Climate Change effects on Vegetation Patterns, Fire, and Insects

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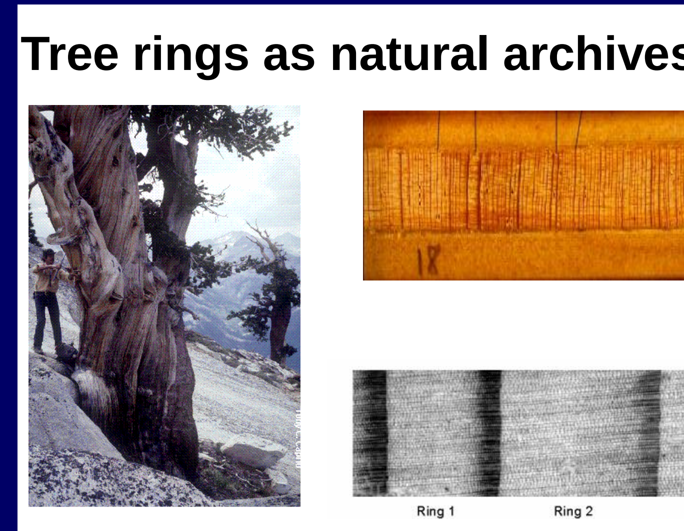
Climate Change effects on Forest Vegetation

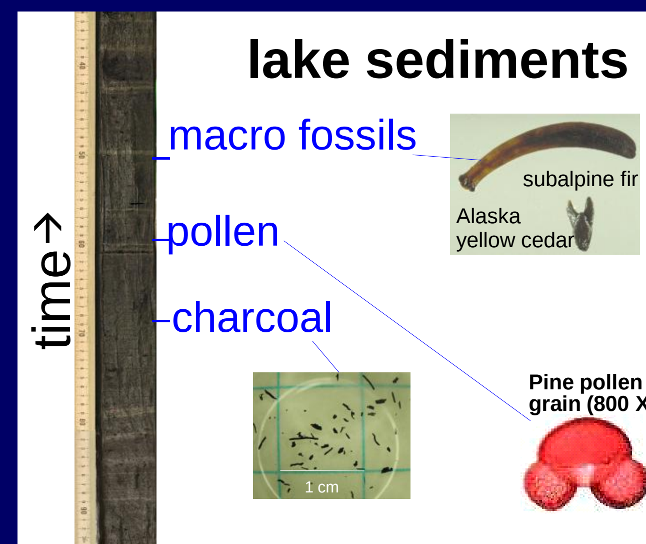
- tree regeneration, growth, productivity, and mortality
- species biogeography and forest composition
- disturbance rates and severity (wind, fire, insects, pathogens)
- Interactions between disturbances

The Tool Box



Historical records

- tree rings (fire scars, ring widths)
- lake sediments (pollen, charcoal, macrofossils)
- fire atlas
- burn severity maps
- aerial forest health surveys



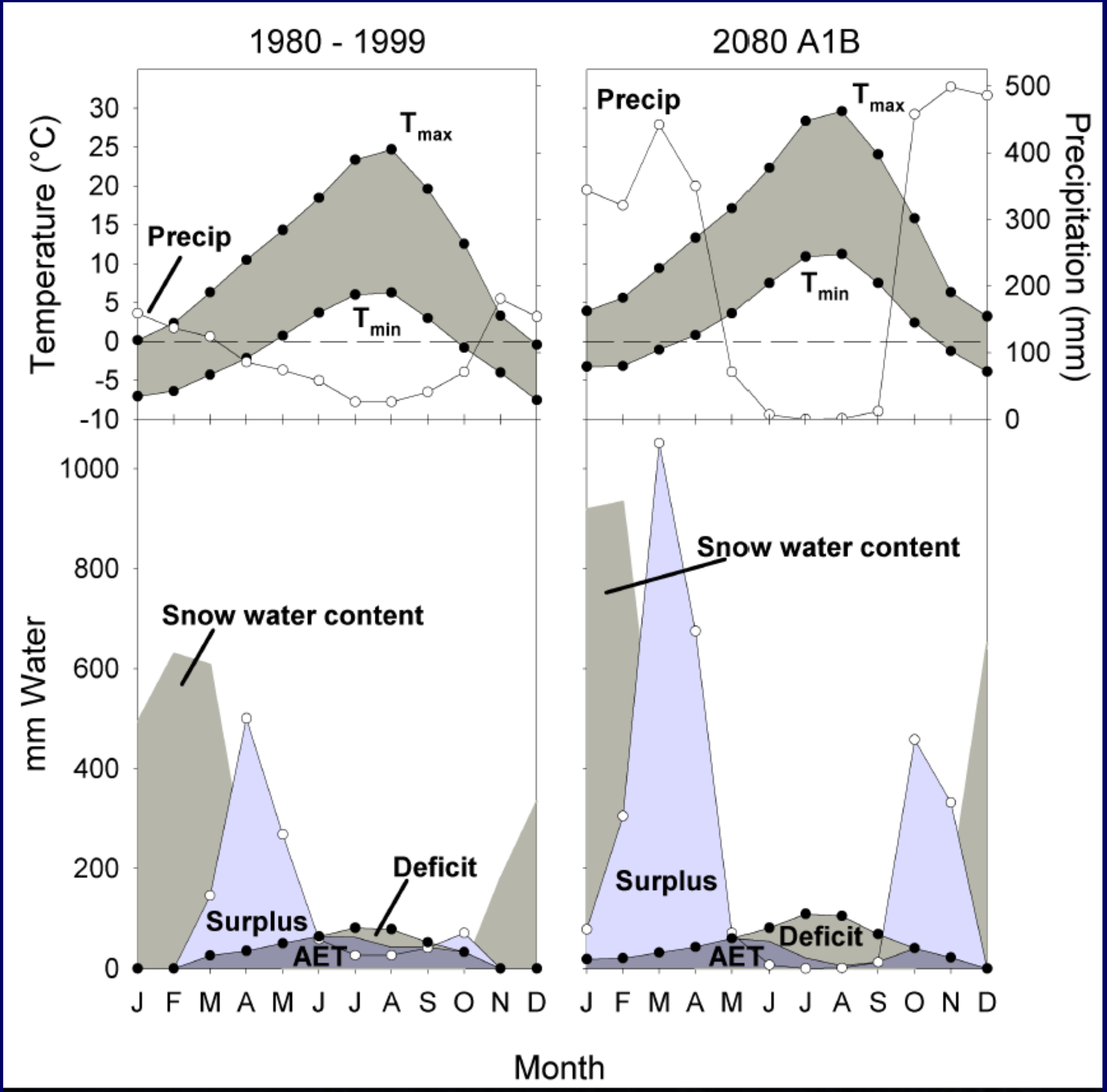
Models

- statistical models
- hydrological models
- ecosystem process models

photos courtesy of: S. Prichard

Water Balance Deficit

the difference between atmospheric demand for water and the water available to satisfy that demand

