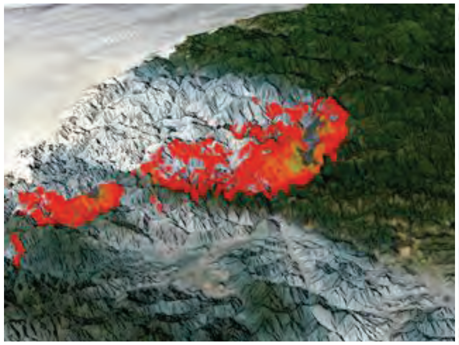
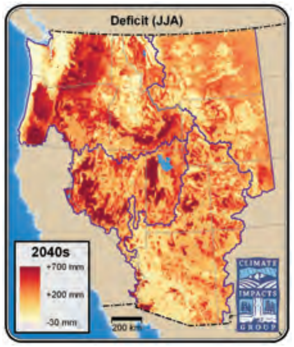
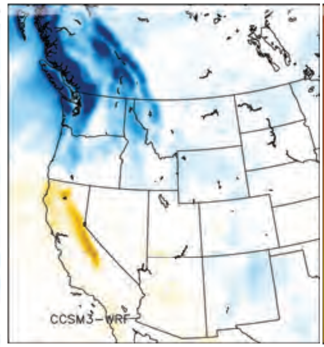
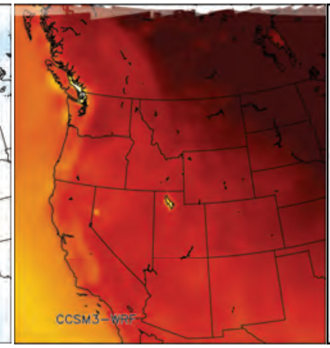
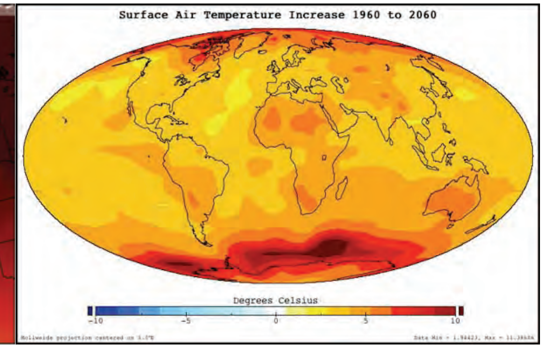
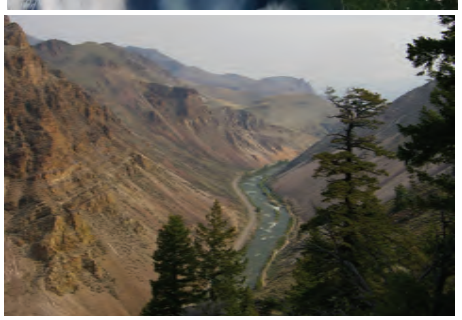












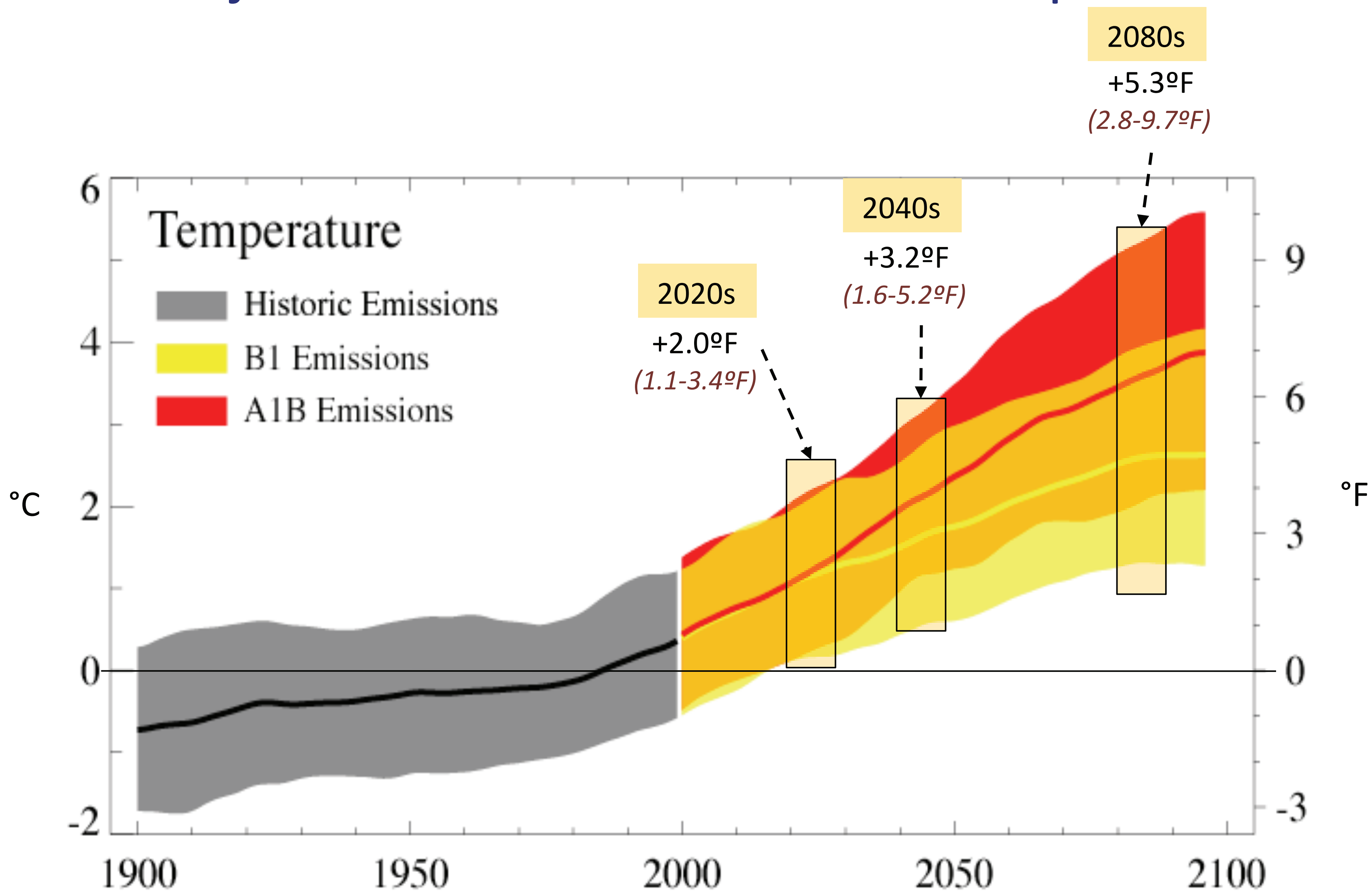
Climate change effects on vegetation and ecological disturbance

