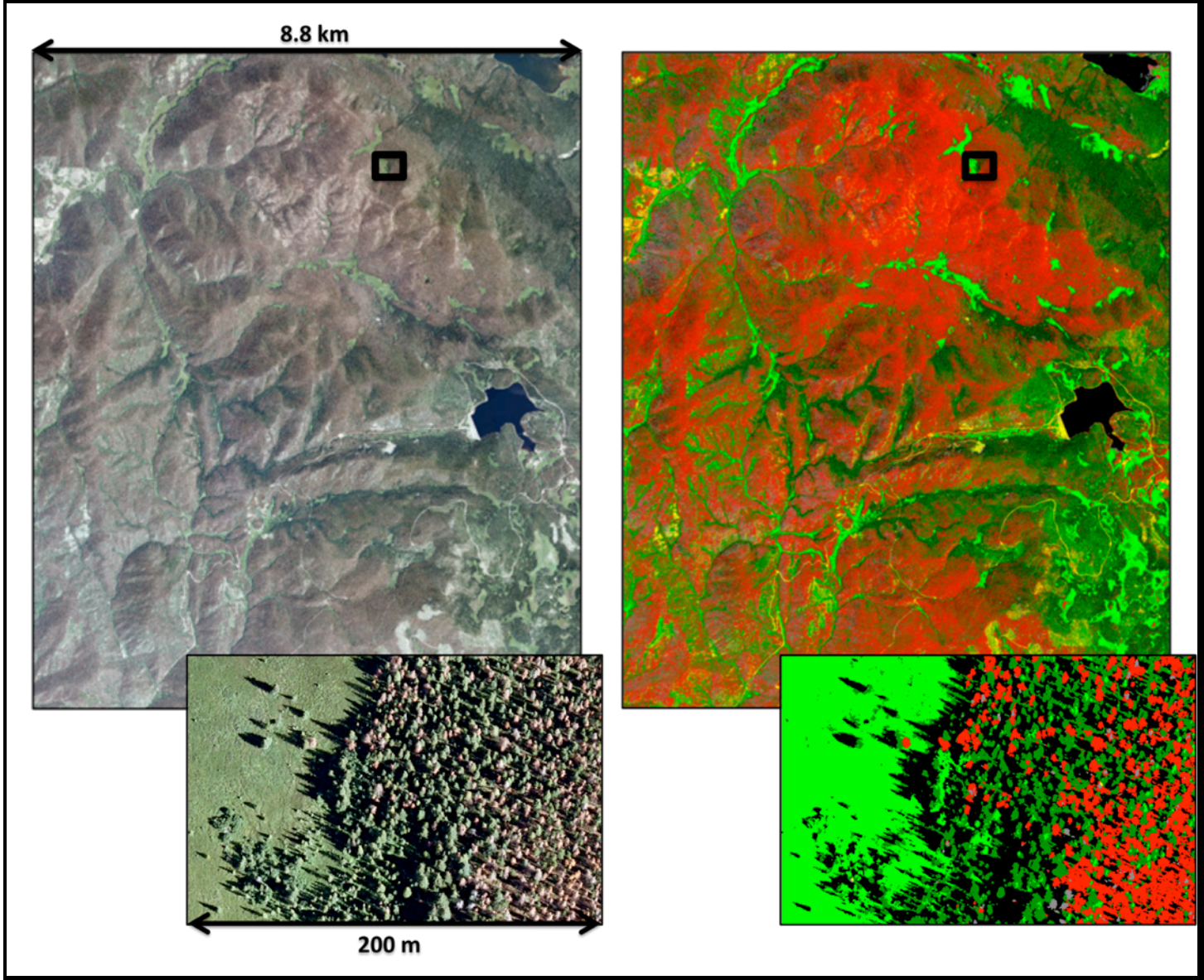


Meddens et al., 2012

Spatial extent versus spatial detail



Mapping at local scales: 30-cm aerial imagery



dark green: undisturbed forest

red: red-attack

gray: gray-attack

light green: herbaceous