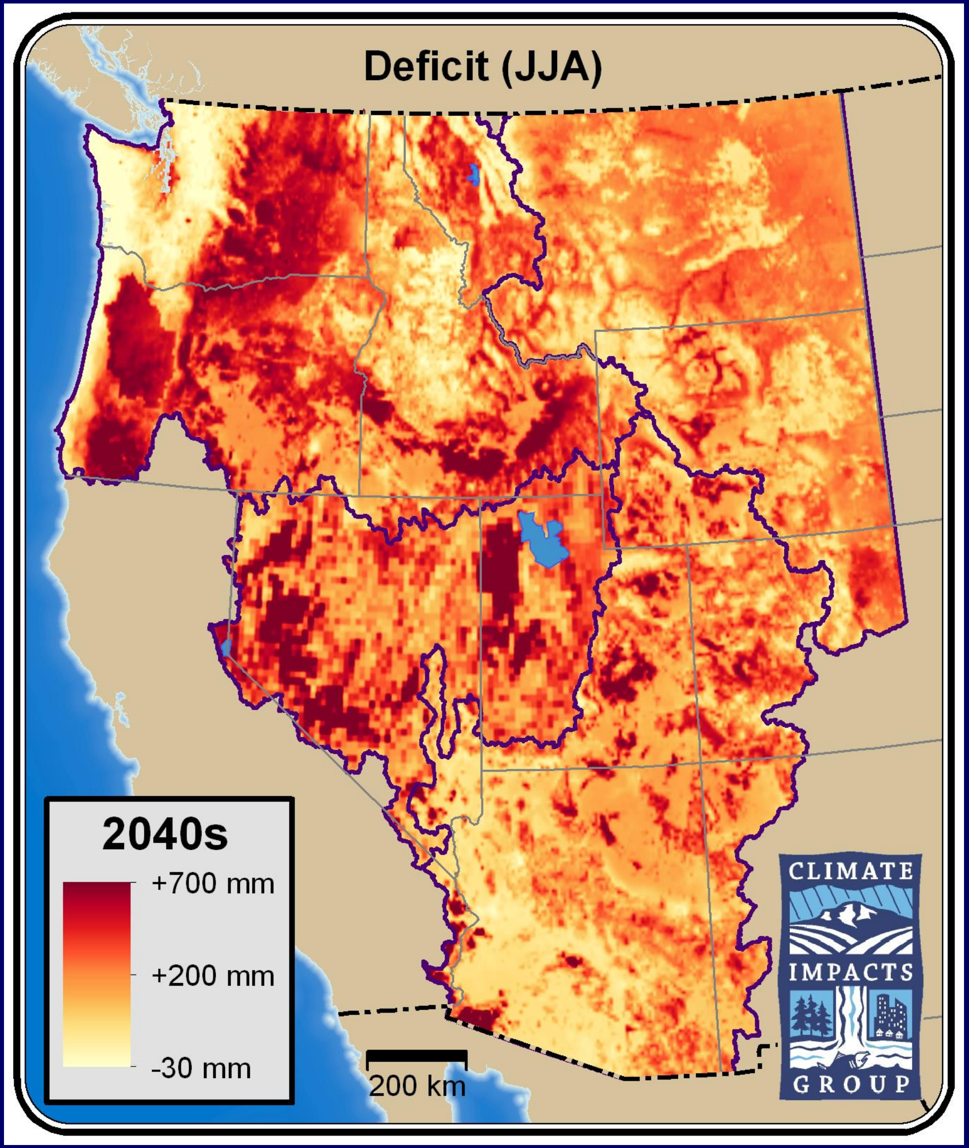


slide courtesy of: J. Littell

Water balance and forest effects

As deficit increases:

- tree growth and regeneration become more limited in water limited systems
- tree vulnerability to insect attack increases
- fuel moisture declines, so fire activity (spread, severity, area, frequency) likely increases in forested systems



slide courtesy of: J. Littell

Climatic Change Effects on Tree Regeneration

Regeneration increases in energy-limited systems when:

- snowpack duration and depth⬇
- growing season length⬆

Regeneration decreases in water-limited systems when:

- Soil moisture ⬇

Conifer Regeneration (Mt. Rainier)

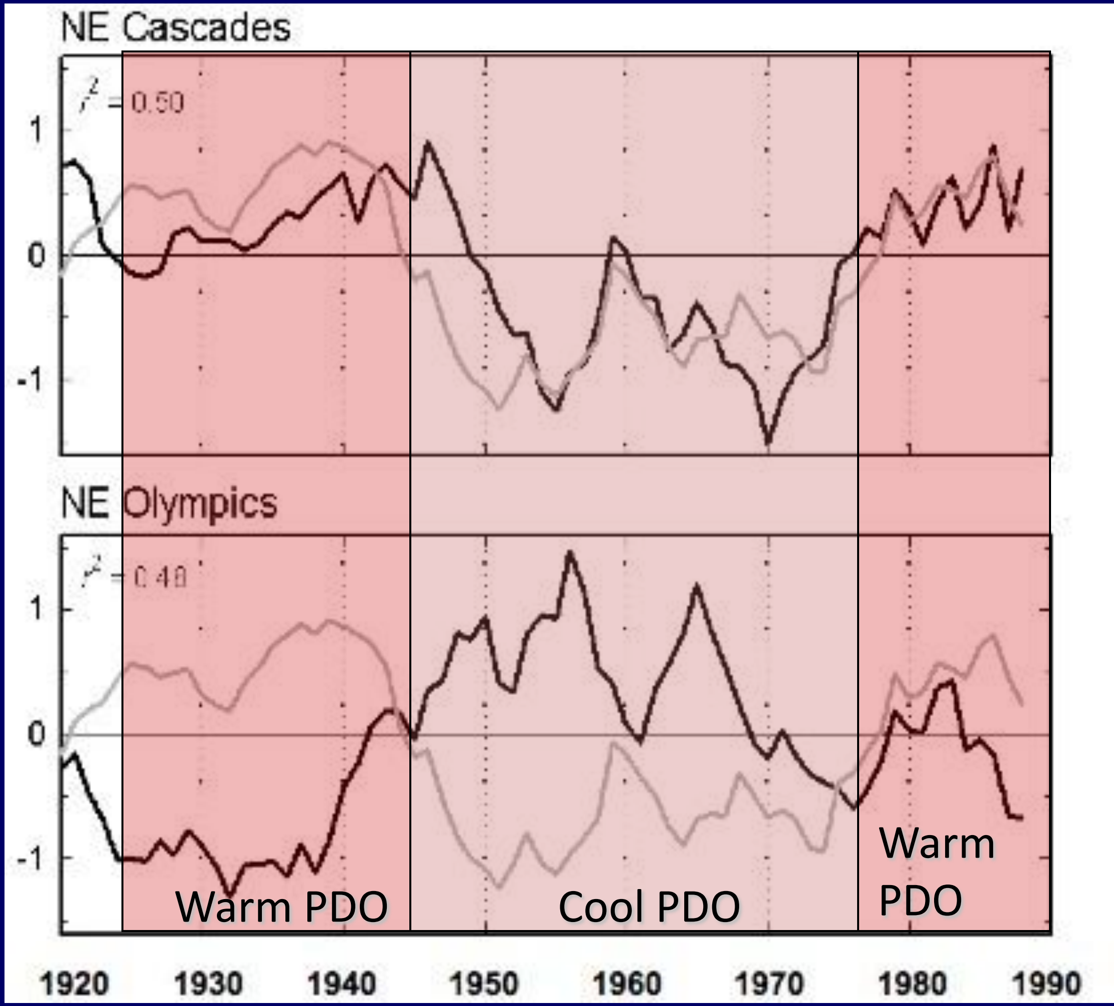
1920

2010

(Rochefort and Peterson 1996)

Climatic variability and tree growth

- Climatic variability affects tree growth at multiple temporal scales
- Decadal-scale growth affected by PDO



(Peterson et al. 2002)