Jeremy Littell

University of Washington College of the Environment
Climate Impacts Group

Climate science in the public interest

Projected Increases in Annual Temperature

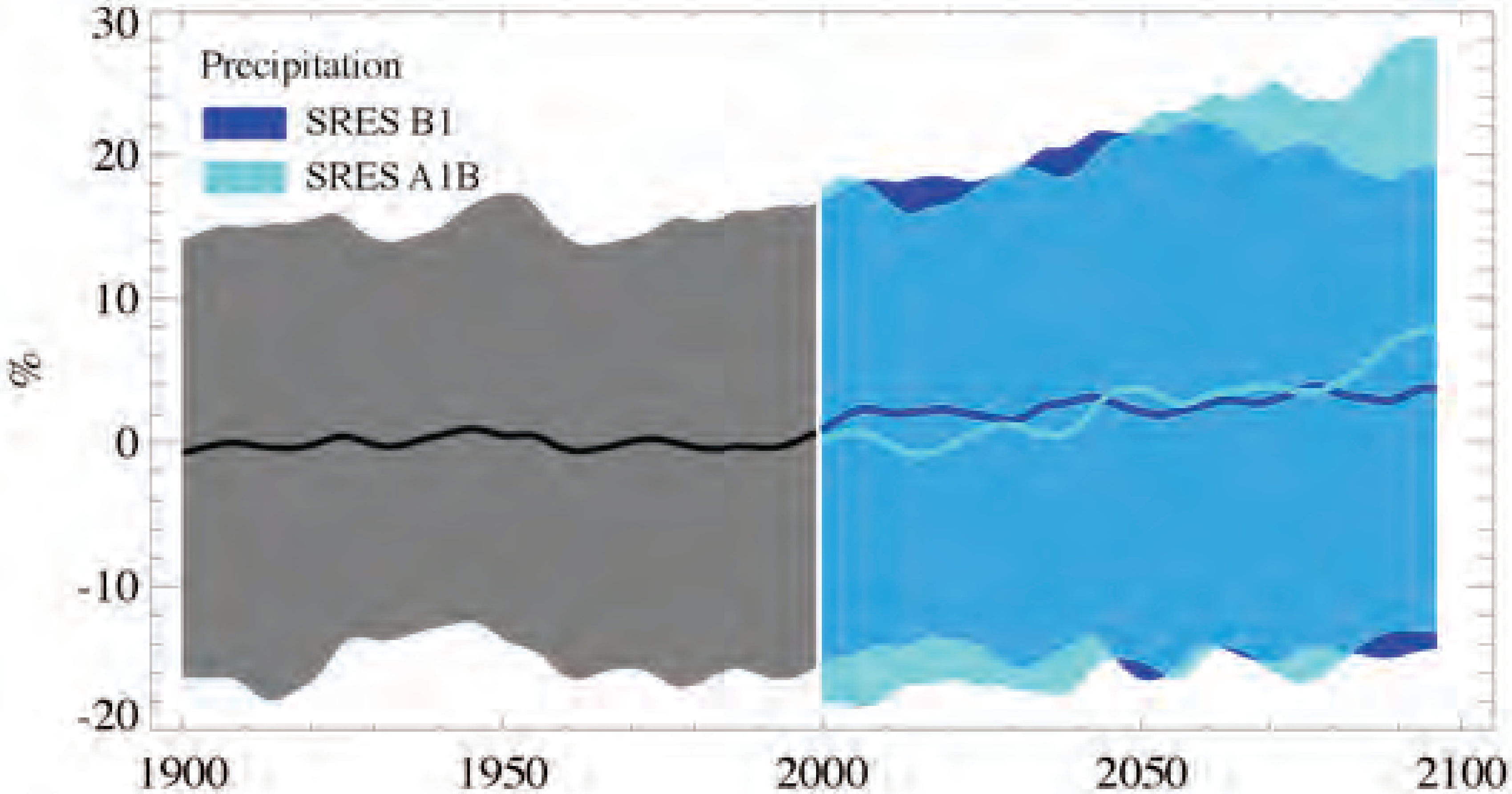


Mote and Salathé, 2009

** Compared with 1970-1999 average*

Projected Changes in Annual Precipitation

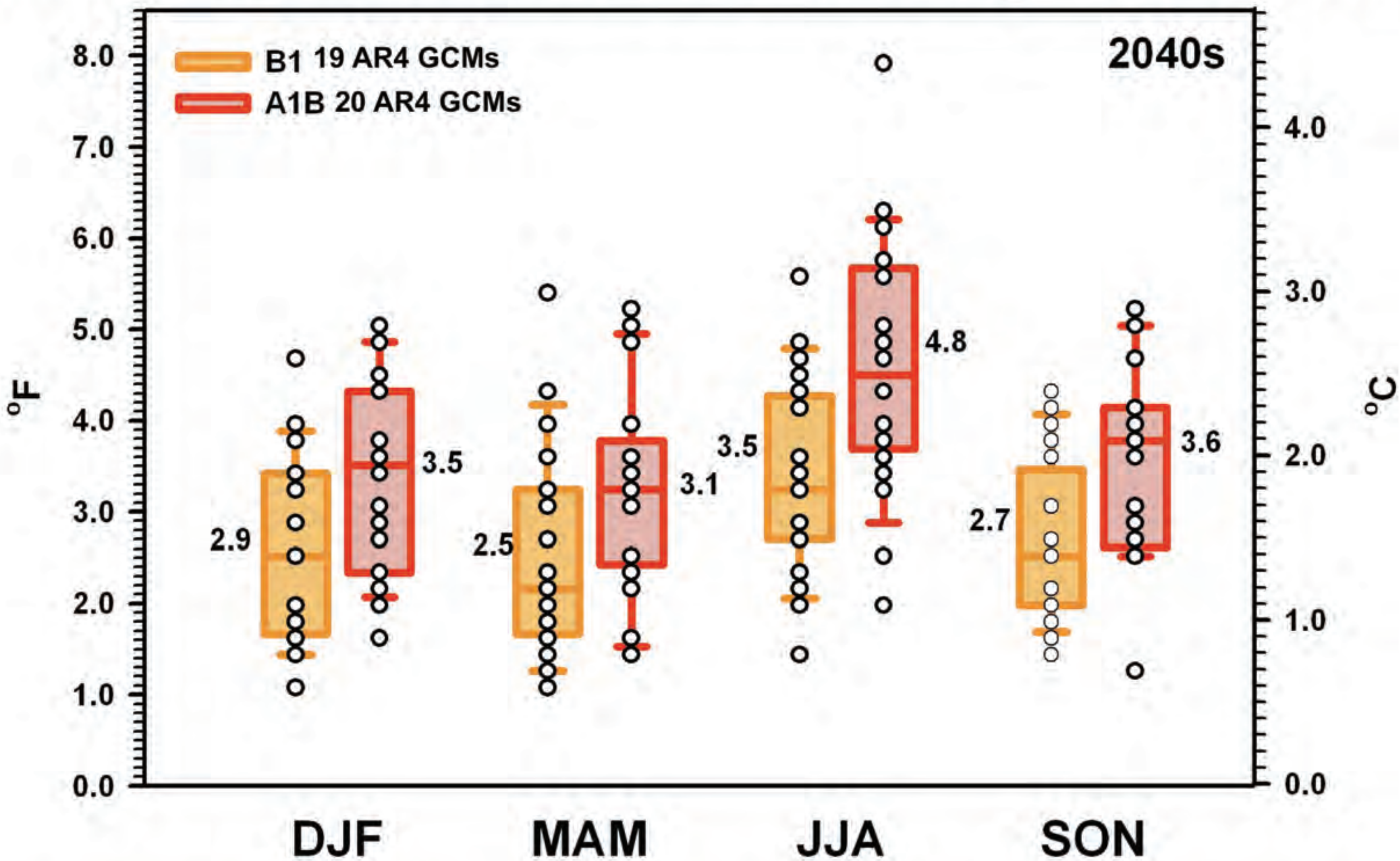
* Compared with 1970-1999 average



Changes in annual precipitation averaged over all models are small but some models show large seasonal changes, especially toward ***wetter autumns and winters*** and ***drier summers*.**

Mote and Salathé, 2009

Seasonal differences - PNW temperature change

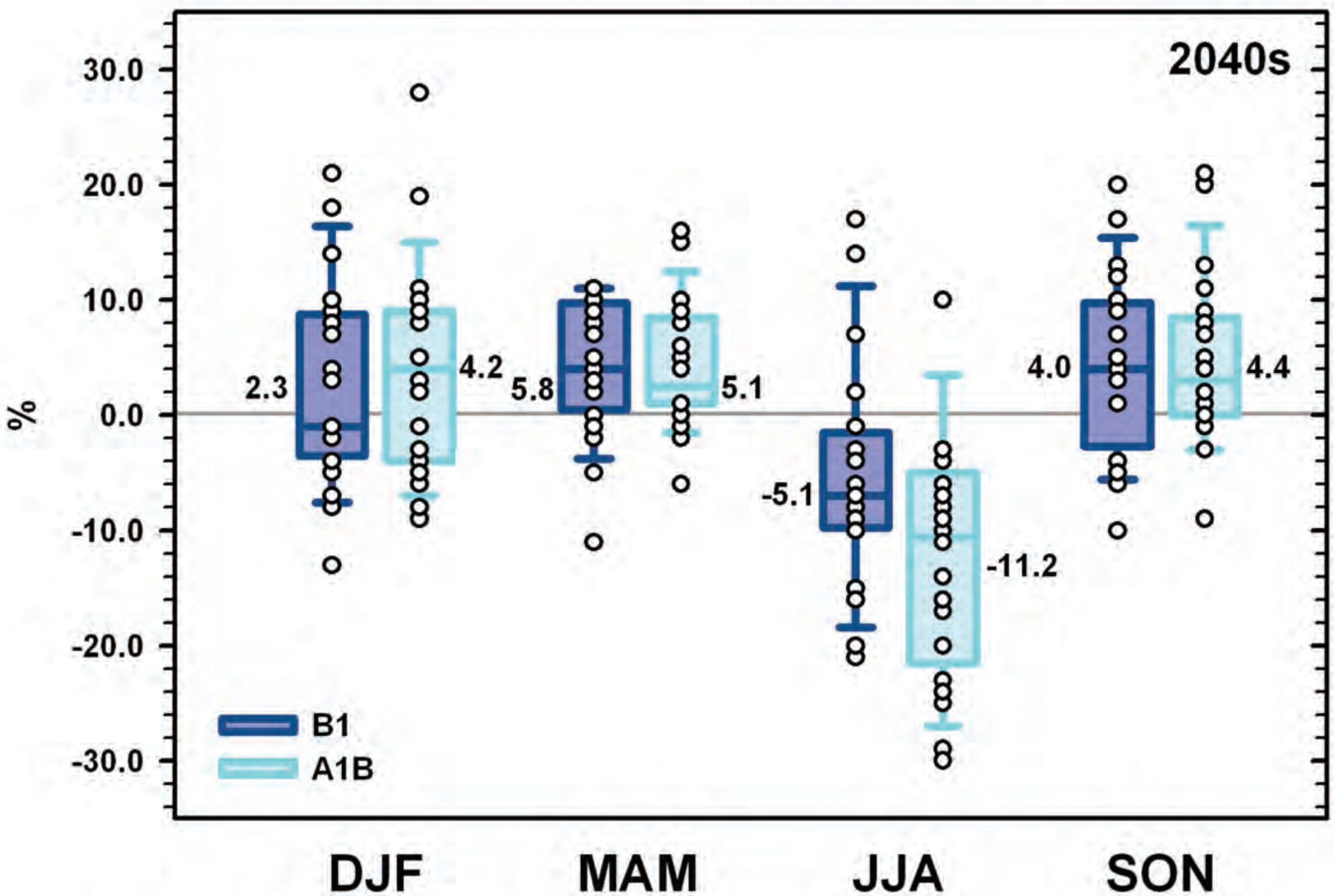


Mean temperature increases taken across models are comparable for winter, spring, and fall, but **higher for summer.**