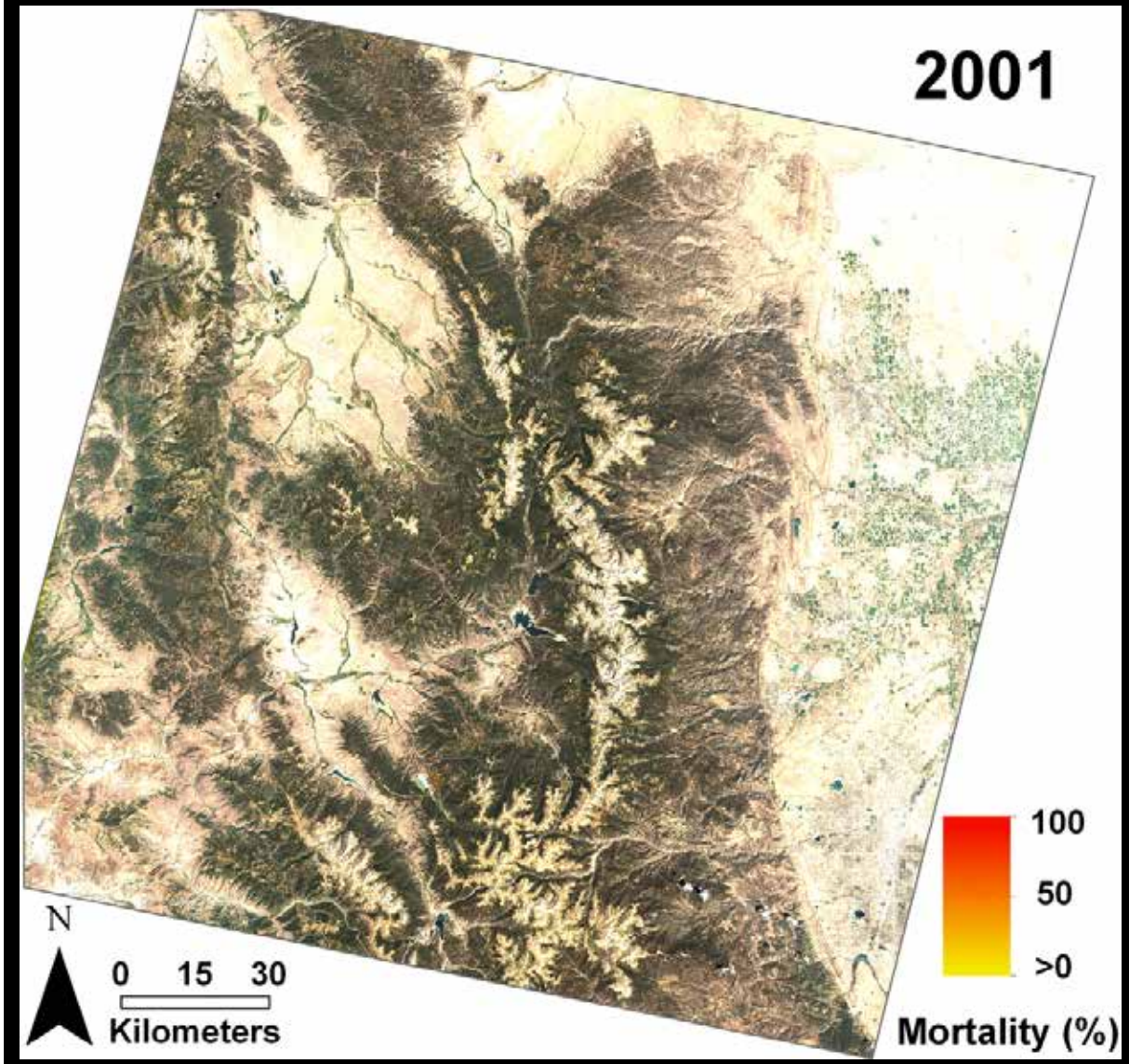
yellow: non-vegetation

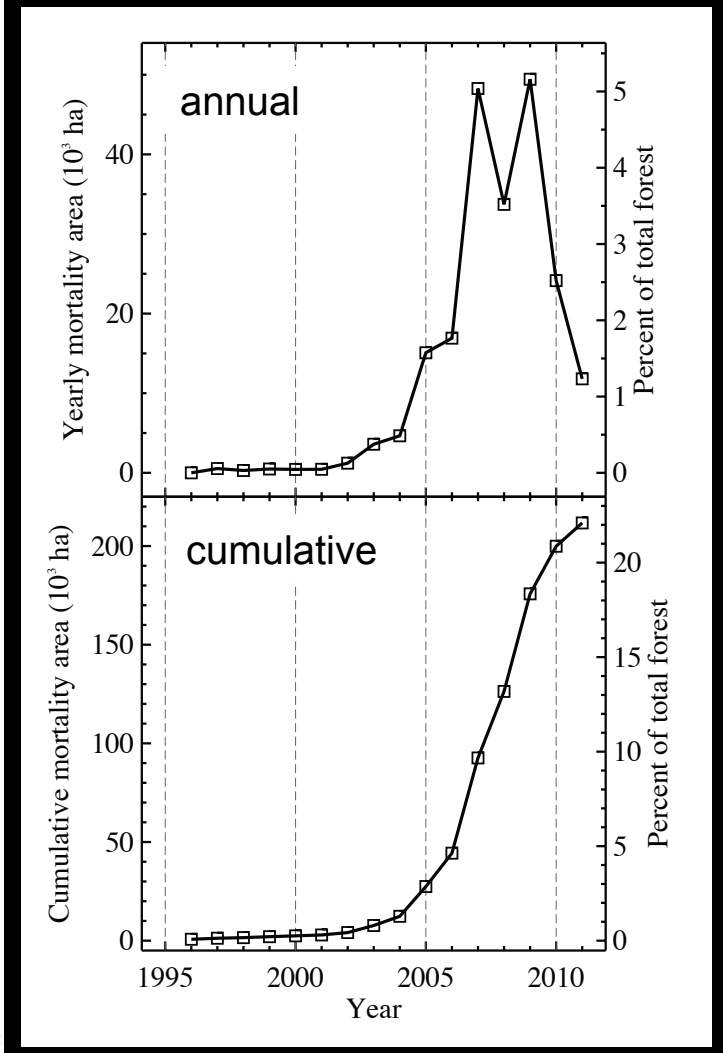
True-color imagery

Classification

Meddens et al., 2011

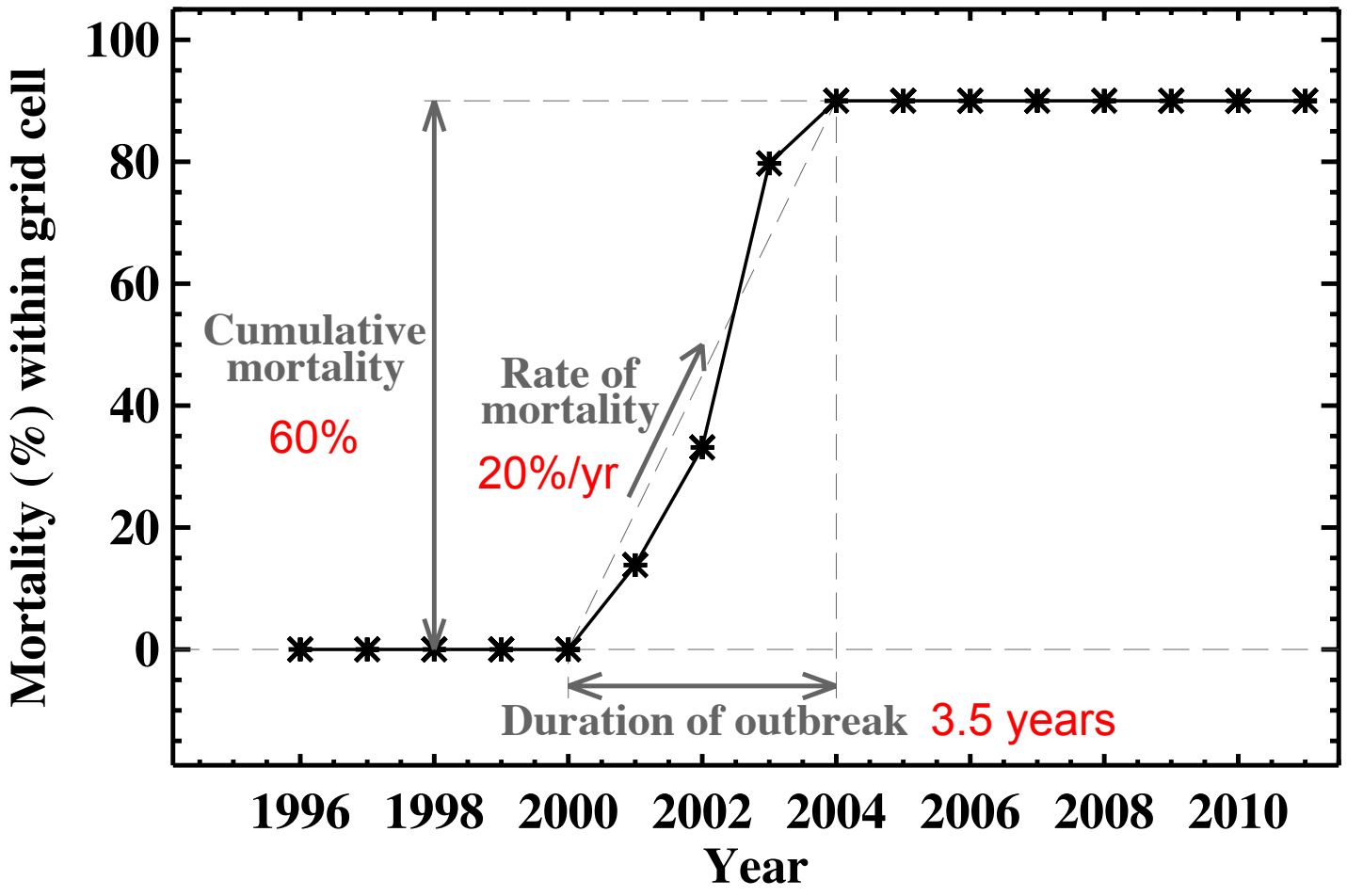
Mapping one outbreak in Colorado





Meddens and Hicke, in prep.