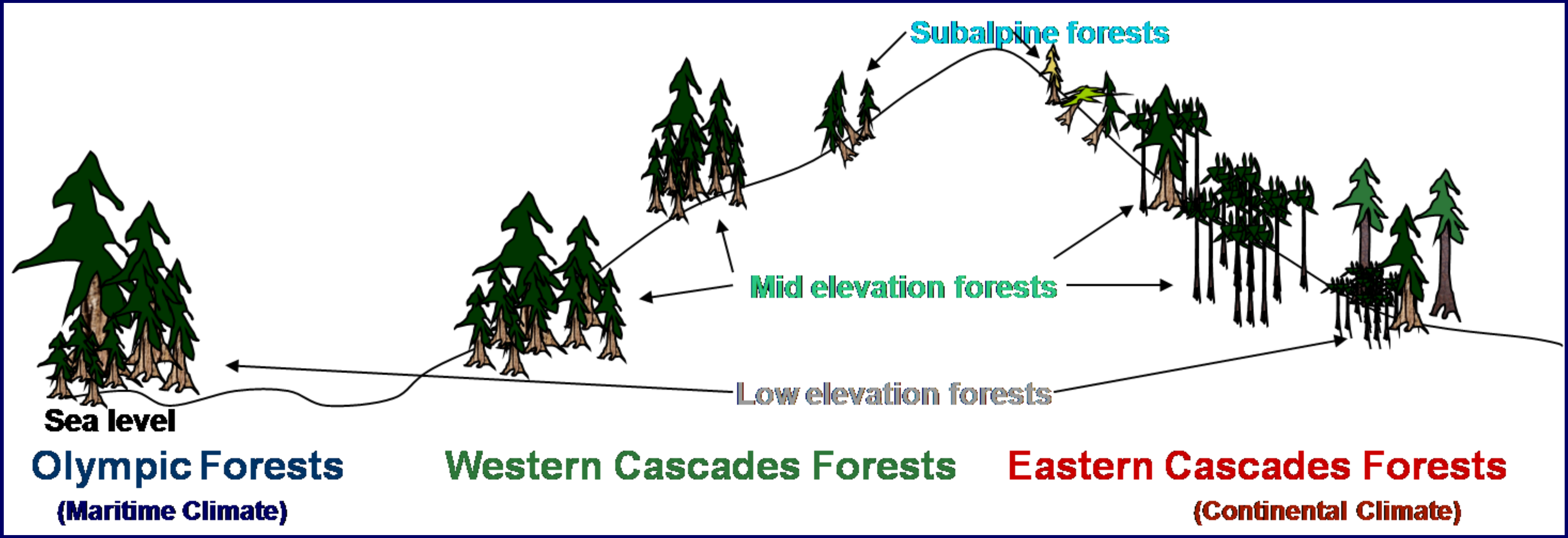
Climatic change and tree growth

Subalpine forests → *growth increase*

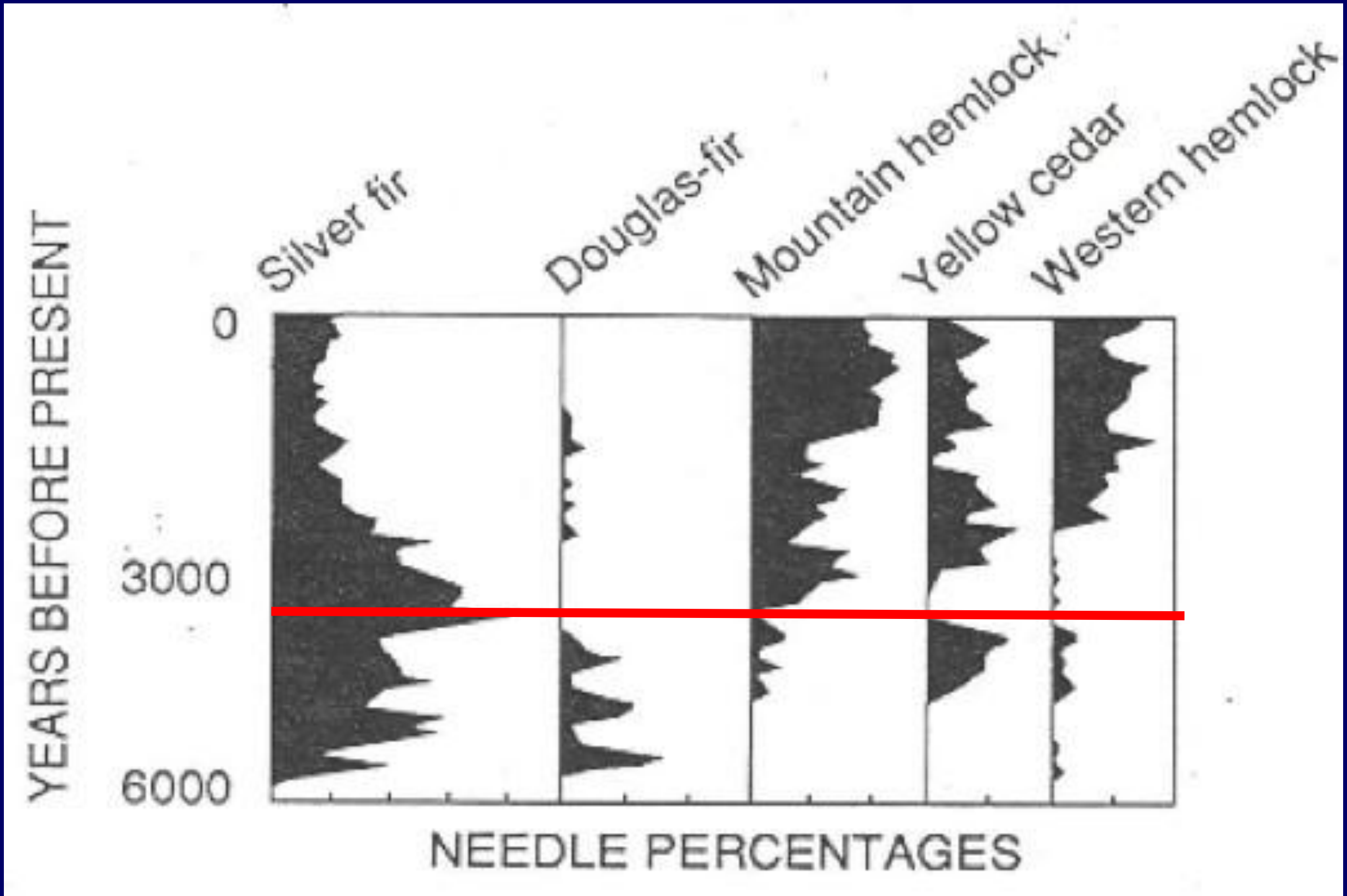
Mid elevation forests → *growth depends on precipitation*

Dry low elevation forests → *large growth decrease*

Wet low elevation forests → *growth increase or decrease*



6000-yr Forest History at Mt. Rainier



Macrofossil record in sediment core
Jay Bath (1300 m), Mount Rainier, WA

(Dunwiddie 1986)

What can we learn from the past?

Abundance and distribution of tree species change individualistically in response to climate change.