Mote and Salathé 2010, Climatic Change

* Compared with 1970-1999 average

Seasonal differences in PNW precipitation changes

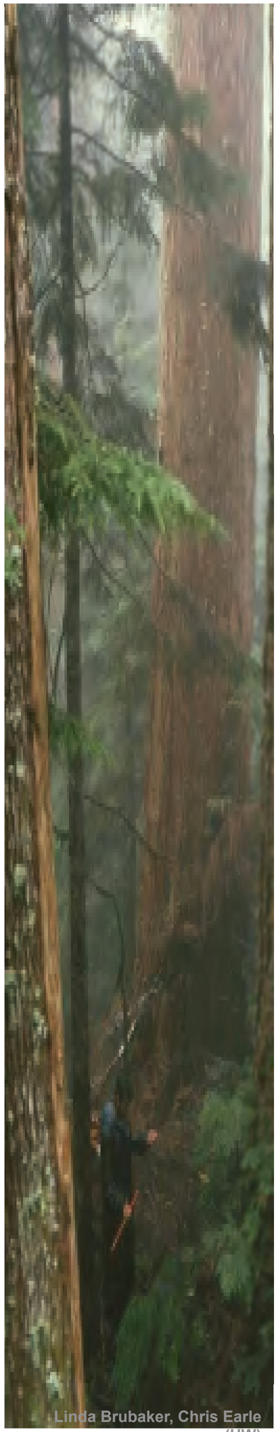


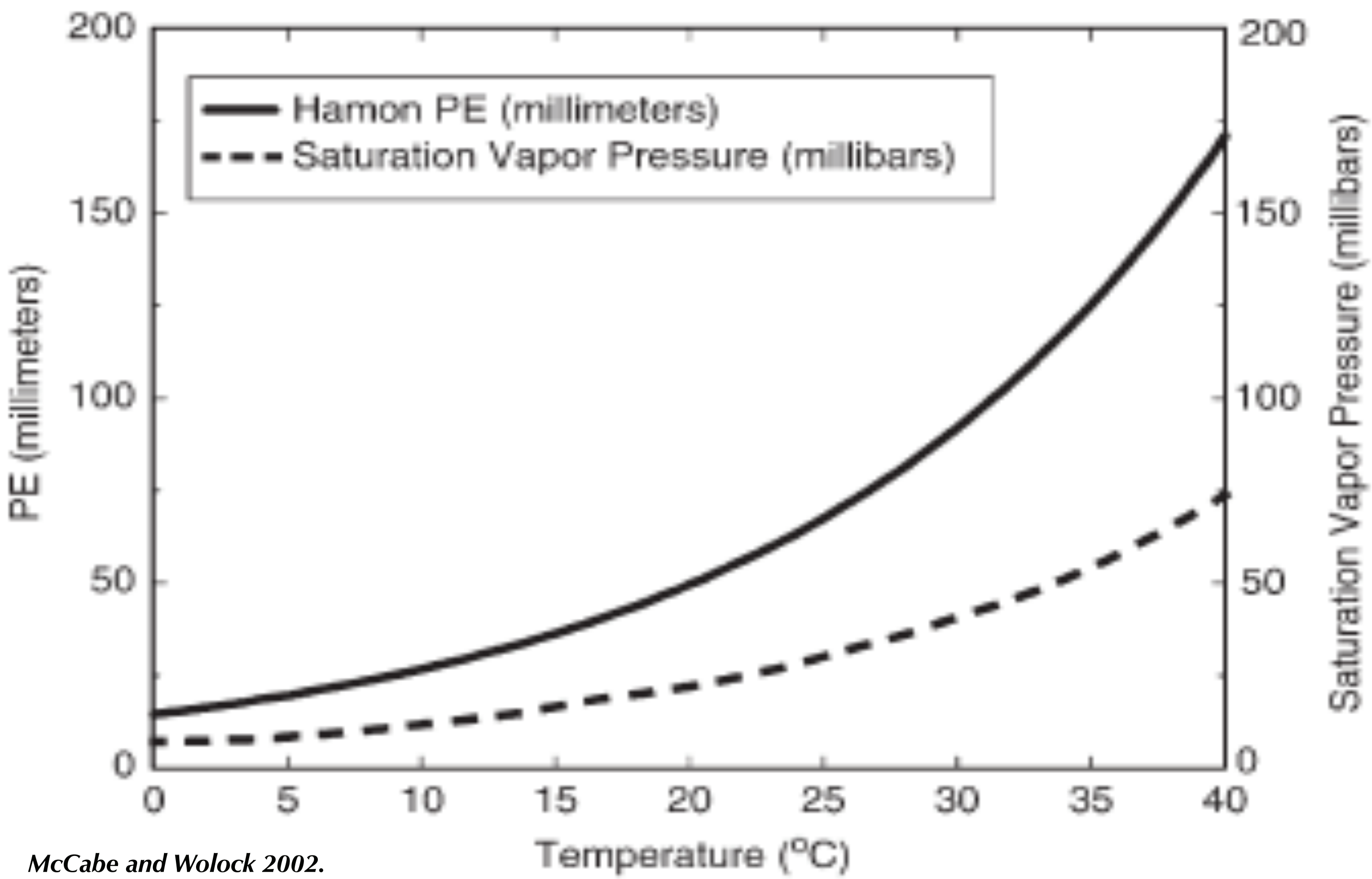
Mean precipitation increases comparable in terms of percentage for winter, spring, and fall. Most models project **summer precipitation decreases.**

Mote and Salathé 2010, Climatic Change

* Compared with 1970-1999 average

As temperature increases, potential evapotranspiration increases quickly, and water balance deficit increases quickly if precipitation does not change.

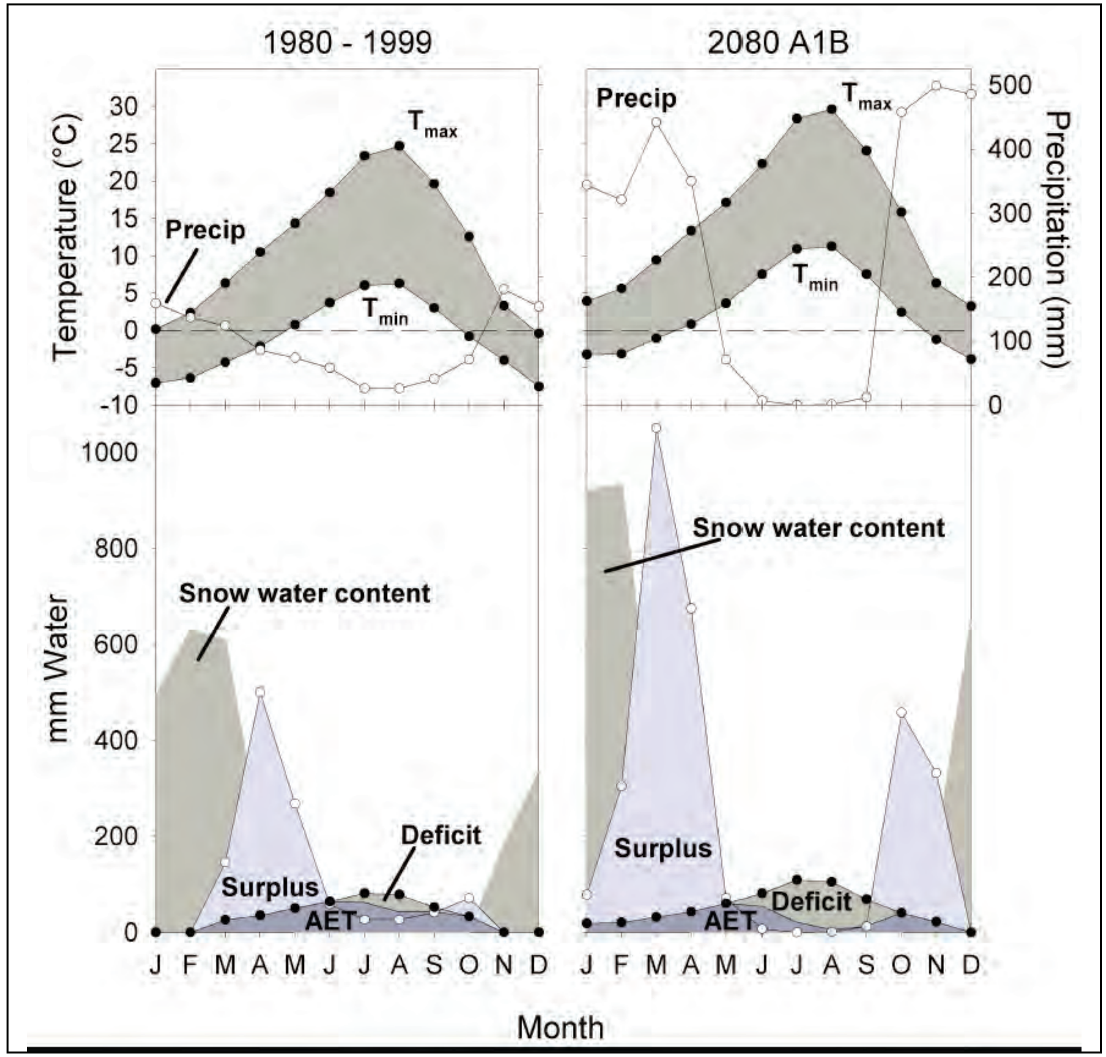




McCabe and Wolock 2002.

Water balance and forest impacts

- ***Water balance deficit*** is the difference between atmospheric demand for water and the water available to satisfy that demand
- As deficit increases, tree growth and regeneration typically become more limited (species dependent)
- Vulnerability to disturbance increases: insect host vulnerability increase, foliar moisture decrease