Mapping one outbreak in Colorado



Meddens and Hicke, in prep.

Outline

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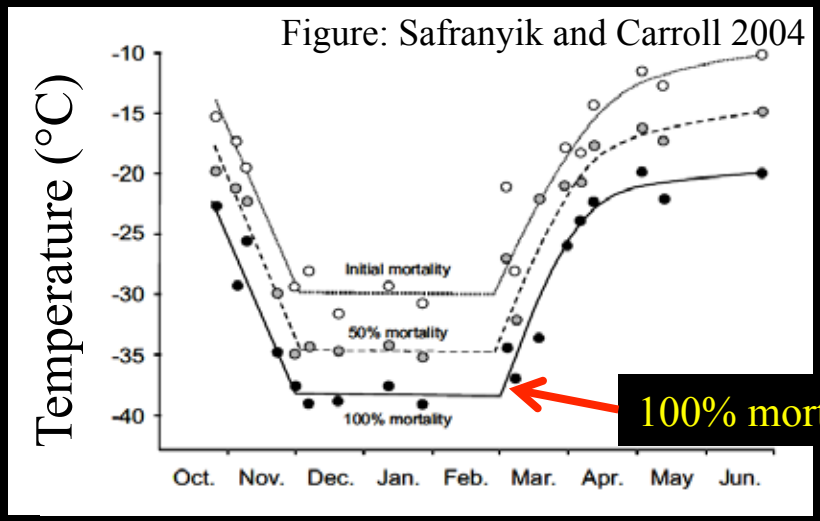
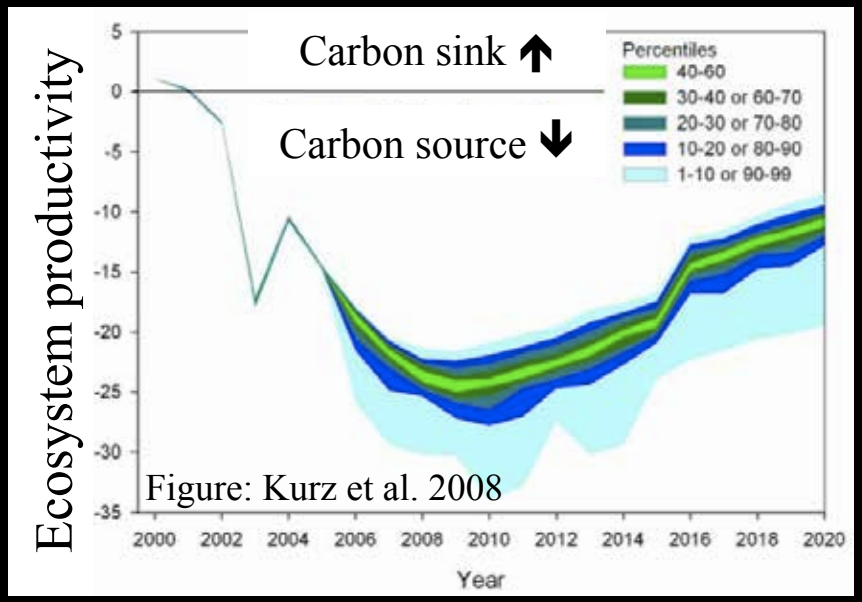
Bark beetles and climate

Climate affects beetles



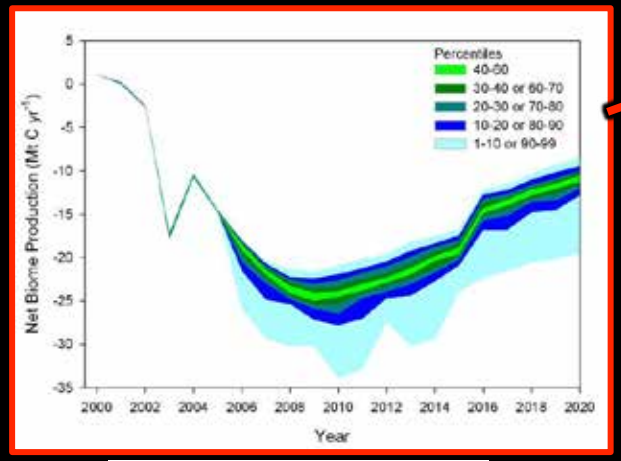
100% mortality ~ -40°C

Beetles affect climate



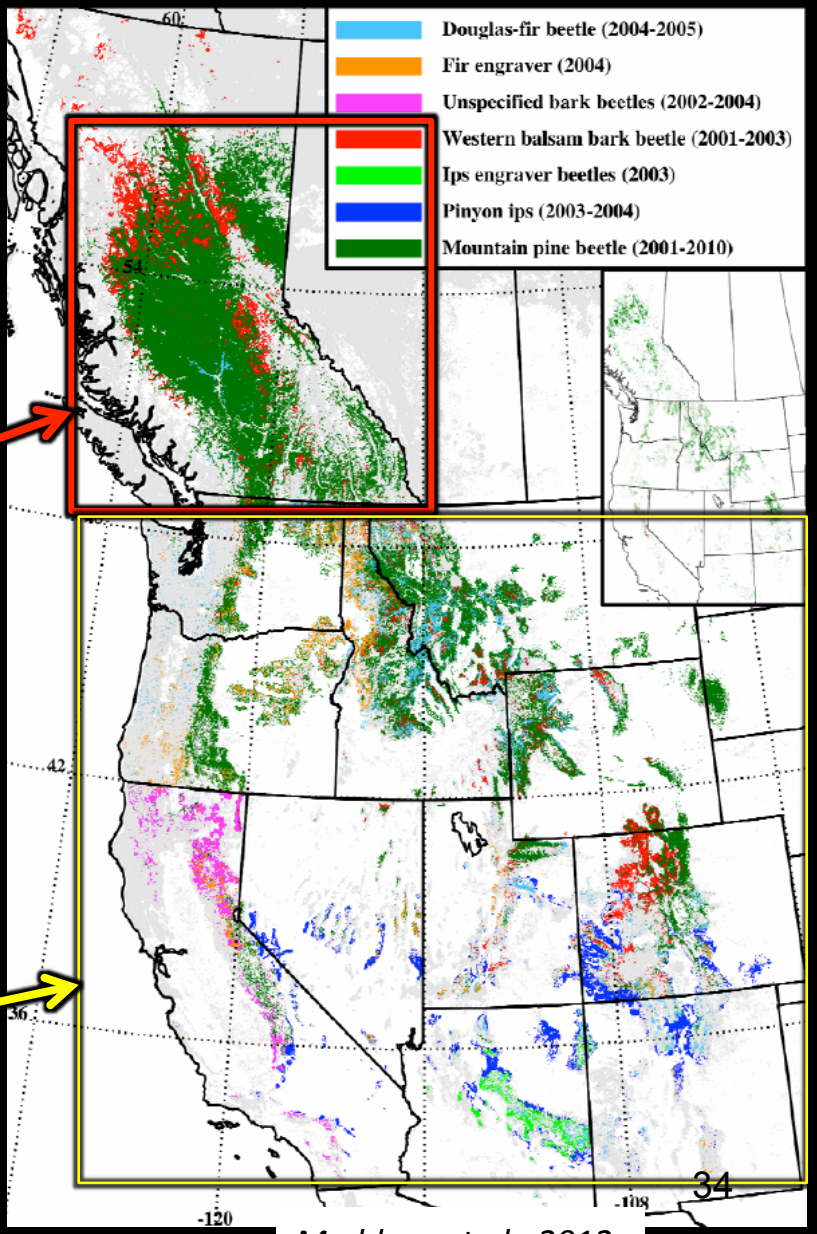
Historical bark beetle outbreaks and C cycling