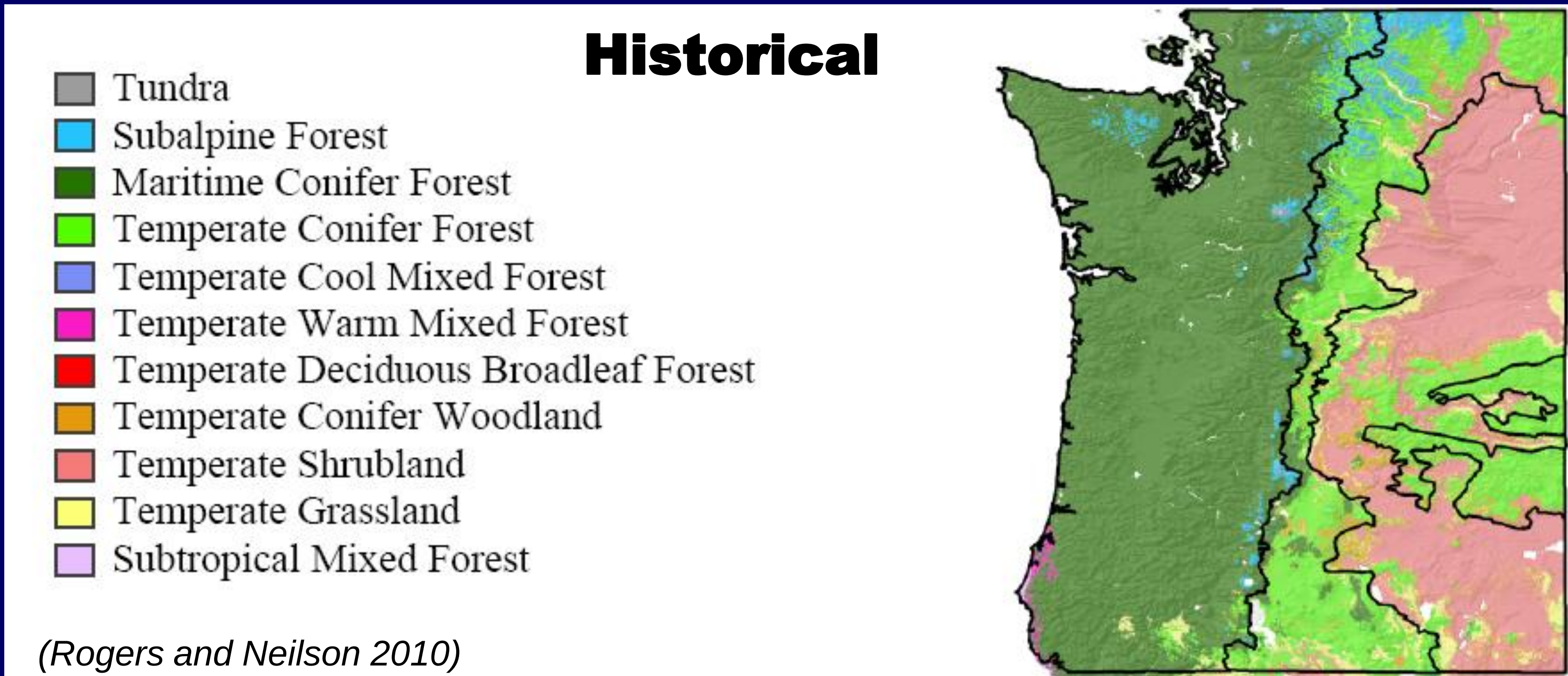
Are warm periods of the past an analog for the future?

- 9000 ~ 5000 years ago
- 900 ~ 700 years ago

But

- current rate of warming is unprecedented
- no analogue climates are likely

Modeled Vegetation Distributions



(Rogers and Neilson 2010)

MC1 vegetation type	Regional examples
Subalpine Forest	subalpine fir, lodgepole pine, mountain hemlock, whitebark pine
Maritime Conifer Forest	Douglas-fir, western hemlock, sitka spruce, Pacific silver fir
Temperate Conifer Forest	Ponderosa pine, Douglas-fir, Lodgepole pine, grand fir, western juniper

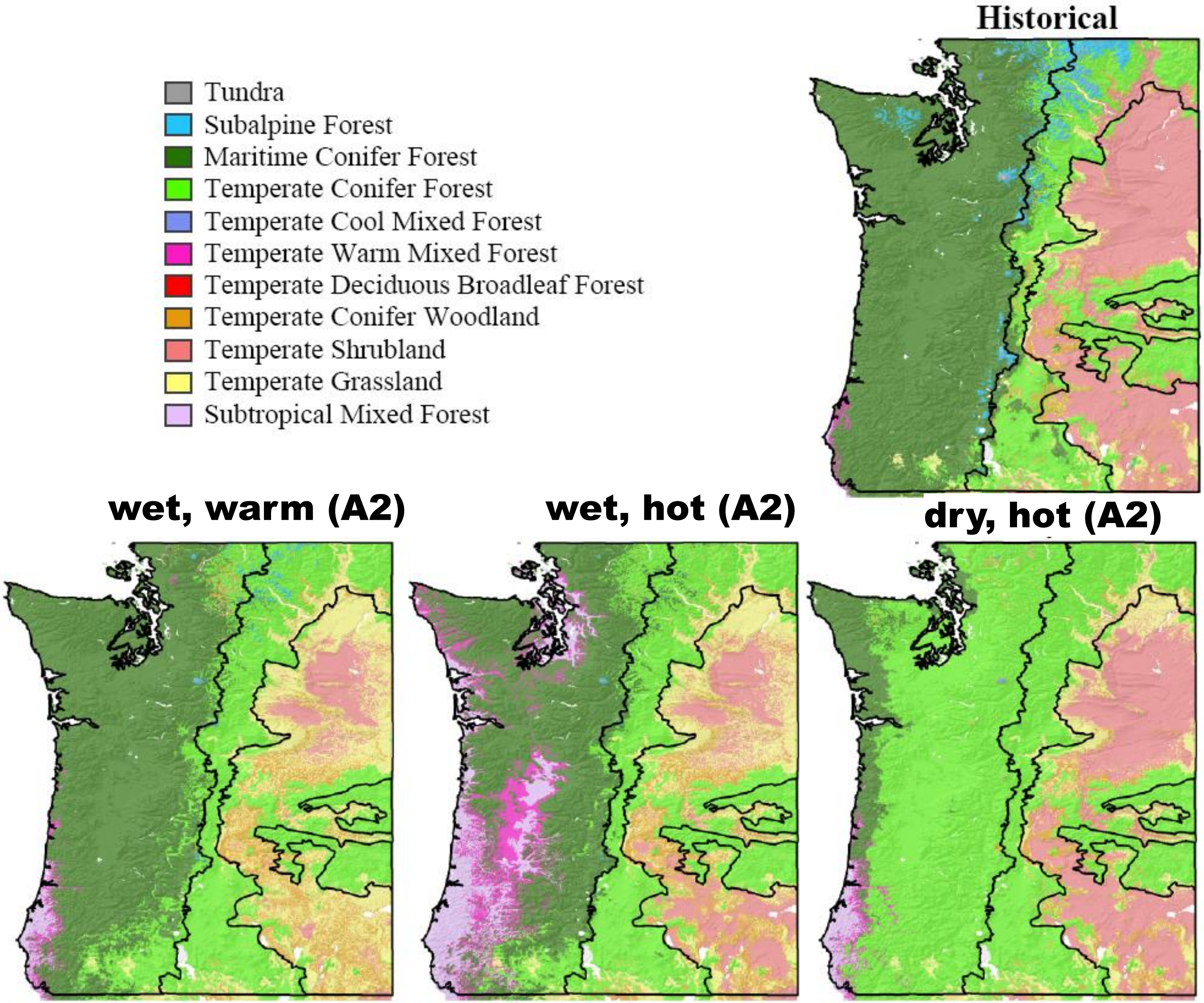
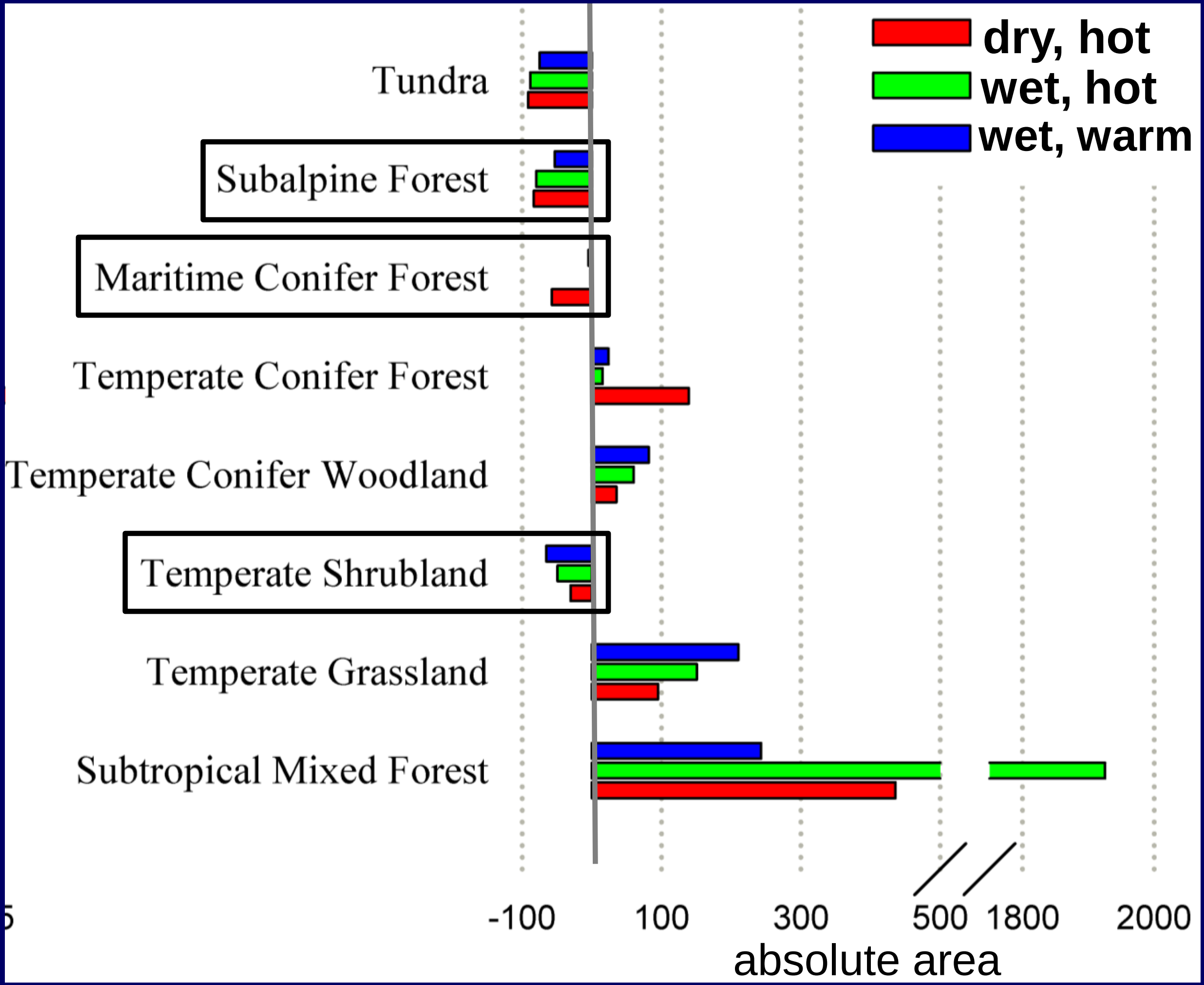