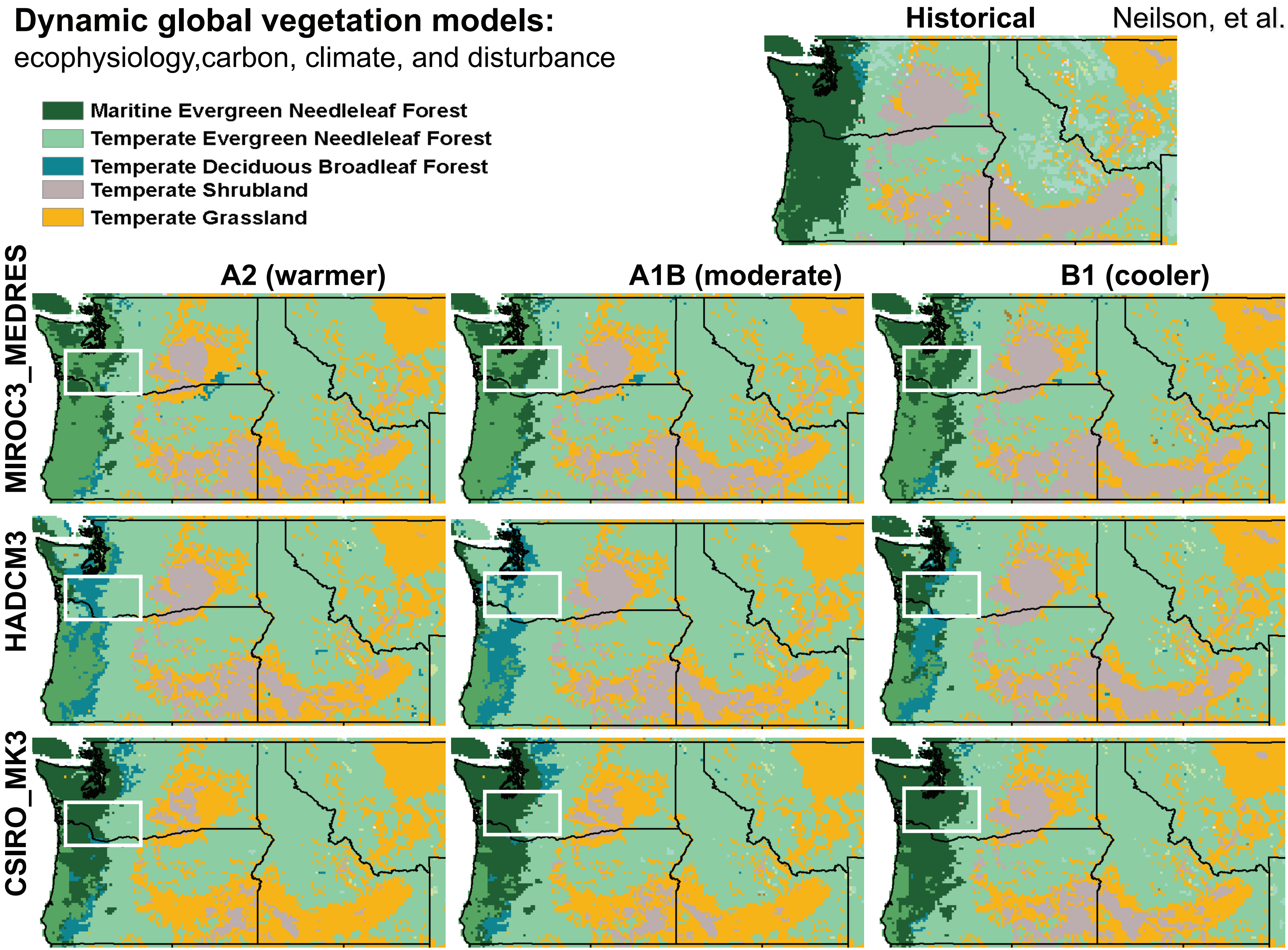


Littell et al. 2009

Disturbance, disturbance interactions, and species responses to climate will change the nature of vegetation and habitat:

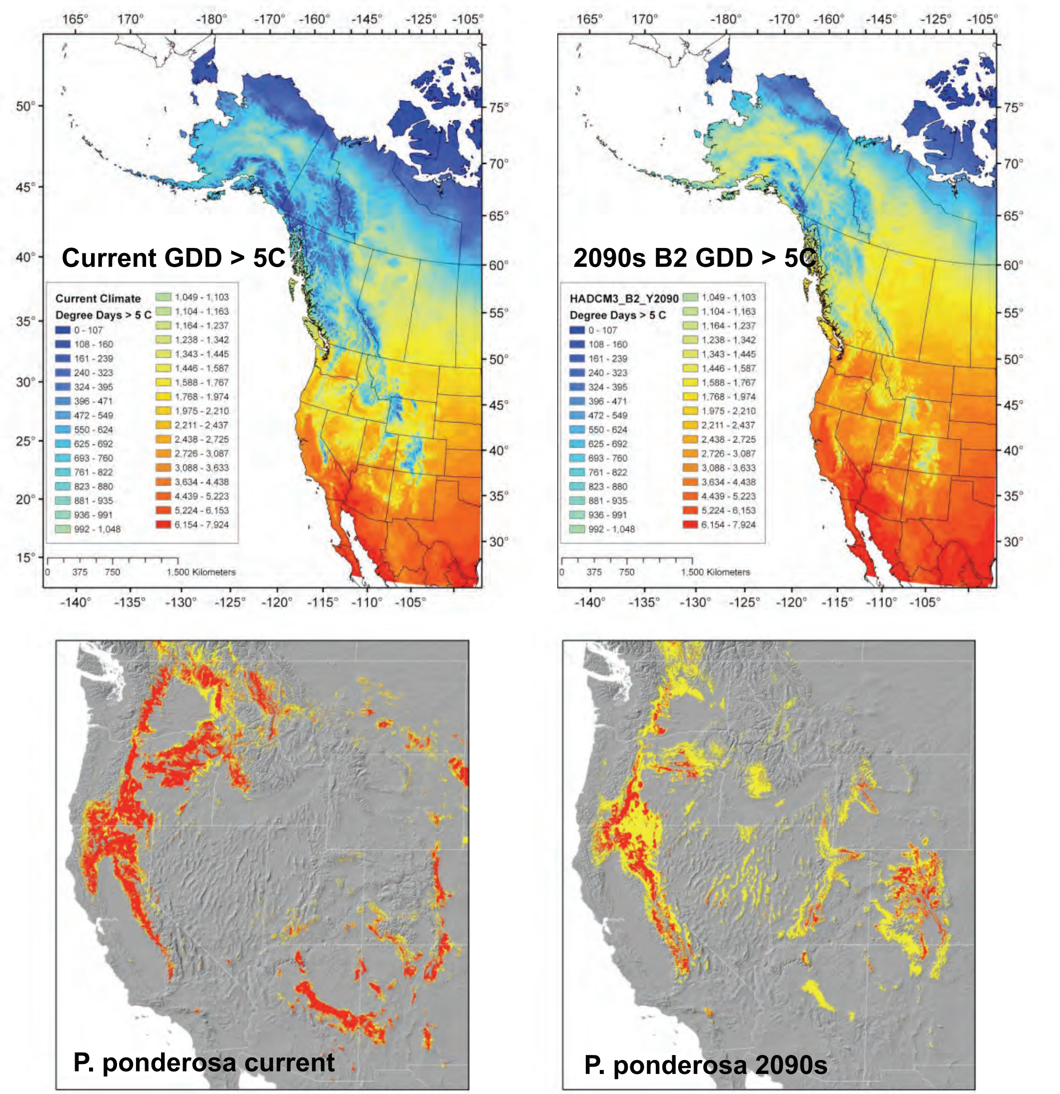
- Changes in tree growth and ecosystem productivity
- Changes in vegetation / species distribution and mortality
- Changes in disturbance rate, severity (fire, insects, pathogens)
- Disturbance interactions
- Forest ecohydrology responses

Dynamic global vegetation models:
ecophysiology,carbon, climate, and disturbance



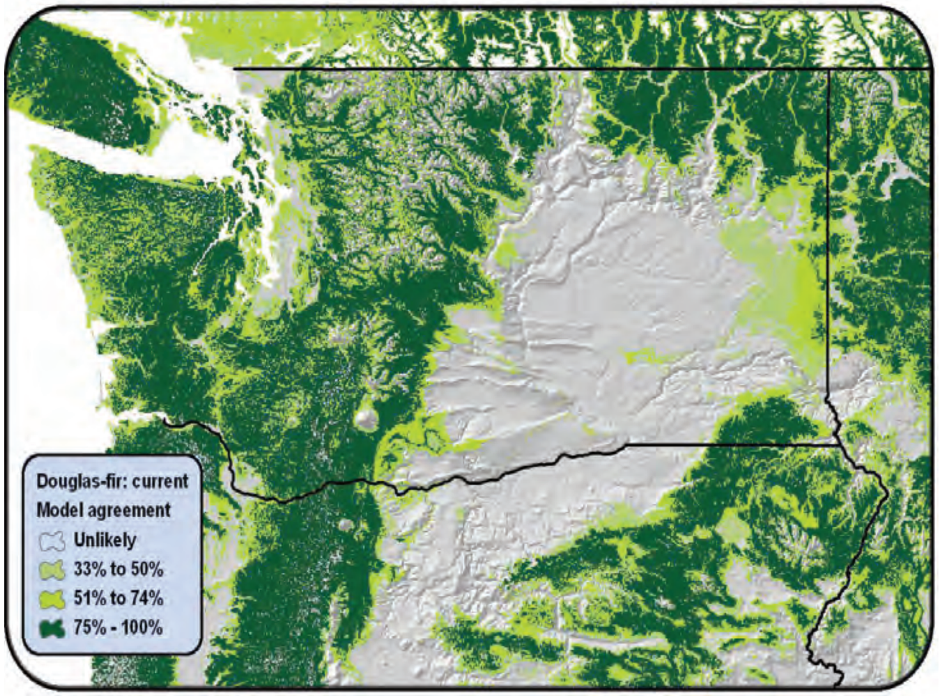
Statistical species distribution models

- Goals:
  - Develop predictive models that relate species distributions with their climatic drivers
  - Use models to extrapolate future potential species distributions based on future climate projections

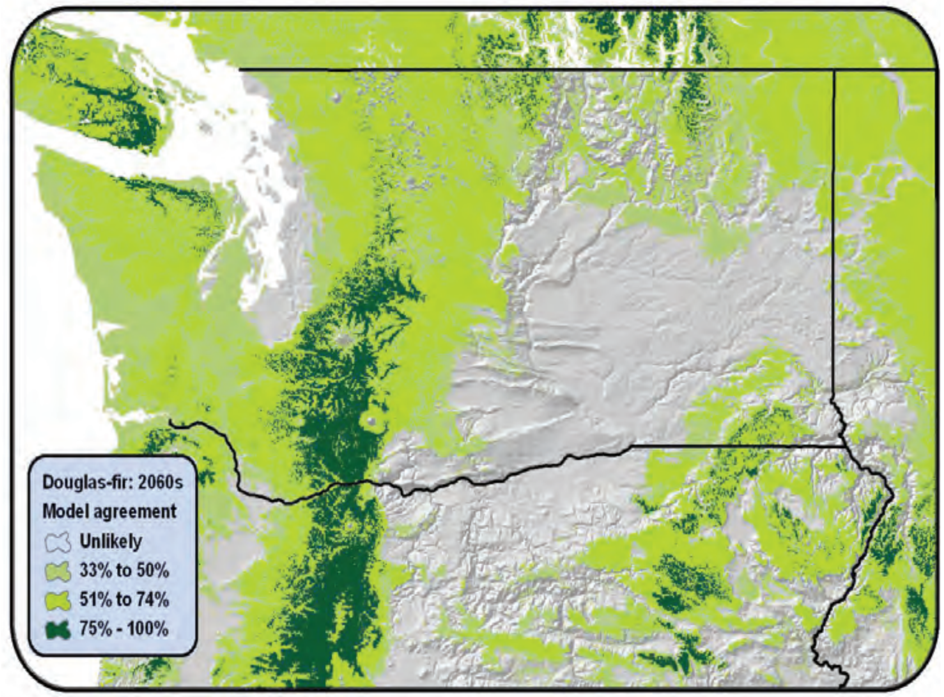


Rehfeldt et al. 2006, http://forest.moscowfsl.wsu.edu/climate/plantDistributions.html

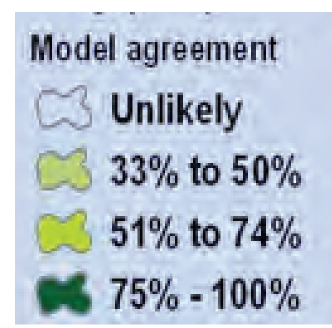
Changes in climatic suitability: Douglas-fir



Current



2060s



Changes in the potential climatically suitable range of Douglas-fir (Data: Rehfeldt et al. 2006, multiple IPCC scenarios).