- Quantify effects of bark beetle-caused tree mortality on carbon stocks and fluxes in the Western US
- Time period 1990 - 2040



Kurz et al. 2008, Nature

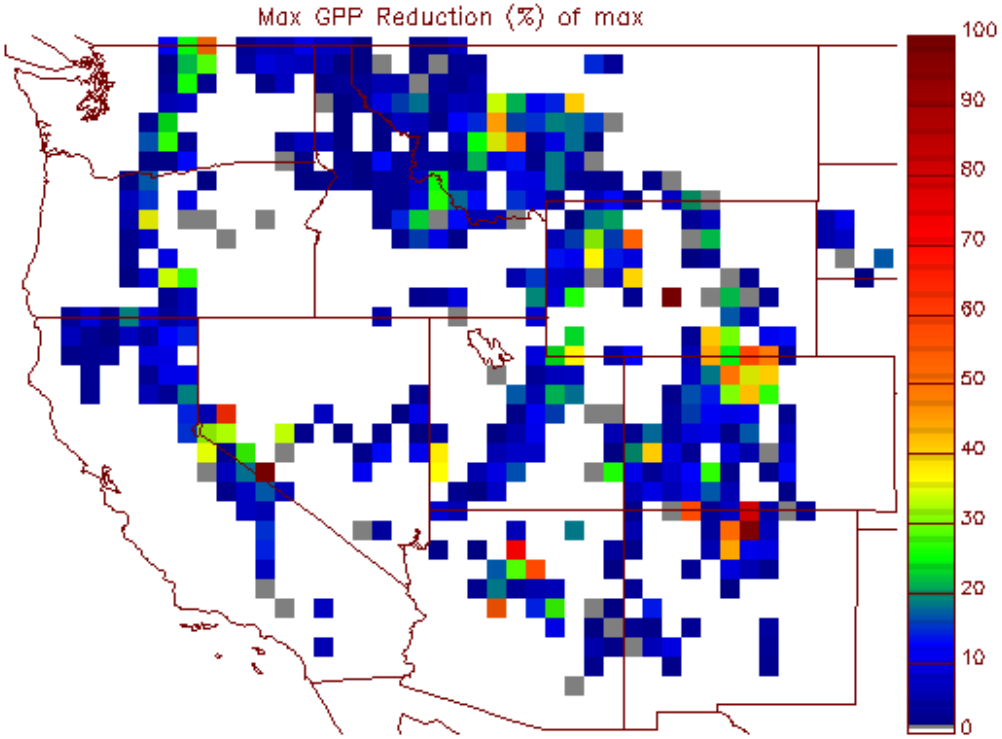
Edburg et al., In prep



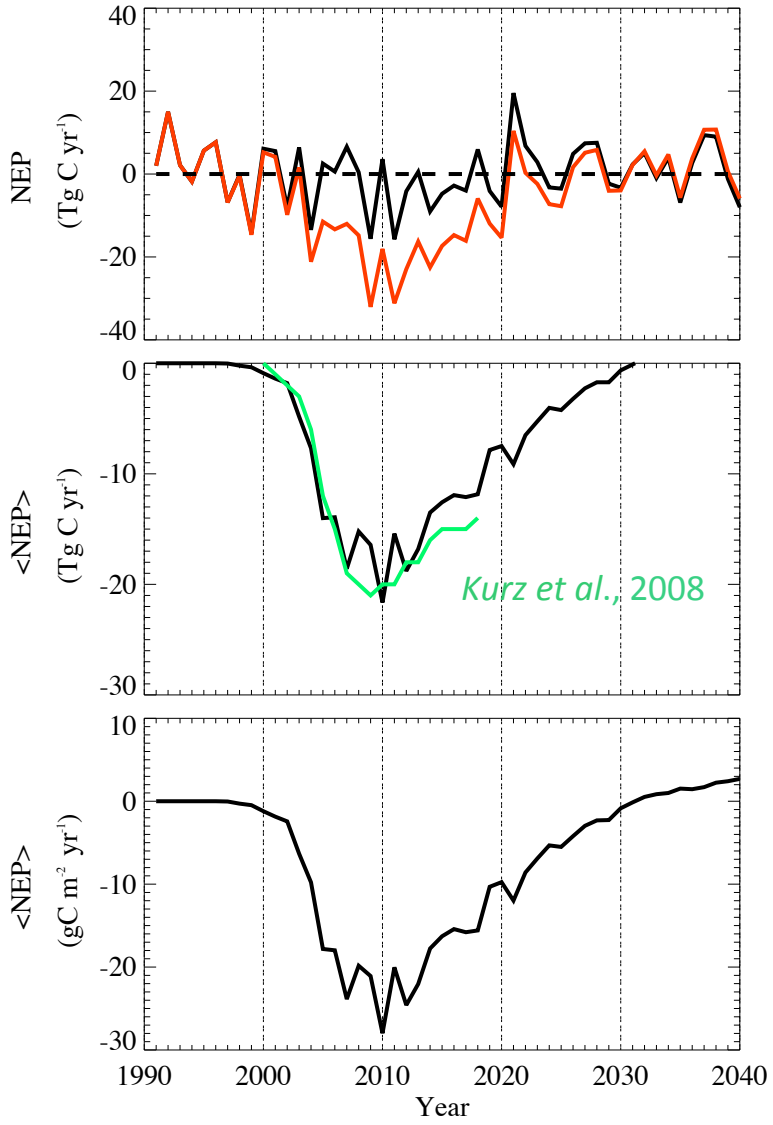
Meddens et al., 2012

Historical bark beetle outbreaks and C cycling

Maximum GPP reduction (%)



Regional NEP impact



Edburg et al., in prep.