Fig 17. Mode vegetation types for historical and future A2 scenarios. *(Rogers and Neilson 2009)*

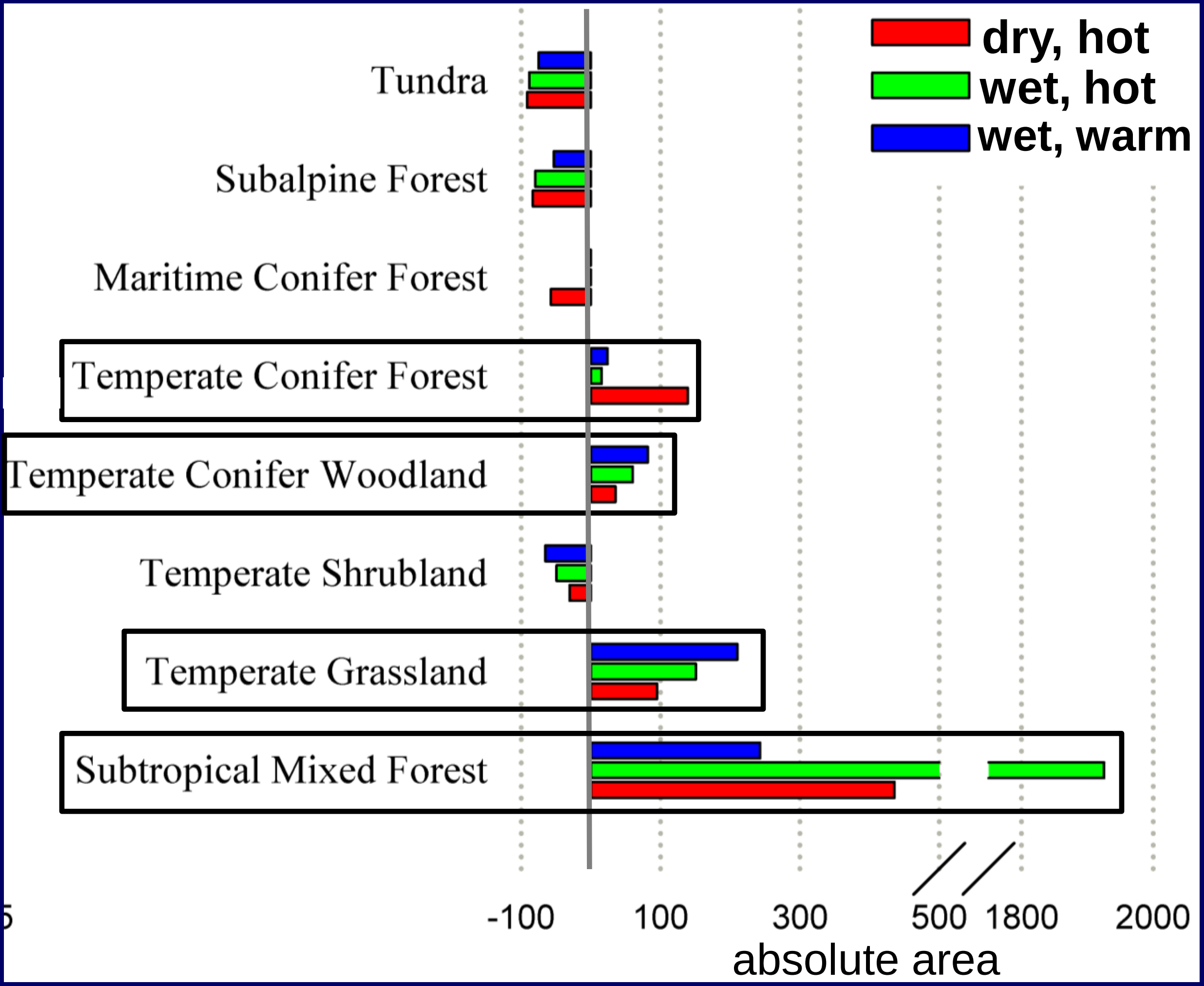
Changes in vegetation distributions



Subalpine Forest	subalpine fir, lodgepole pine, mountain hemlock, whitebark pine
Maritime Conifer Forest	Douglas-fir, western hemlock, sitka spruce, Pacific silver fir
Temperate Shrubland	big sagebrush- bluebunch wheat grass, big sagebrish-Idaho fescue