Littell et al. 2009

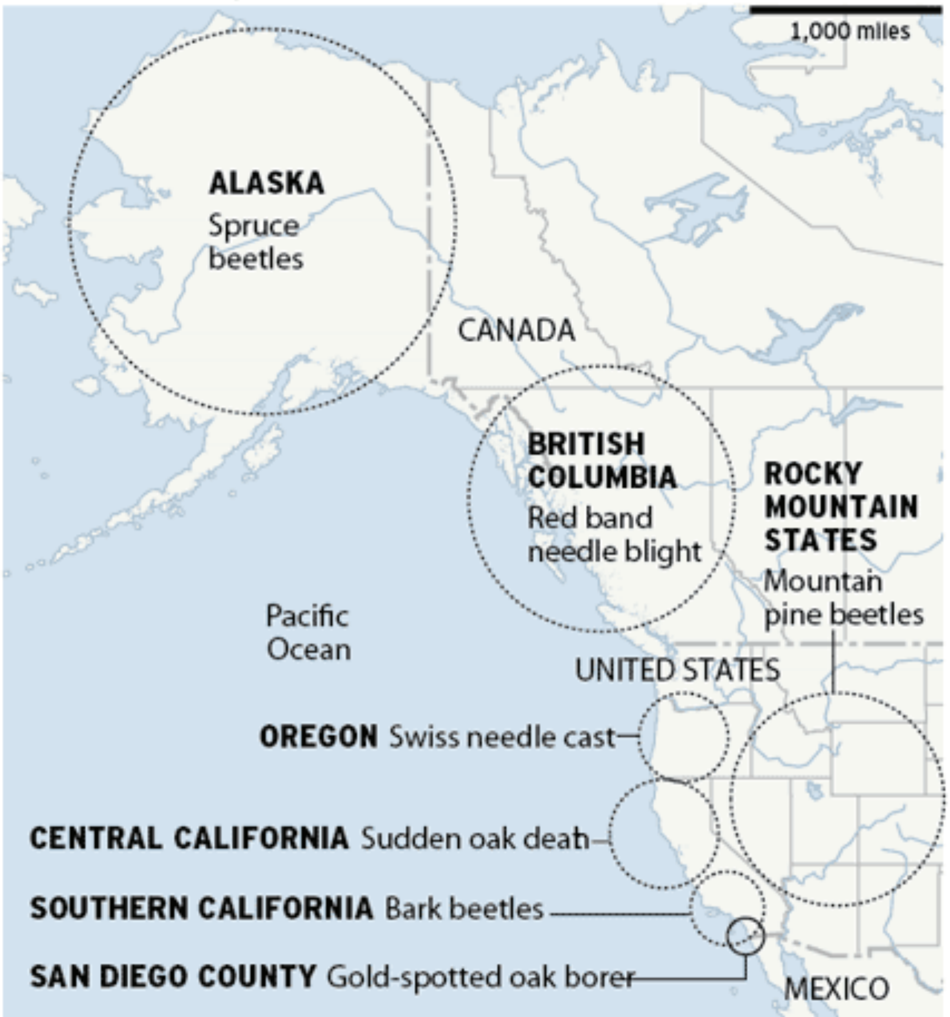
Climate and seedling establishment



- Key to consequences of both direct climate influences on species distributions AND implications of disturbance for landscapes, connectivity, and future management

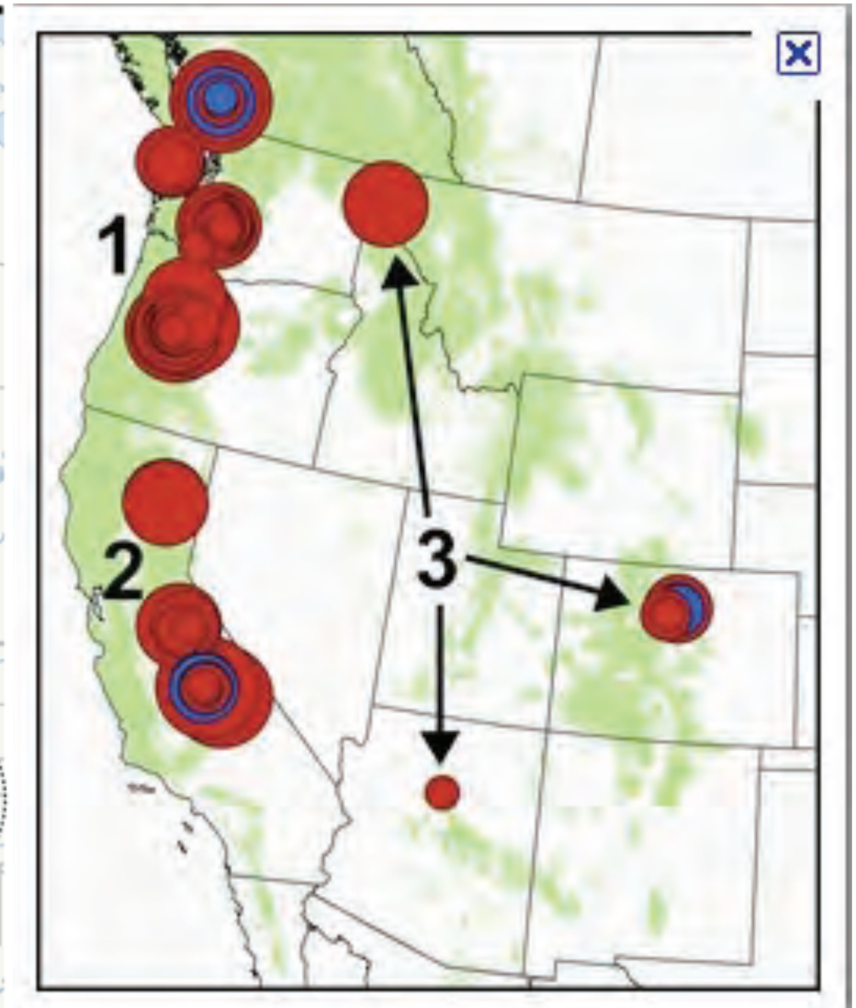
DYING FORESTS

Across the West, scientists are linking large-scale tree deaths to the changing climate. A look at some of the insects and diseases killing trees and the areas they afflict.