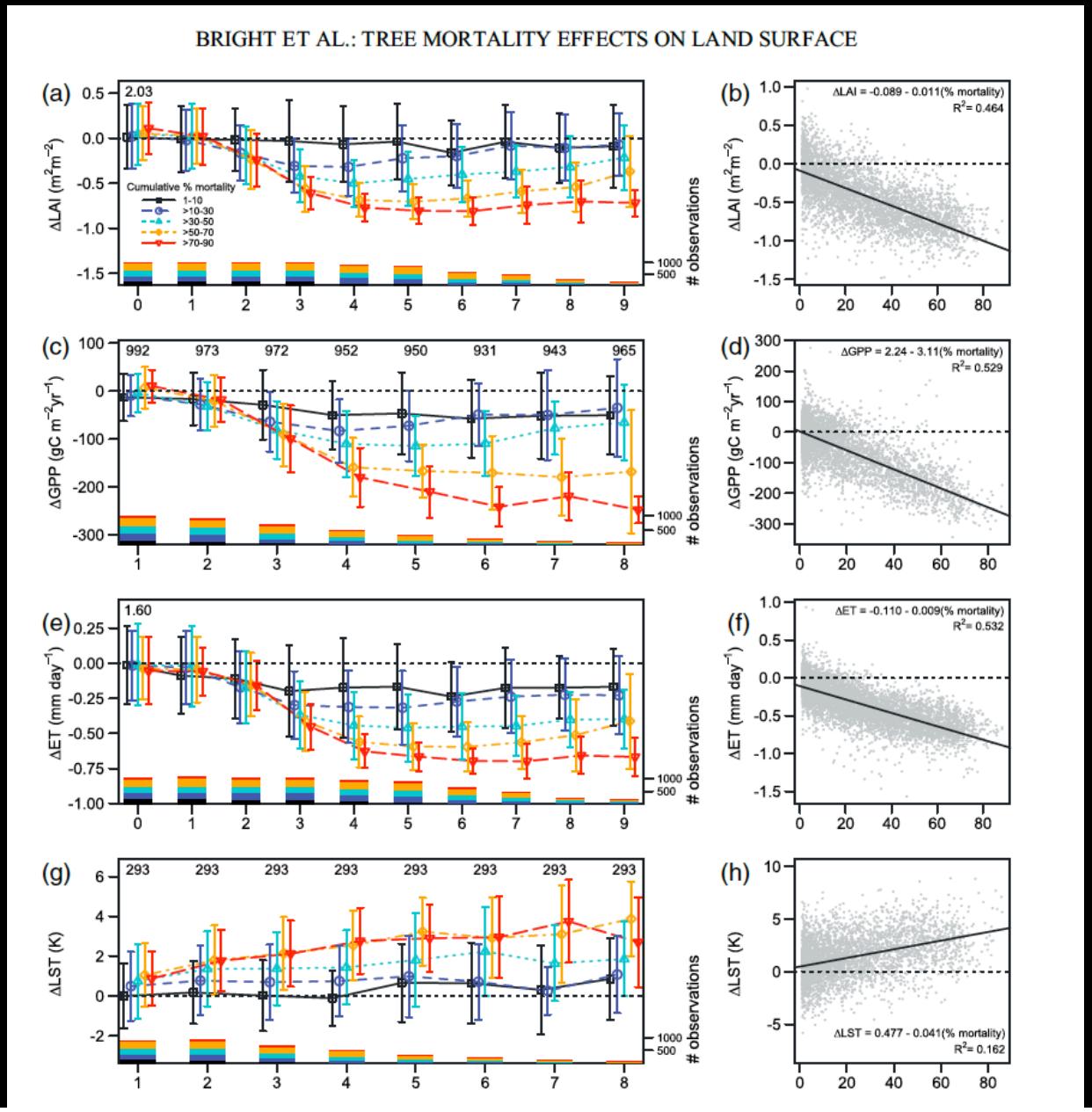
Impacts measured from space

Leaf area (-)

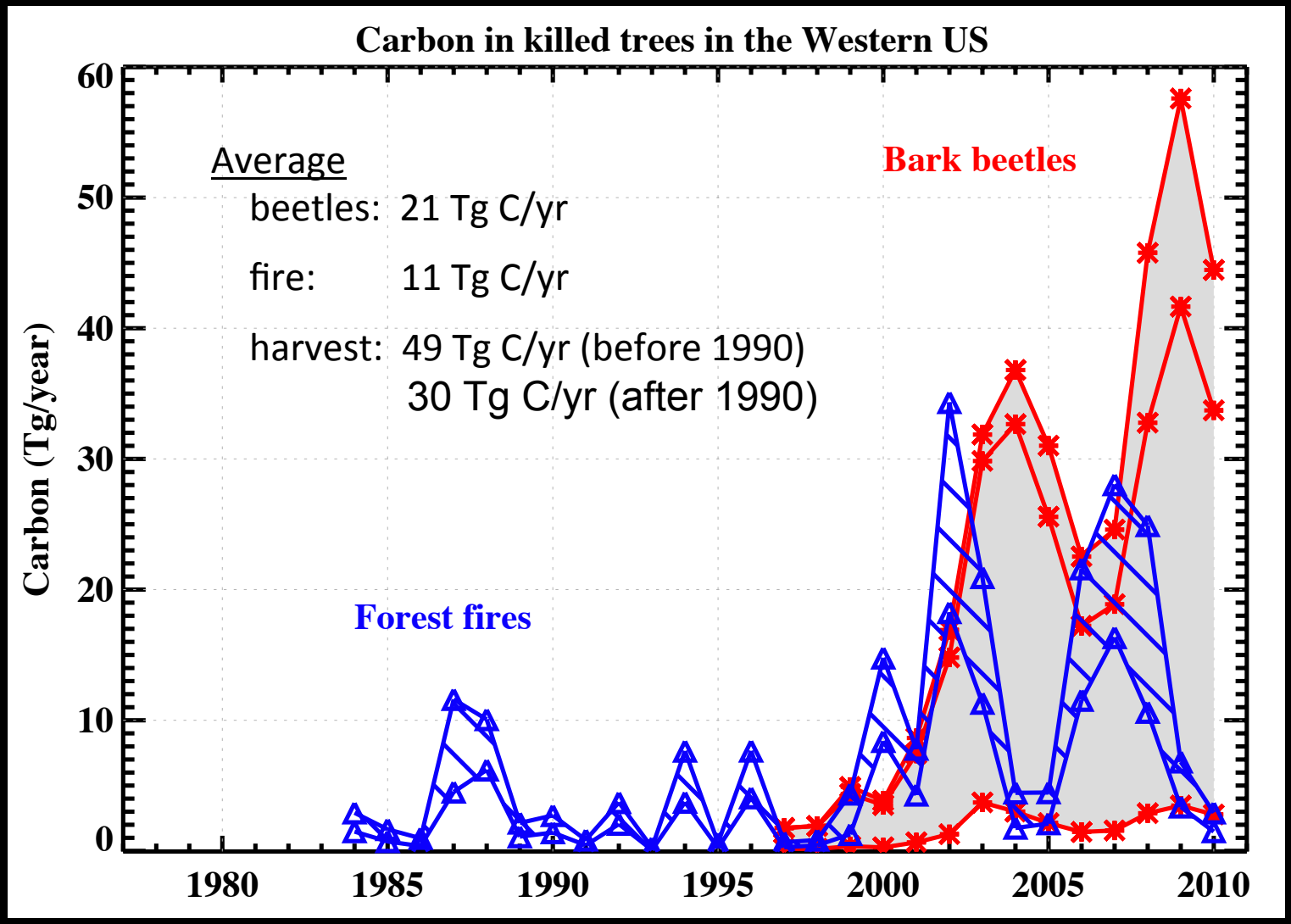
Plant productivity (GPP) (-)