(Rogers and Neilson 2009)

Changes in vegetation distributions



Temperate Conifer Forest	ponderosa pine, Douglas-fir, lodgepole pine, grand fir
Temperate conifer woodland	ponderosa pine – western juniper woodland
Temperate Grassland	bluebunch wheat grass, Idaho fescue
Subtropical mixed forest	Douglas-fir – Madrone –Tanoak

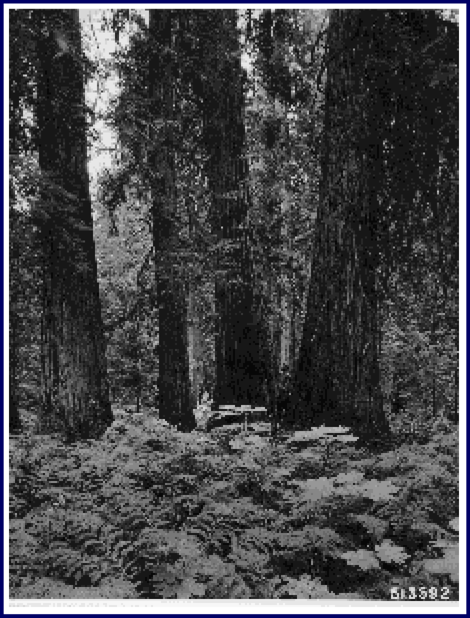
(Rogers and Neilson 2009)

Fuels and ecosystem pattern influence how climate affects fire

- Different fuel types respond differently to climate

Two mechanisms:

- *Production* of fuels in *fuel-limited systems* (shrub and grasslands)
- *Drying* of fuels in *climate-limited* systems (forests)



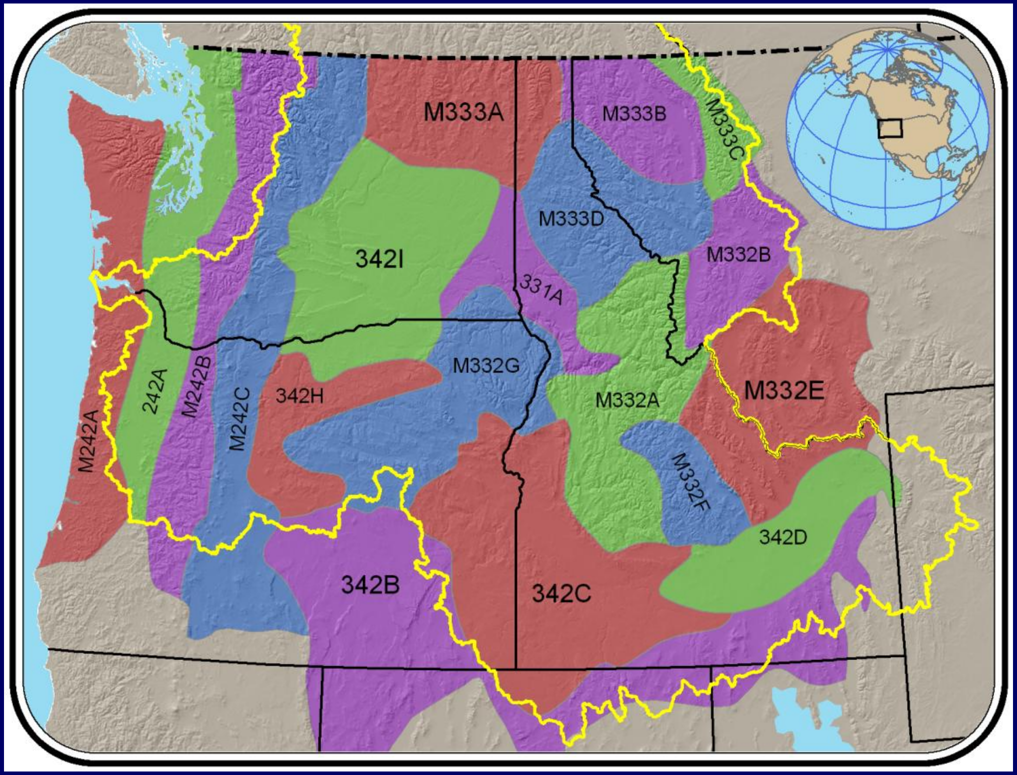
Littell, McKenzie, Peterson, and Westerling 2009

Projecting future area burned in the PNW

1. Build a model with 20th century climate and fire
   - regional precip. and temp.1916-2006)
   - sub-regional: precip., temp., water balance deficit variables (1980 – 2006)

2. Projected and down-scaled climate for the 2020s, 2040s, and 2080s

3. Use model to project area burned in the 21st C with 21st C climate



Littell et al. 2010

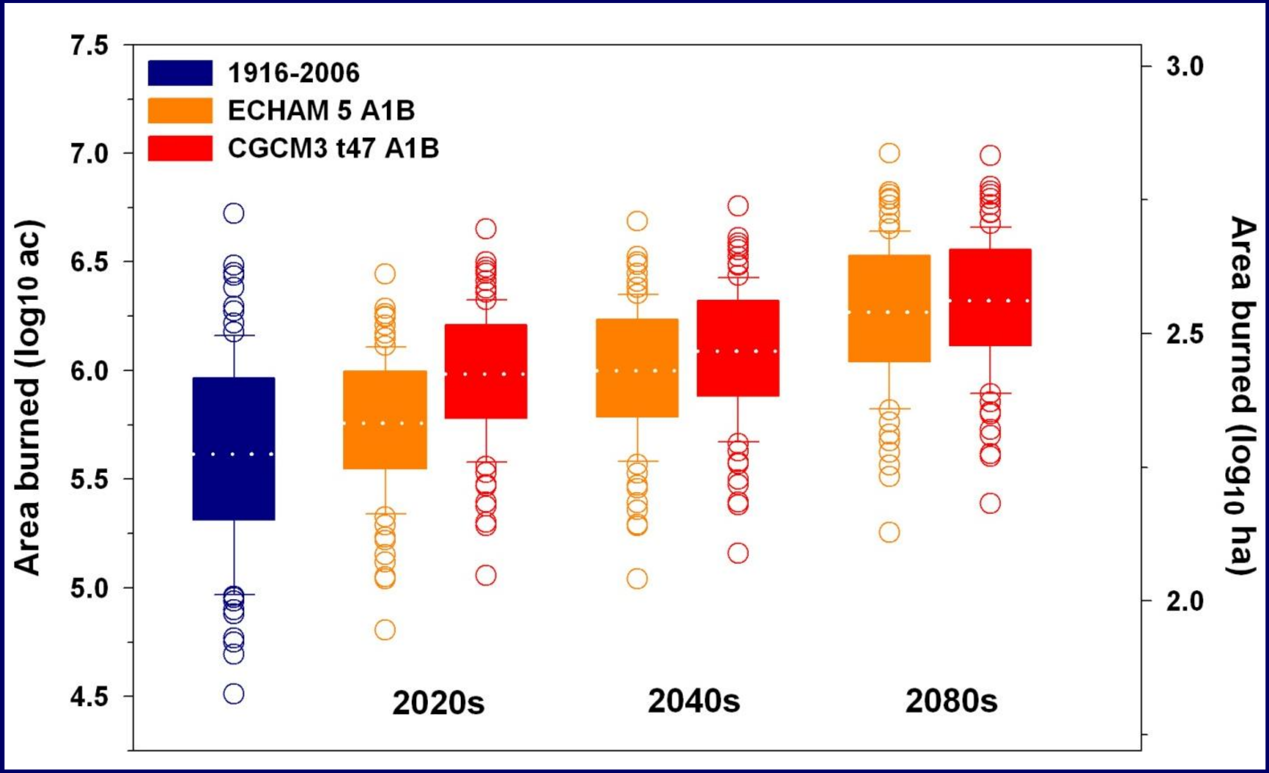
Projections of future area burned for the PNW