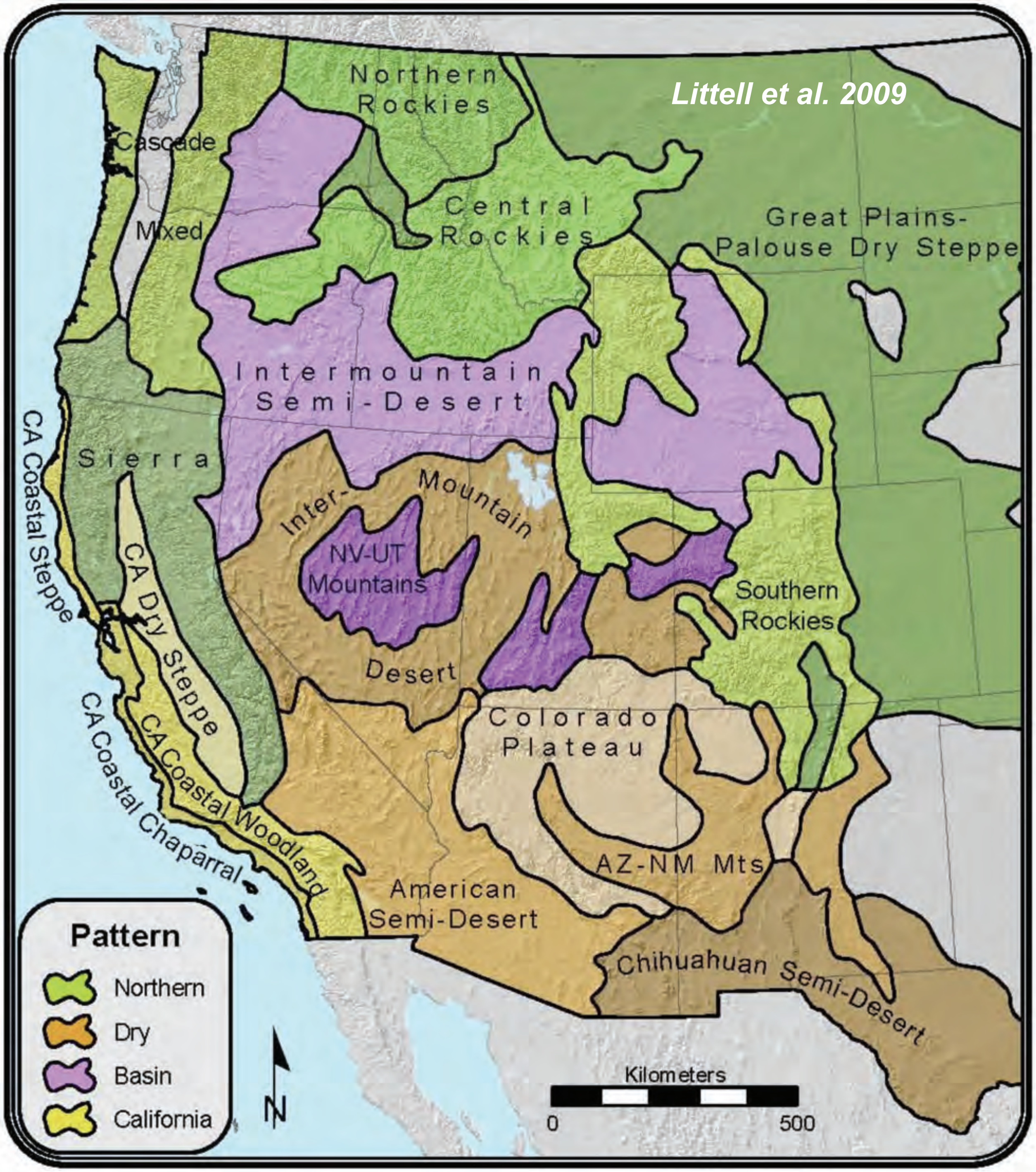
SOURCES: U.S. Forest Service; ESRI

AARON STECKELBERG / Union-Tribune



Van Mantgem et al. 2009, Science

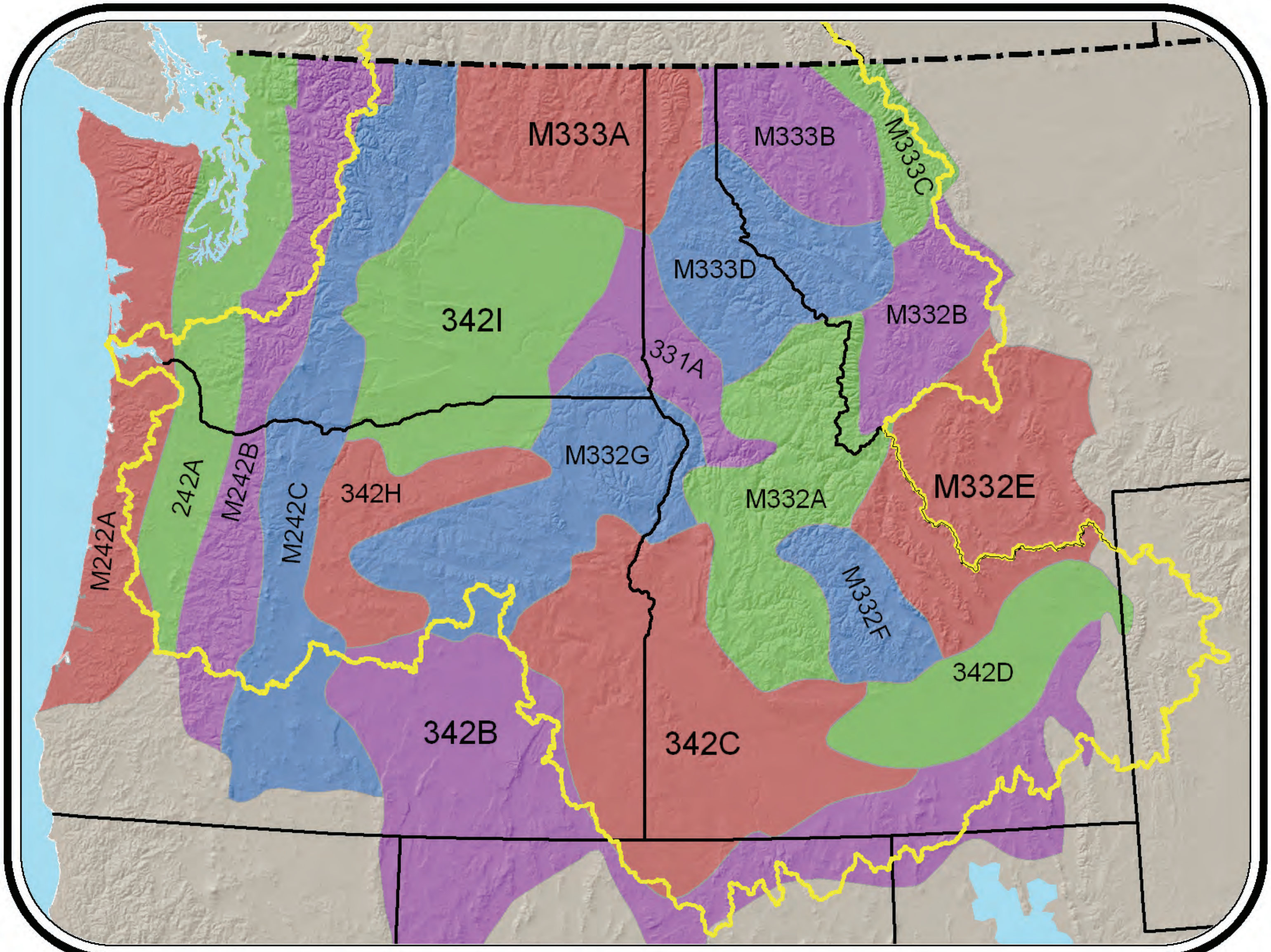
Climate effects on disturbance area, rate, severity (fire, insects, pathogens)



- Different fuel types respond differently to climate (T, P, PDSI)
- Two mechanisms:
  - *drying* of fuels
  - *production* of fuels
- Fuel (moisture) - limited systems
- Climate (energy) - limited systems
- At scale of eco-provinces, both represented – hybrid models common

Map: R. Norheim

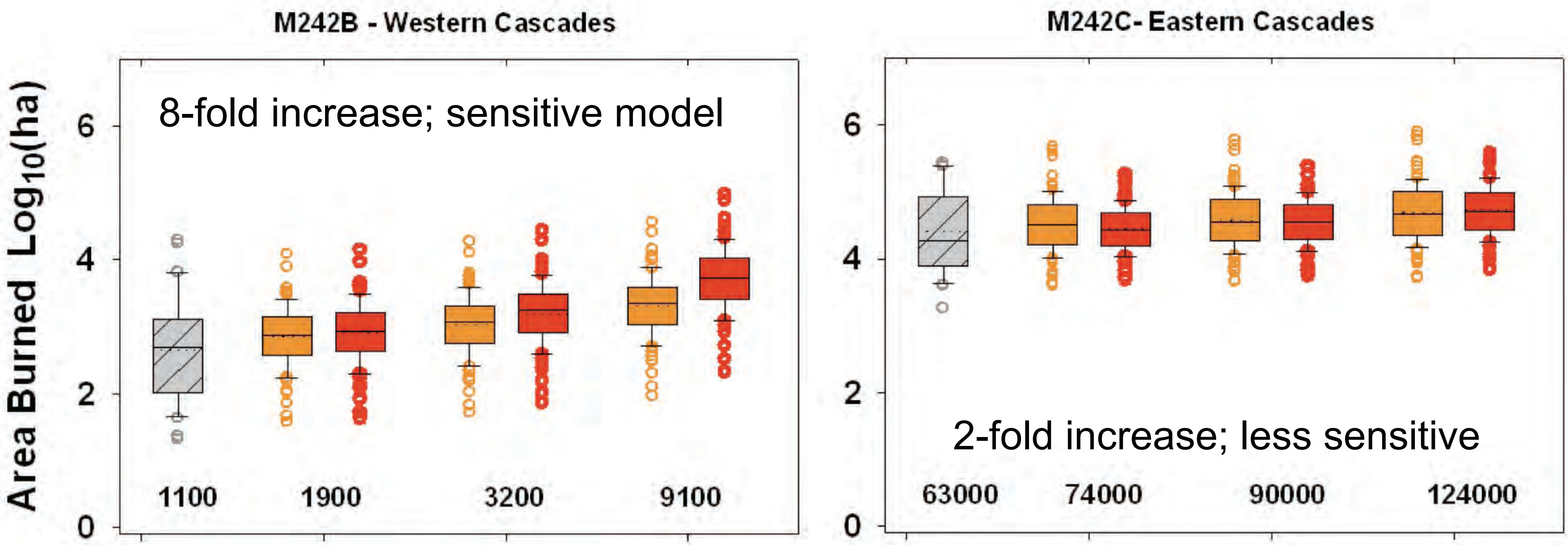
Bailey's Ecosections, water balance and fire



Map: Rob Norheim

Littell and Gwozdz, 2011

Future area burned in ecosections



- Historical regional average: 425,000 acres
  - 2020s: 0.8 million; 2040s: 1.4 million; 2080s: 1.8 million

- Probability of a year >> 2 million acres:
  - Hist.: 5%; 2020s: 5% (1 in 20); 2040s: 17% (~1 in 6); 2080s: 47% (~1 in 2)

Based on statistical fire models and future climate derived from 20 GCMs and the VIC hydrologic model. Best models include: summer precip + summer temp OR summer water balance deficit. Littell et al. 2010 Climatic Change

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"

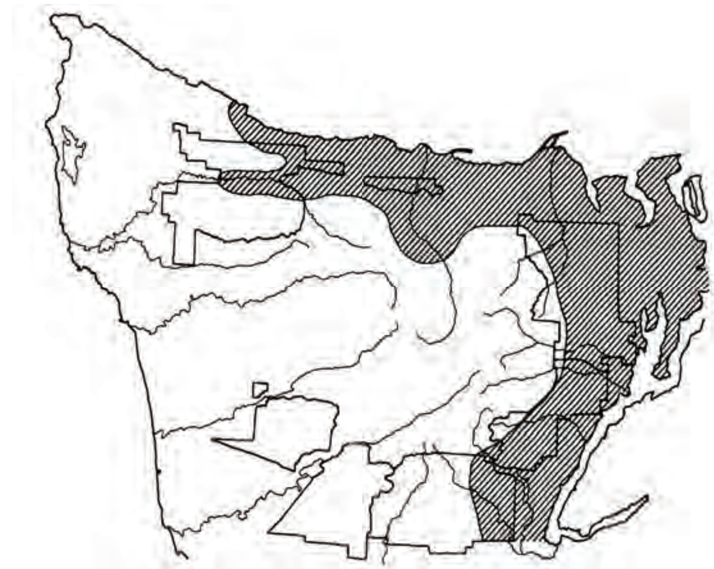
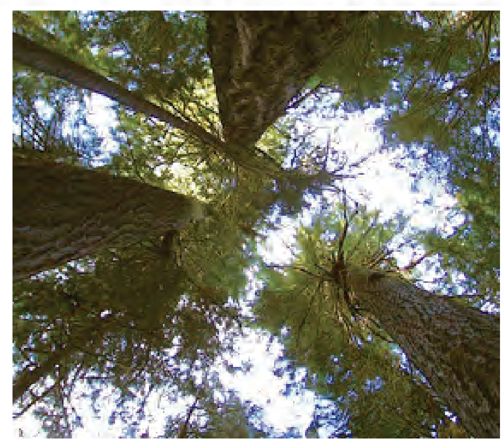