H2O to atmosphere from plants and evaporation (-)

Surface temperature (+)



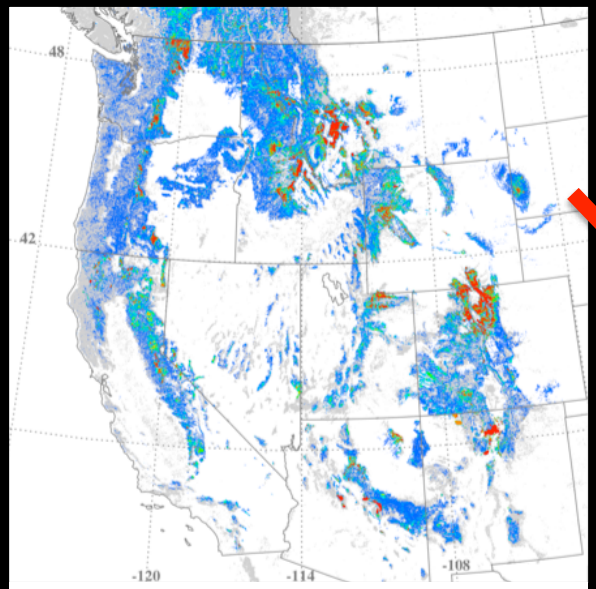
Bark beetle outbreaks and C stocks



Hicke et al., ERL, 2013

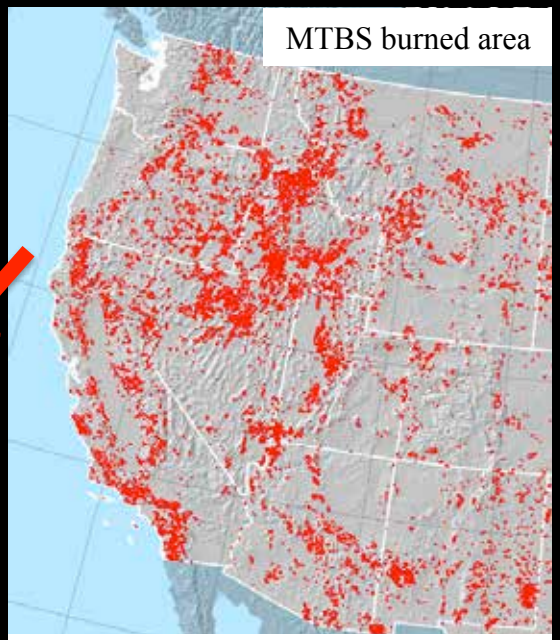
Current work: Comparison of carbon impacts from fires and bark beetles in the western US using CLM

Forest mortality from insects

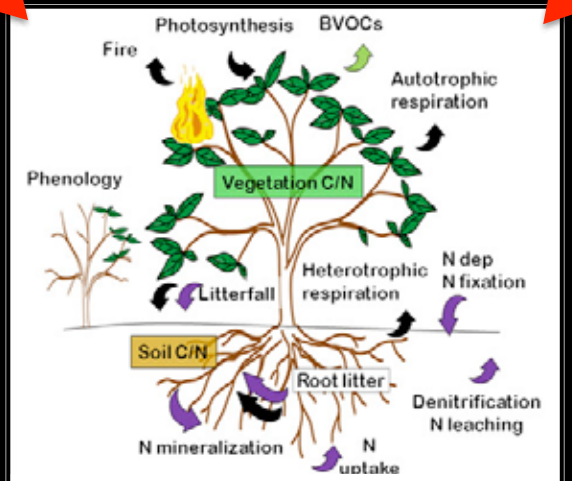


Meddens et al. 2012, *Ecological Applications*

Forest mortality from fires



http://www.mtbs.gov/dataaccess.html



Community Land Model (CLM)

Spatial and temporal estimates of regional carbon losses from fires and bark beetle-caused tree mortality