Historical average: 425,000 acres

- 2020s: 0.8 million
- 2040s: 1.1 million
- 2080s: 2.0 million

Probability of a yr >> 2 million acres:

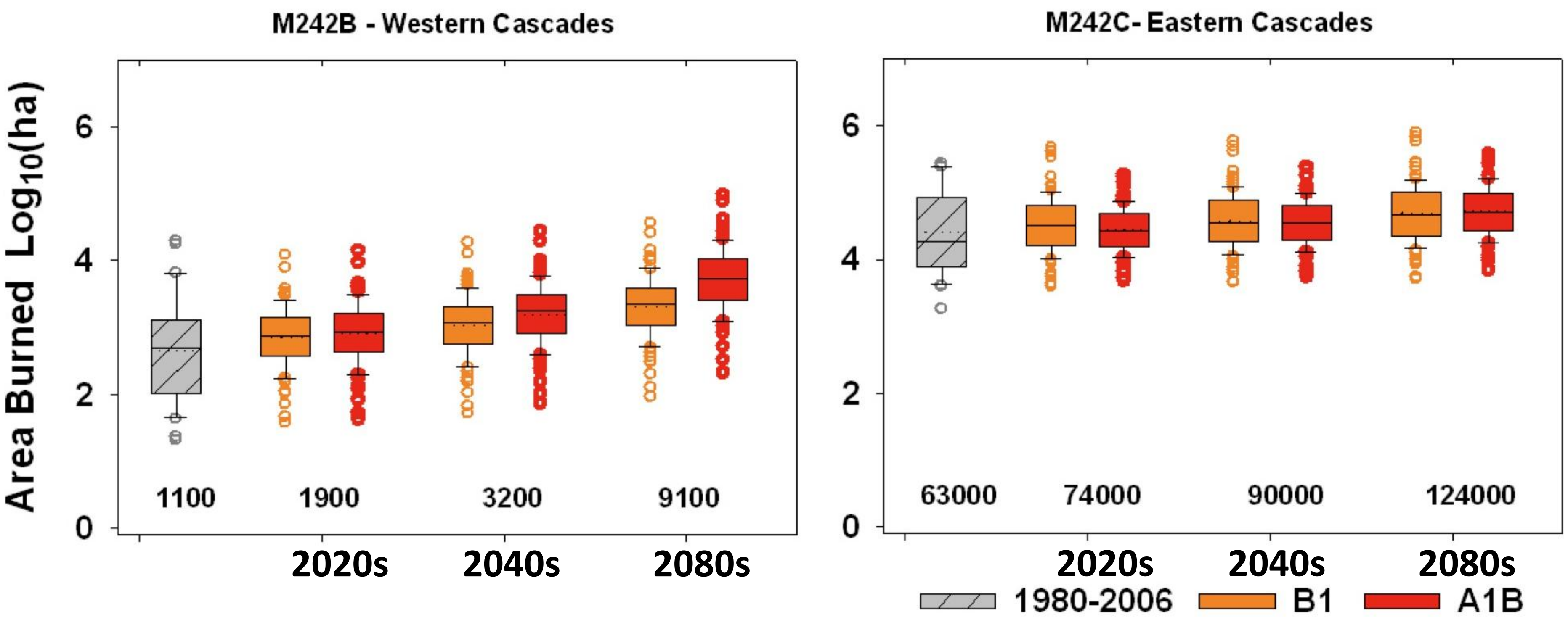
- Historical: 5%
- 2020s: 5% (1 in 20)
- 2040s: 17% (~1 in 6)
- 2080s: 47% (~1 in 2)



*Best model (tie): summer precip + summer temp OR summer water balance deficit

Littell et al. 2010

Future area burned in ecosections



- Western Cascades: 8-fold increase
- Eastern Cascades: 2-fold increase

Littell et al. 2010

Pre-settlement large fires in the western Cascades

- Tree age data from Douglas-fir points to large fire ~1308*: large fire or series of fires "swept western Washington" and burned "at least half of the Olympic Peninsula"*
- ~1701: fires burned about "1 million acres on the Olympic peninsula and 3 – 10 million in western Washington"

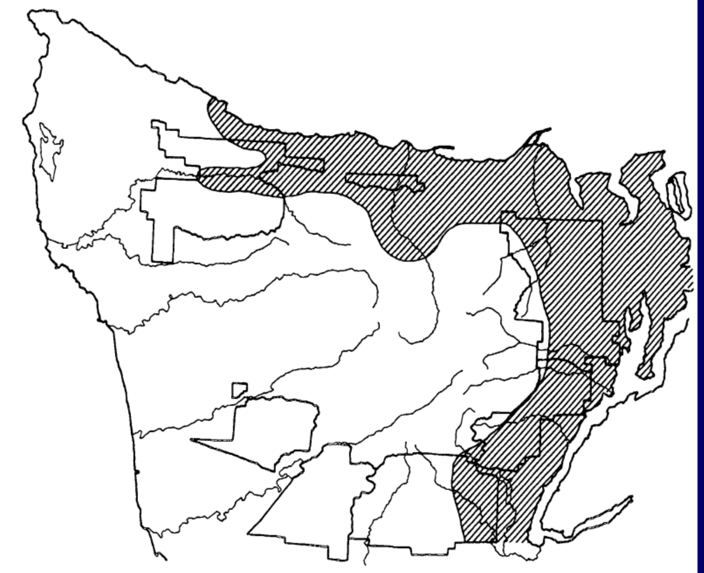
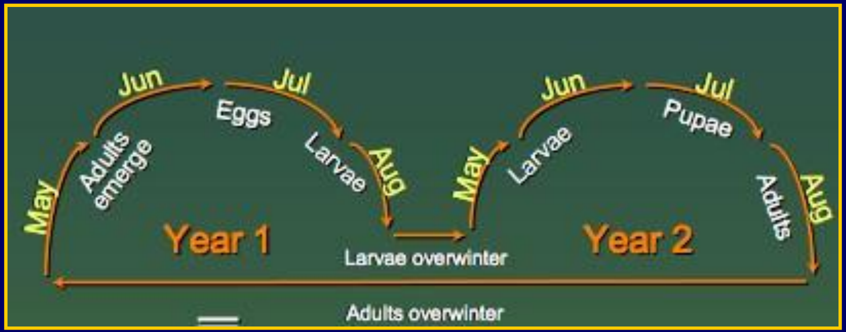


Figure 5. Map of Olympic Peninsula showing the remnant stands from the fire about 1701.

Henderson, J. A., D. H. Peter, R. D. Lesher, and D. C. Shaw. 1989. Forested Plant Associations of the Olympic National Forest. USDA Forest Service, Pacific Northwest Region. R6-ECOL-TP 001-88. 502 p.