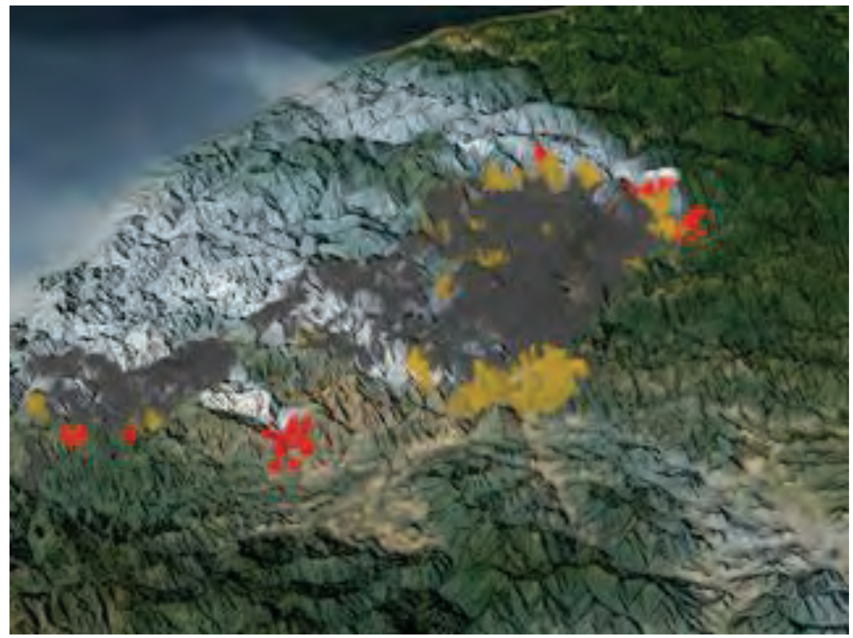
Figure 5. Map of Olympic Peninsula showing the remnant stands from the fire about 1701.



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.

What does all this mean for fire on real landscapes, and what do we do about it?

- Is it more fires like the ones we have experience with?
- Is it more larger fires? How severe are they?
- Is it simply just a longer fire season full of more of the same?



Biscuit fire, image: NASA

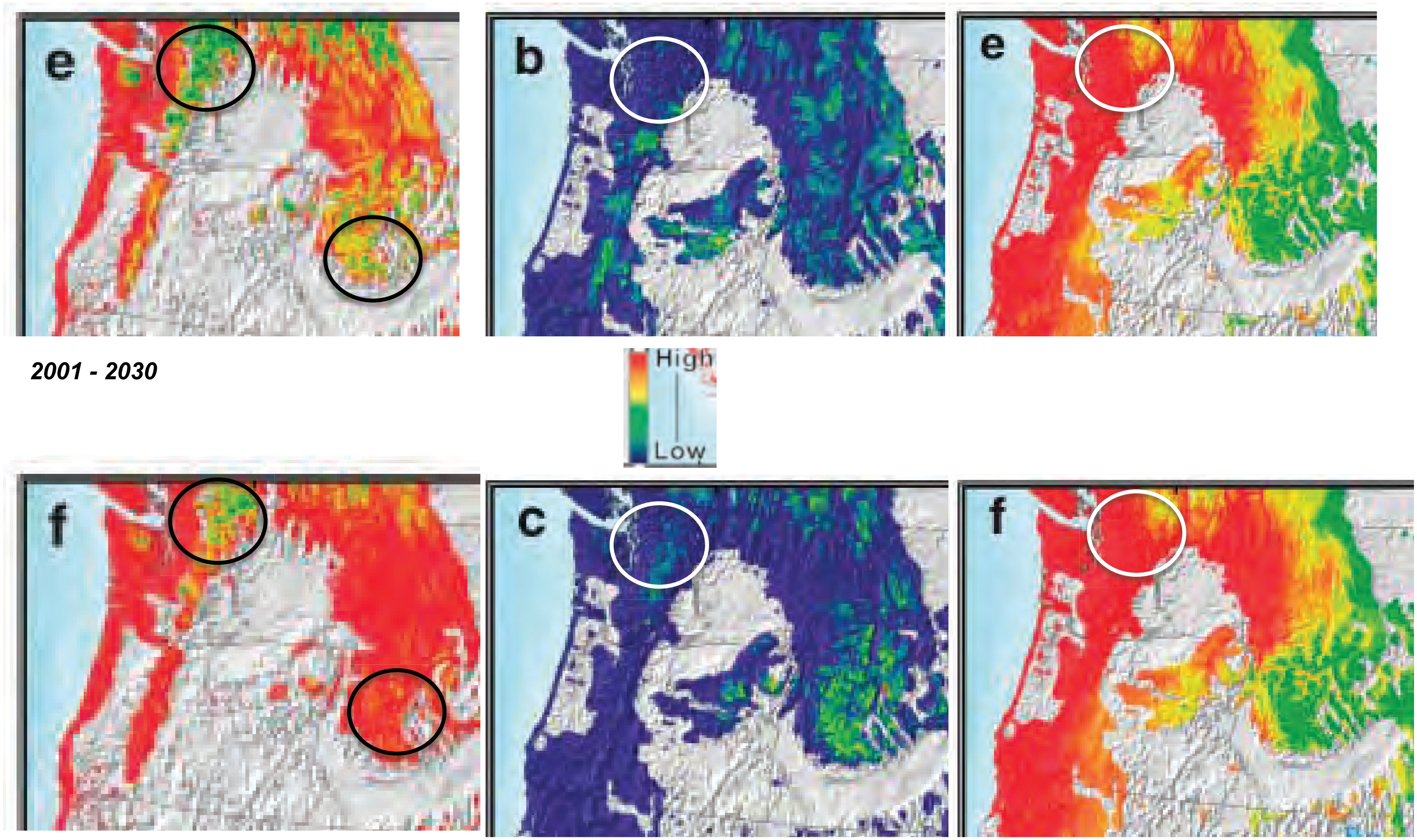
What we do about it may actually be informed by experience as much as science…..we manage our expectations and risk

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

Kawuneeche Valley Mountain Pine Beetle Kill at Farview Curve by Fort Photo /

Insects: Mountain Pine Beetle (and others)

- Two ways climate affects forest vulnerability:
  - Insects' life cycle:
    - Increased temperature decreases generation time
    - failure of cold temperatures decrease winter mortality
  - Trees' resistance:
    - Increased summer temperature and decreased precipitation decrease resistance
- Some insects more closely tied to climate than others:
  - Mountain pine beetle
  - Western spruce budworm
  - Spruce beetle

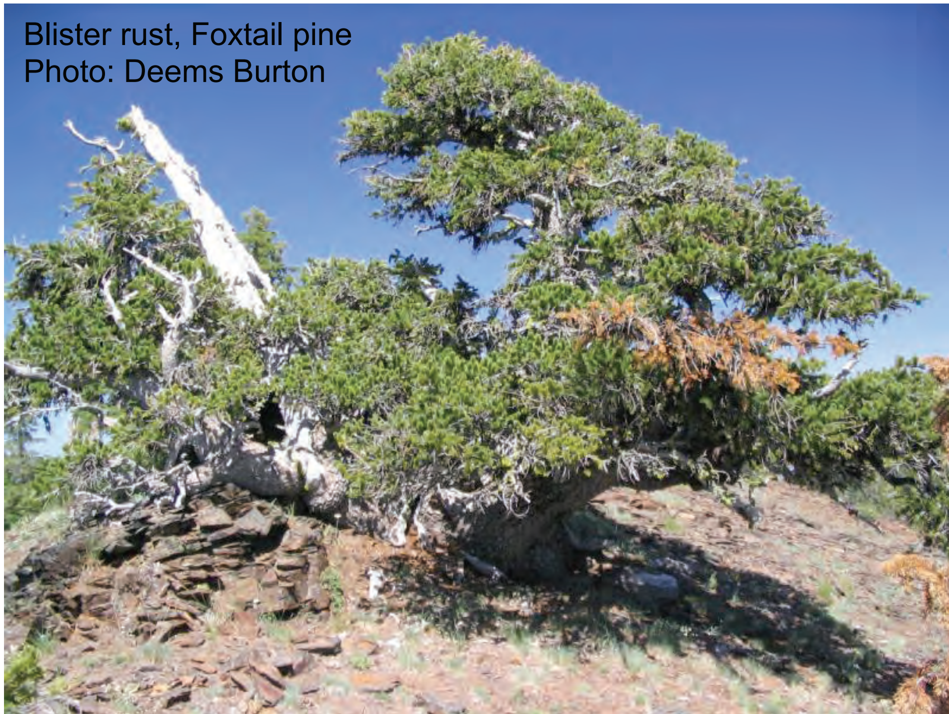


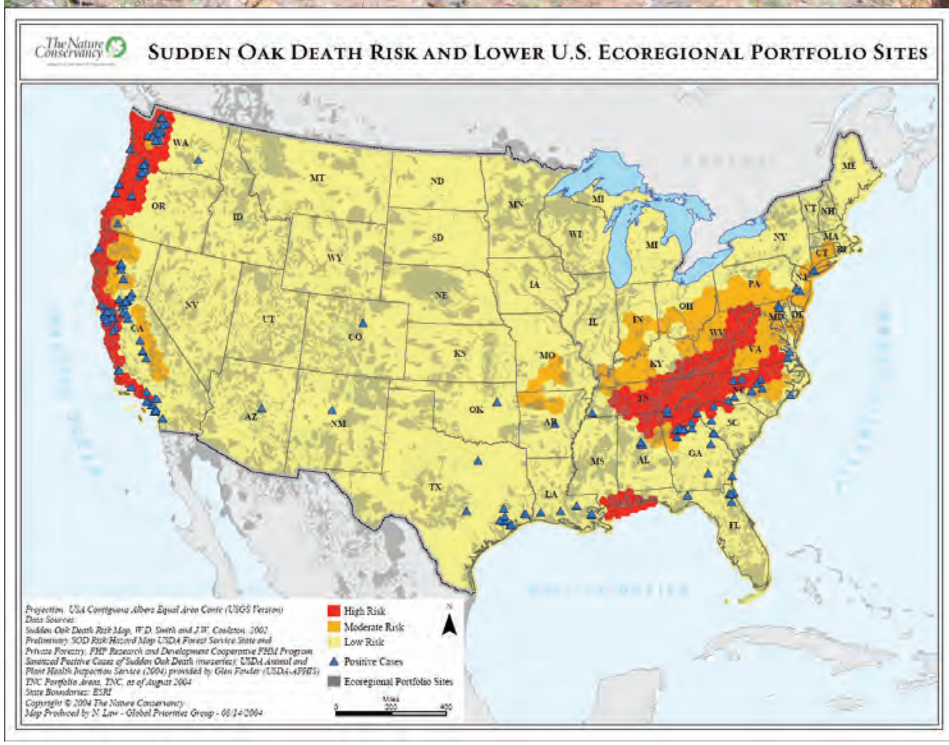
2001 - 2030

2071 - 2100

Spruce beetle univoltine (probability) ***MPB adaptive seasonality*** ***MPB cold survival***