Outline

Photo by J. Hicke

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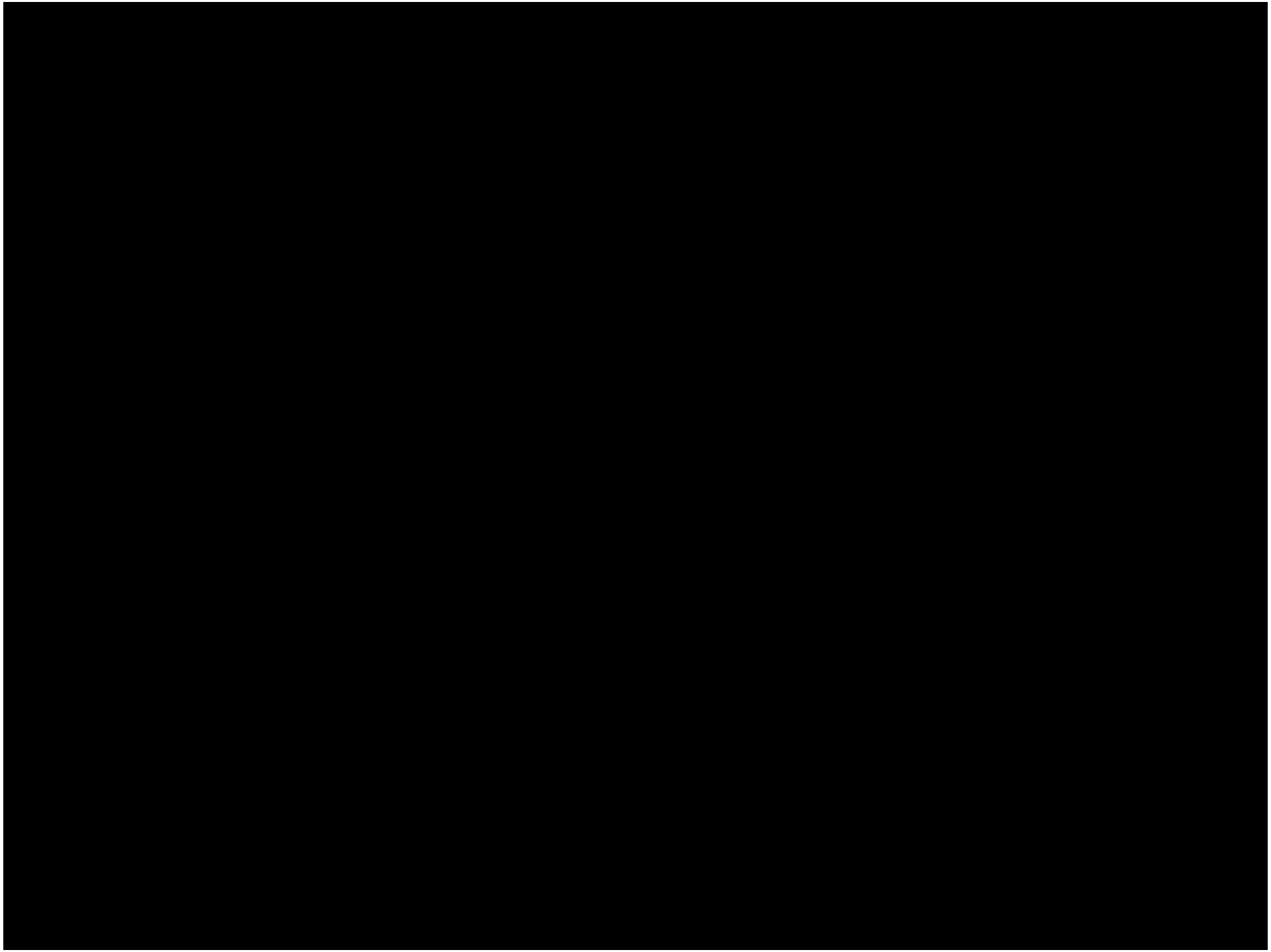
Conclusions:

1. Bark beetle cause large scale forest disturbances across North America

2. Bark beetles, their hosts, and climate are tightly coupled through:
   a. Live-cycle development → Governed by year-round temperatures
   b. Cold mortality → Cold temperatures kill beetles
   c. Host trees → Negatively affected by dry and warm years

3. Beetle outbreaks occur outside the known historic range (higher elevations and more northern)

4. By killing trees beetles affect carbon uptake of forests and can turn forests from carbon sinks to carbon sources

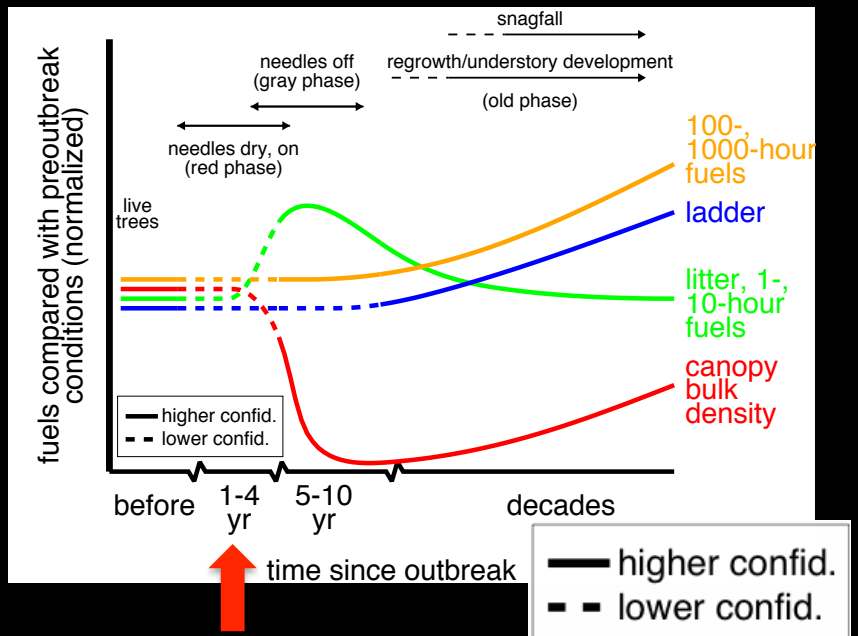


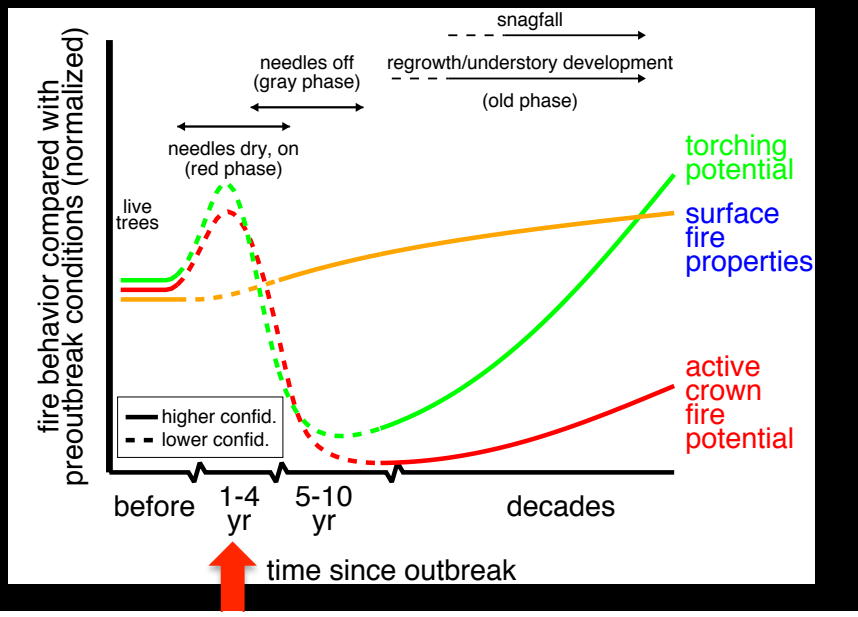
Do beetle-killed trees affect forest fires?