Insects: Mountain Pine Beetle (and others)

Mountain pine beetle mortality in whitebark pine, Yellowstone. Jane Pargiter, 2007.



courtesy of: A. Carroll

Two ways climate affects forest vulnerability:

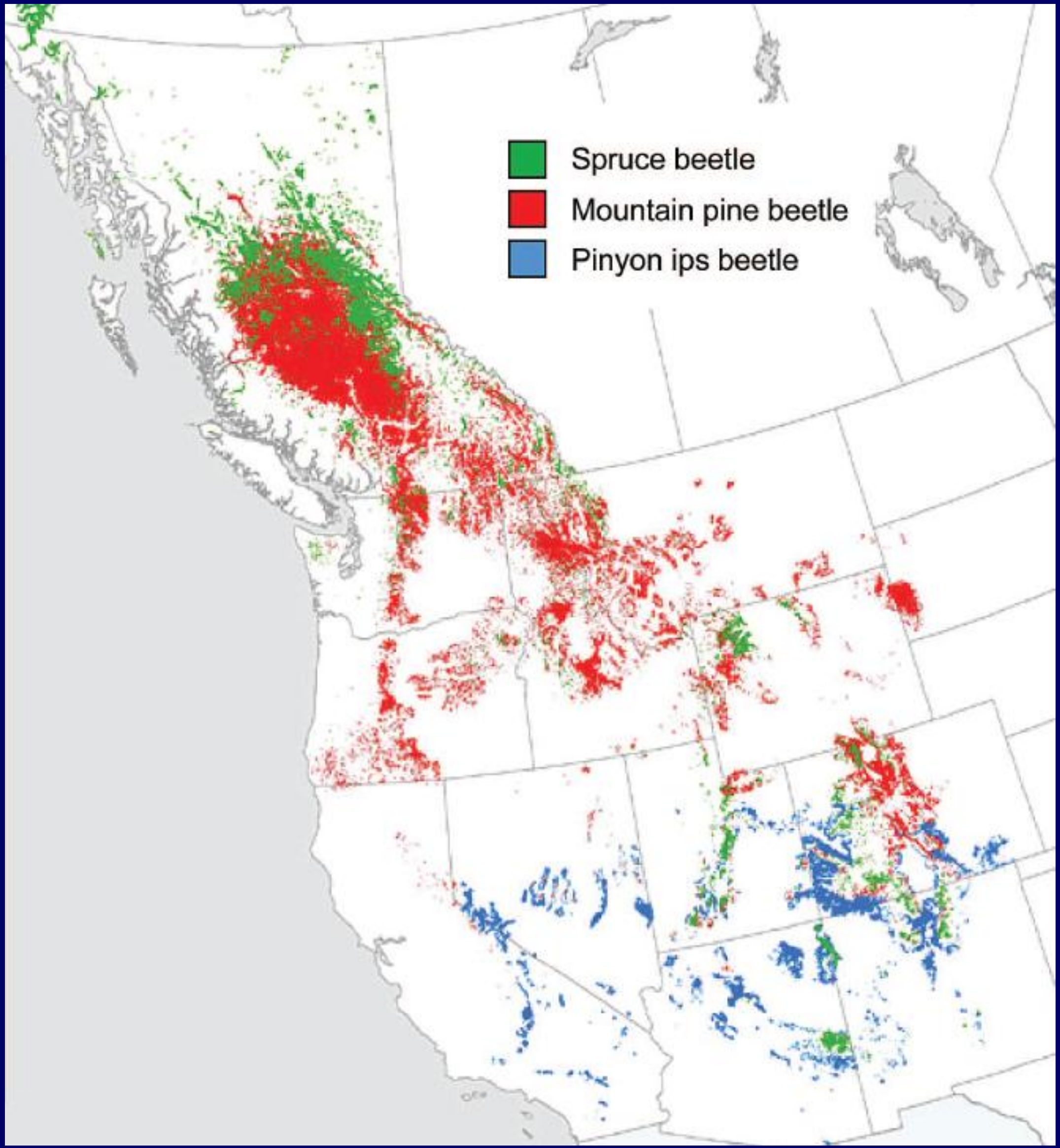
- Insect life cycle:
  - Increased temperature decreases generation time
  - Failure of cold temperatures decrease winter mortality
- Tree resistance:
  - Increased summer temperature and decreased precipitation decrease resistance

Climate Change and Insects

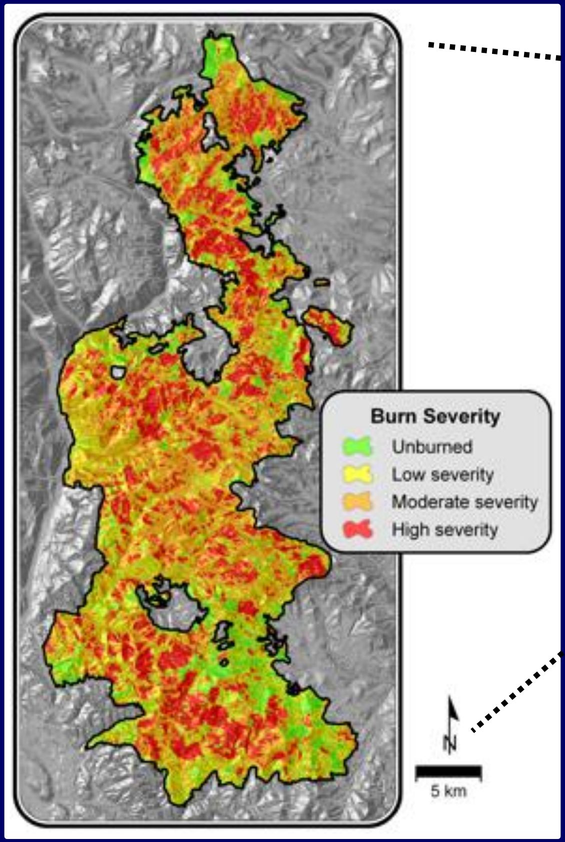
Some insects more closely tied to climate than others:

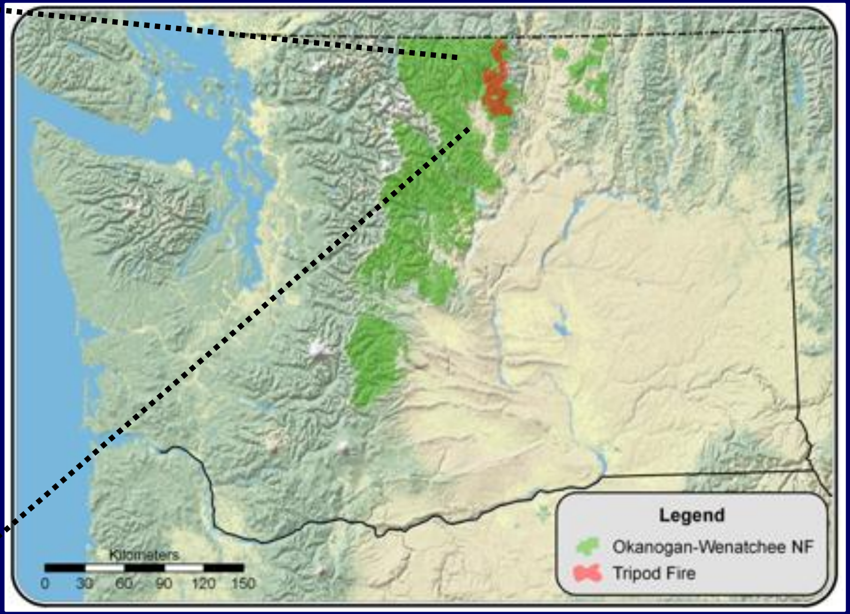
- Mountain pine beetle
- Western spruce budworm
- Spruce beetle

Left: Recent mortality of major western conifer biomes to bark beetles (Raffa et al. 2008).



Slide: Don McKenzie, USFS





Tripod Complex Fire 2006

Highest-severity patches had mountain pine beetle

Questions