Bentz et al. 2010 Bioscience


Blister rust, Foxtail pine
Photo: Deems Burton



Disease

- Changes in climate affect:
  - Tree susceptibility
  - Pathogen ranges
  - Pathogen survivorship
  - Host - pathogen physiology

- Varies with climate, pathogen / host biology, and other stressors

CLIMATE IMPACTS GROUP

Disease

- Increased connectivity and global trade may present unique risk

- Likely that increased stress from multiple sources in many tree species will increase infection rate and mortality

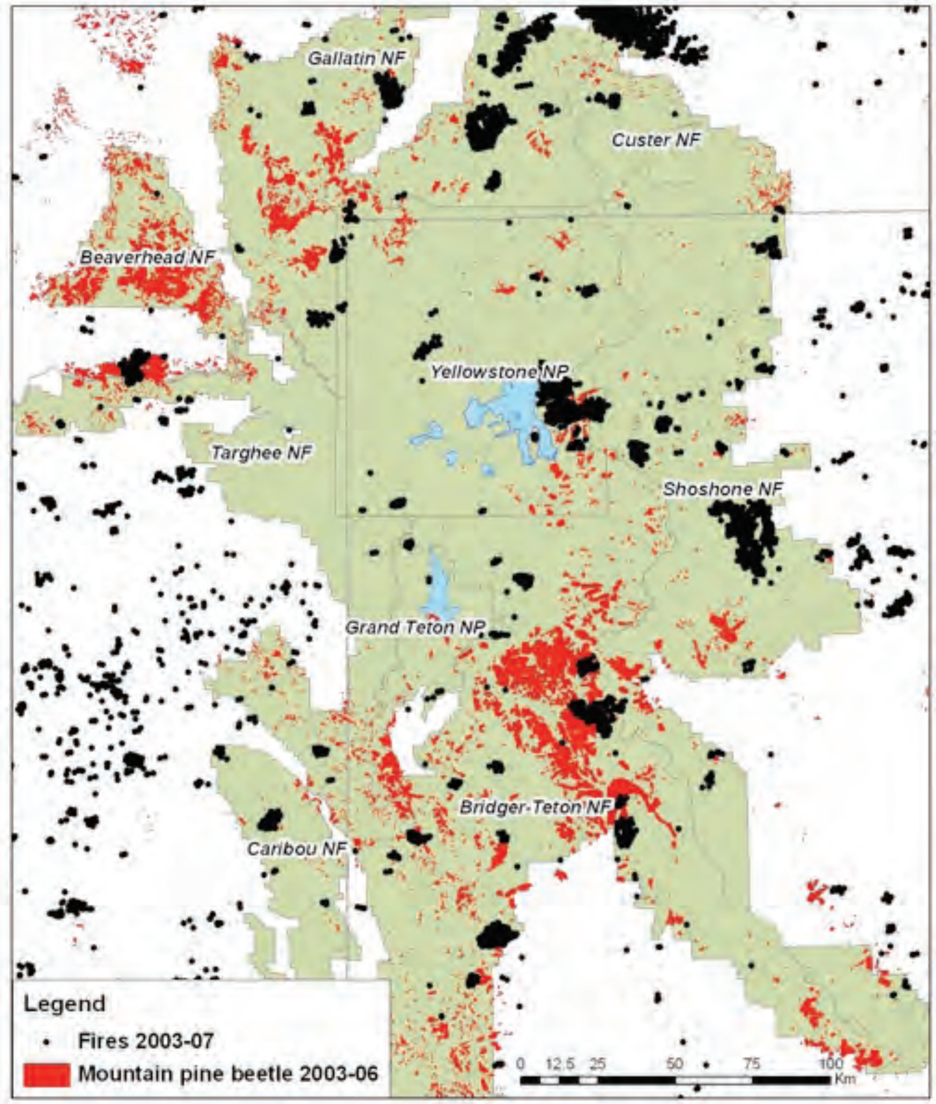
Credit: Woods, B.C. Ministry of Forests
Lodgepole pine plantation in Northwest British Columbia heavily impacted by red band needle blight caused by Dothiostroma pini.

CLIMATE IMPACTS GROUP

Disturbance interactions

Timing of wildfires and insect outbreaks can produce positive or negative feedbacks.

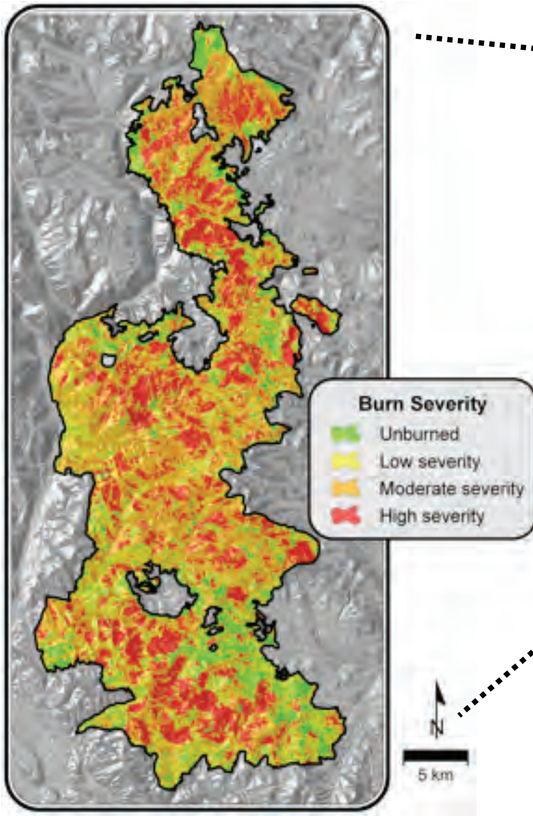
Thresholds can be reached via cumulative effects or one big event.

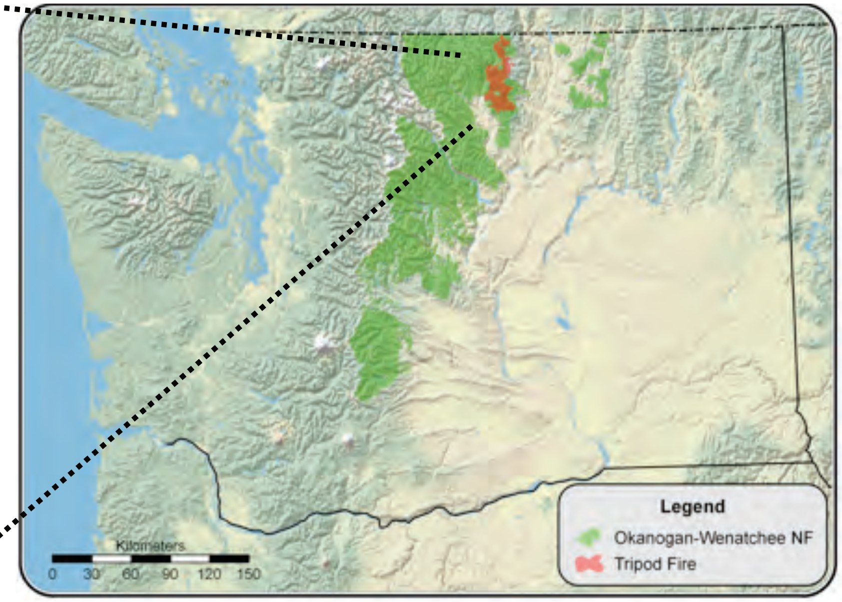


Yellowstone -- *Simard 2008*

Slide: Don McKenzie, USFS

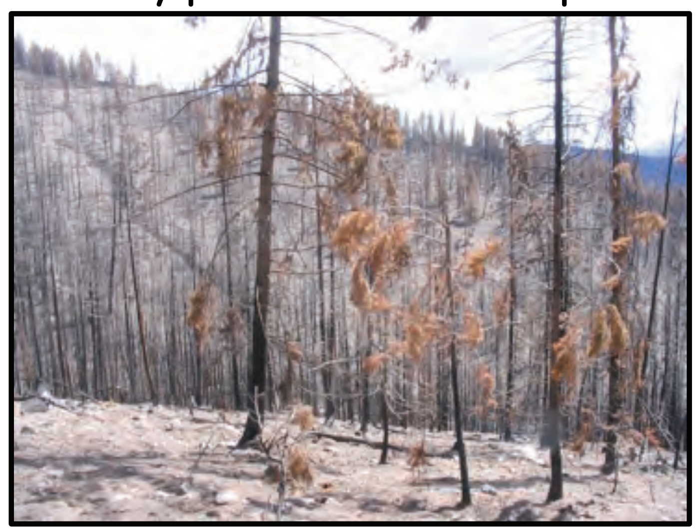
Slide: Don McKenzie, USFS





Tripod Complex Fire 2006

Highest-severity patches had mountain pine beetle



Disturbance uncertainties and implications

- Uncertainties:
  - Disturbance synergies, interactions with and limitations of vegetation
  - West Cascades and Olympics sensitivity is possibly “threshold”, and statistical fire models probably do a poor job – if anything, we UNDERESTIMATE
  - Other insects’ climatic sensitivity
  - Climate – decadal variability: role of “chance” events in ecosystems
- Implications:
  - Rate of vegetation and landscape change would potentially be much faster than species responses alone.
  - Large fires are destructive, but potentially an opportunity to affect ecosystem trajectories too - if new varieties or new species are planned, conversion can be faster.
  - Cross-jurisdictional issues – partnerships and joint planning probably beneficial

Modeled climate and hydrology → real landscapes?
Science – management partnerships =
better – *and more useful* - prediction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More information on Columbia basin and PNW climate impacts and planning for climate change is available from::
www.cses.washington.edu/cig