Photo by Matt Stensland

www.steamboatpilot.com/news/2008/aug/17/dying_forests_increase_wildfire_danger_across_west

Effects of bark beetle-caused tree mortality on wildfire

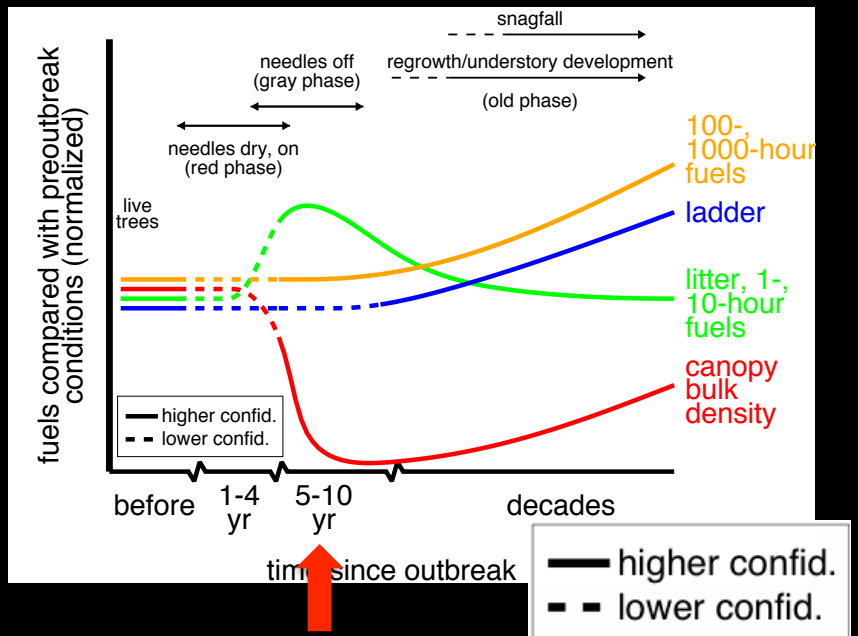


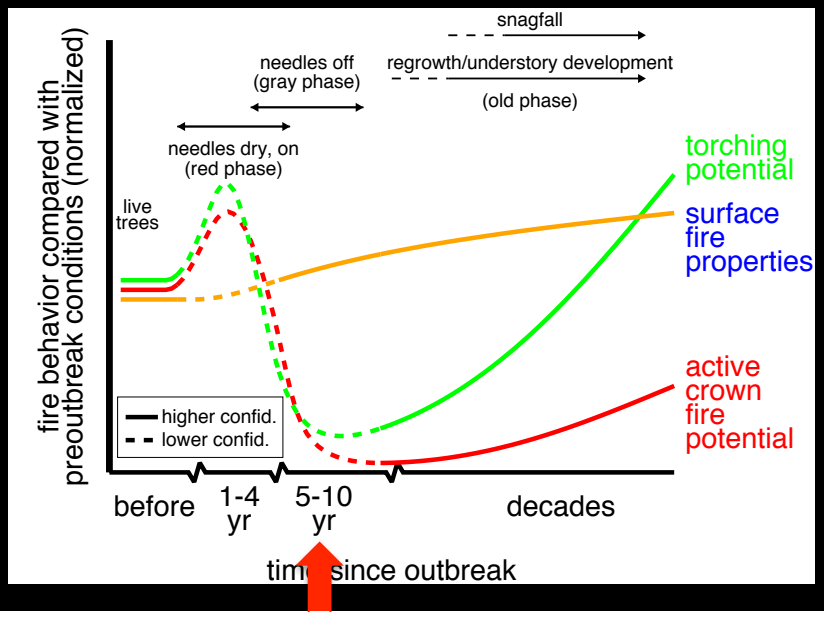


1-4 yr: red phase

Hicke et al., 2012

Effects of bark beetle-caused tree mortality on wildfire

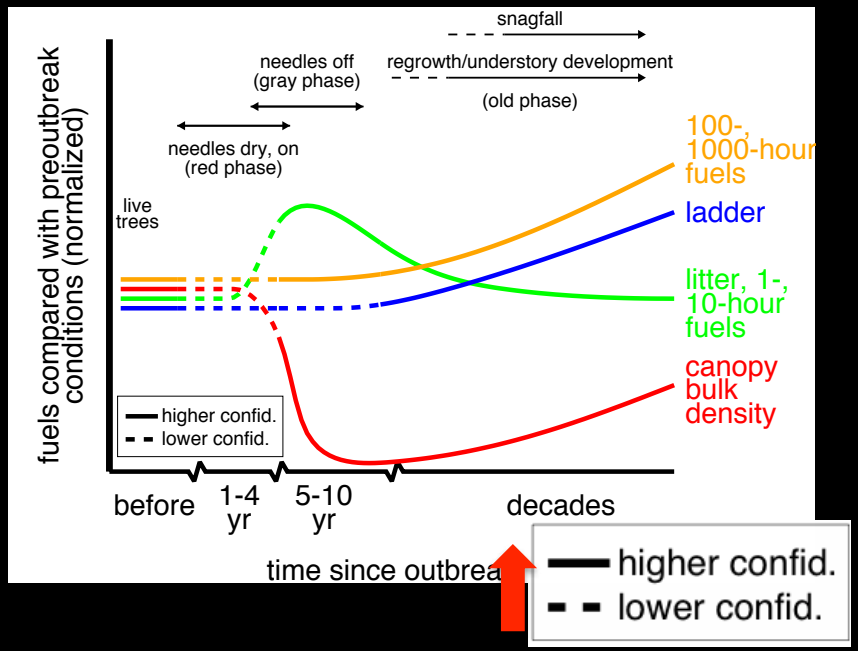


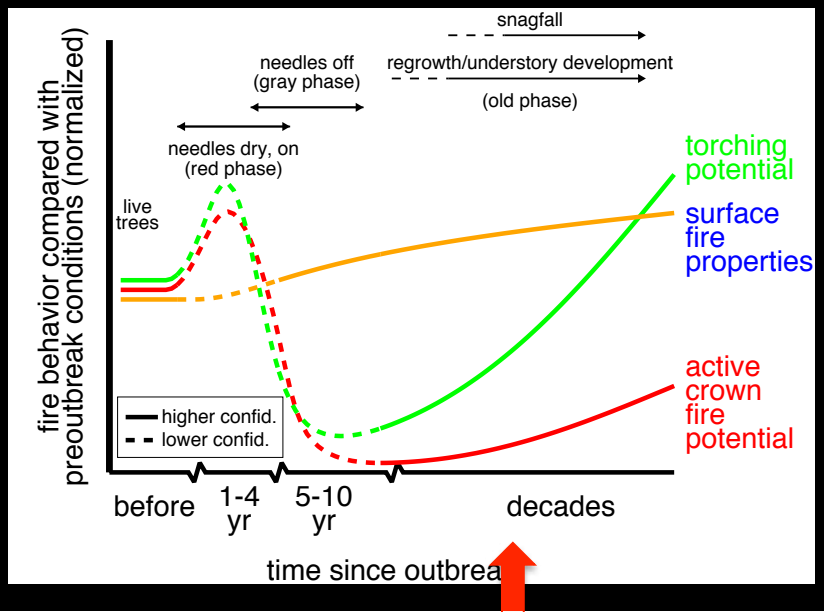


5-10 yr: gray phase

Hicke et al., 2012

Effects of bark beetle-caused tree mortality on wildfire





decades: old phase

Hicke et al., 2012