Climate change, mountain pine beetles, and whitebark pine forests of the Greater Yellowstone Area

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photo P. Buotte

Presentation Outline

1. Introduction

1. Objectives

1. Methods

1. Results & Discussion

1. Conclusions

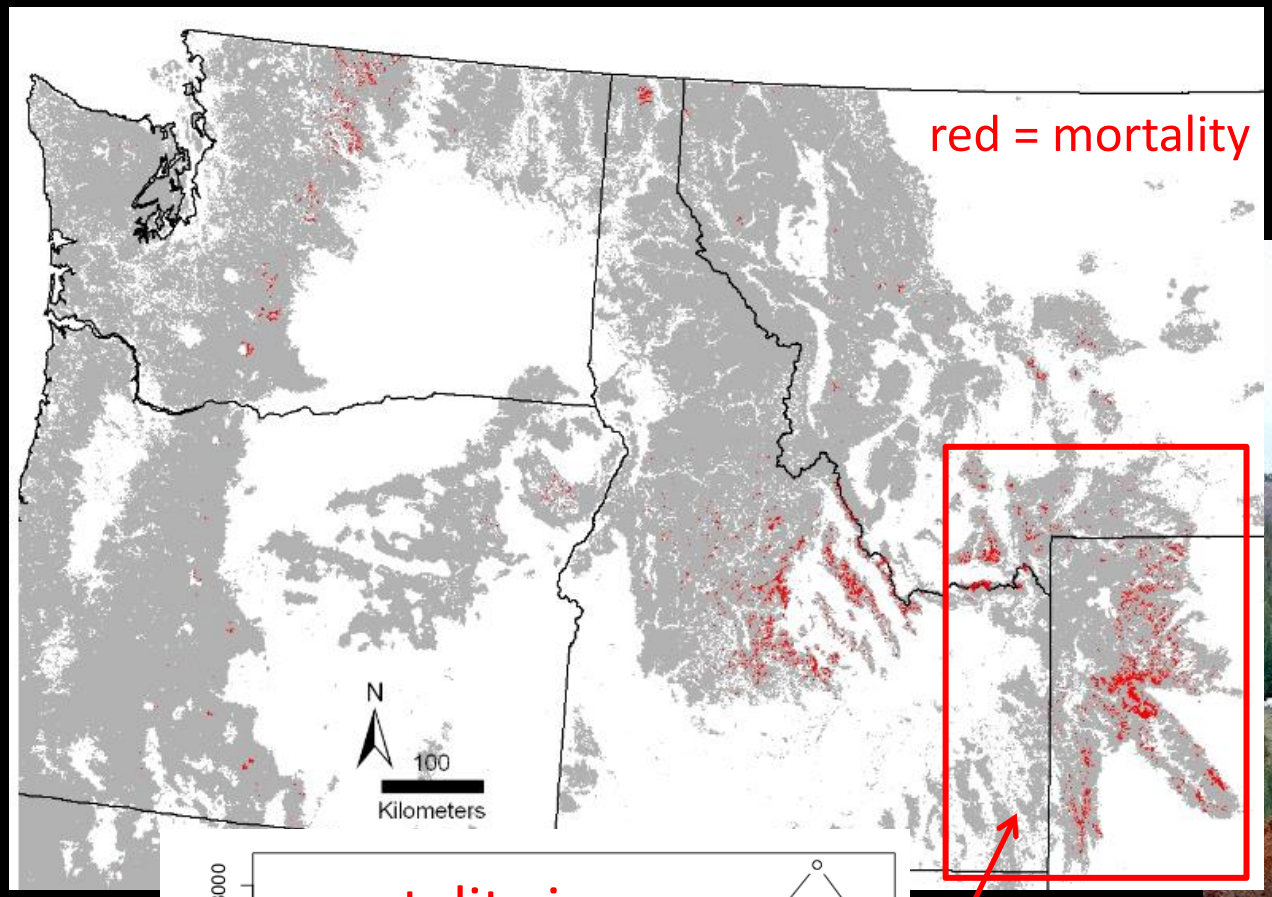
2. Summary

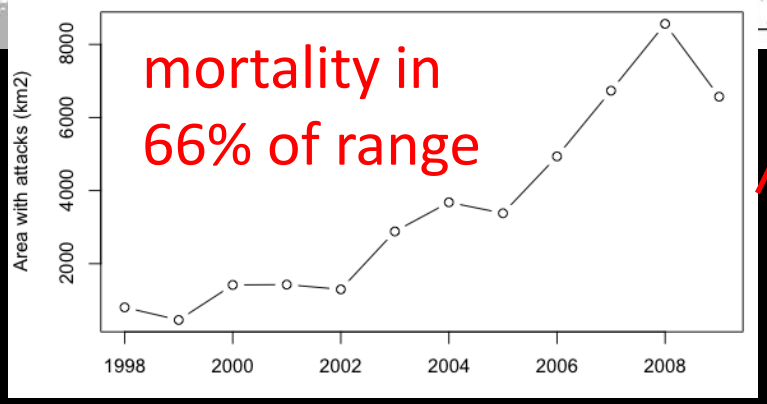
http://commons.wikimedia.org/wiki/File:Whitebark_pine_Pinus_albicaulis_20-Lakes.jpg

Whitebark pine
A keystone species

Whitebark pine is declining

Whitebark pine mortality from beetles 1997-2010





Mountain pine beetle life cycle

Summer	Fall	Winter	Spring	Summer
Adults attack trees and lay eggs	Eggs grow into larvae	Development stops	Development resumes	Adults emerge and fly to new trees

Mountain pine beetle life cycle

Summer	Fall	Winter	Spring	Summer
Adults attack trees and lay eggs	Eggs grow into larvae	Development stops	Development resumes	Adults emerge and fly to new trees

Adaptive seasonality:
1-year life cycle
mass emergence

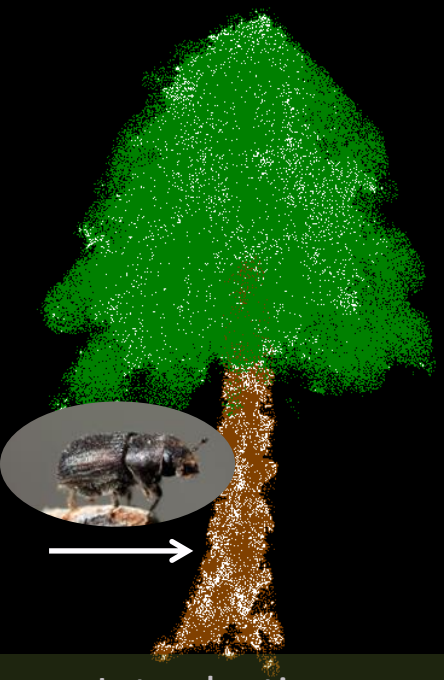
Mountain pine beetle life cycle

Summer	Fall	Winter	Spring	Summer
Adults attack trees and lay eggs	Eggs grow into larvae	Development stops	Development resumes	Adults emerge and fly to new trees

Winter beetle mortality

Mountain pine beetle life cycle

Summer	Fall	Winter	Spring	Summer
Adults attack trees and lay eggs	Eggs grow into larvae	Development stops	Development resumes	Adults emerge and fly to new trees



Tree drought stress

Objectives

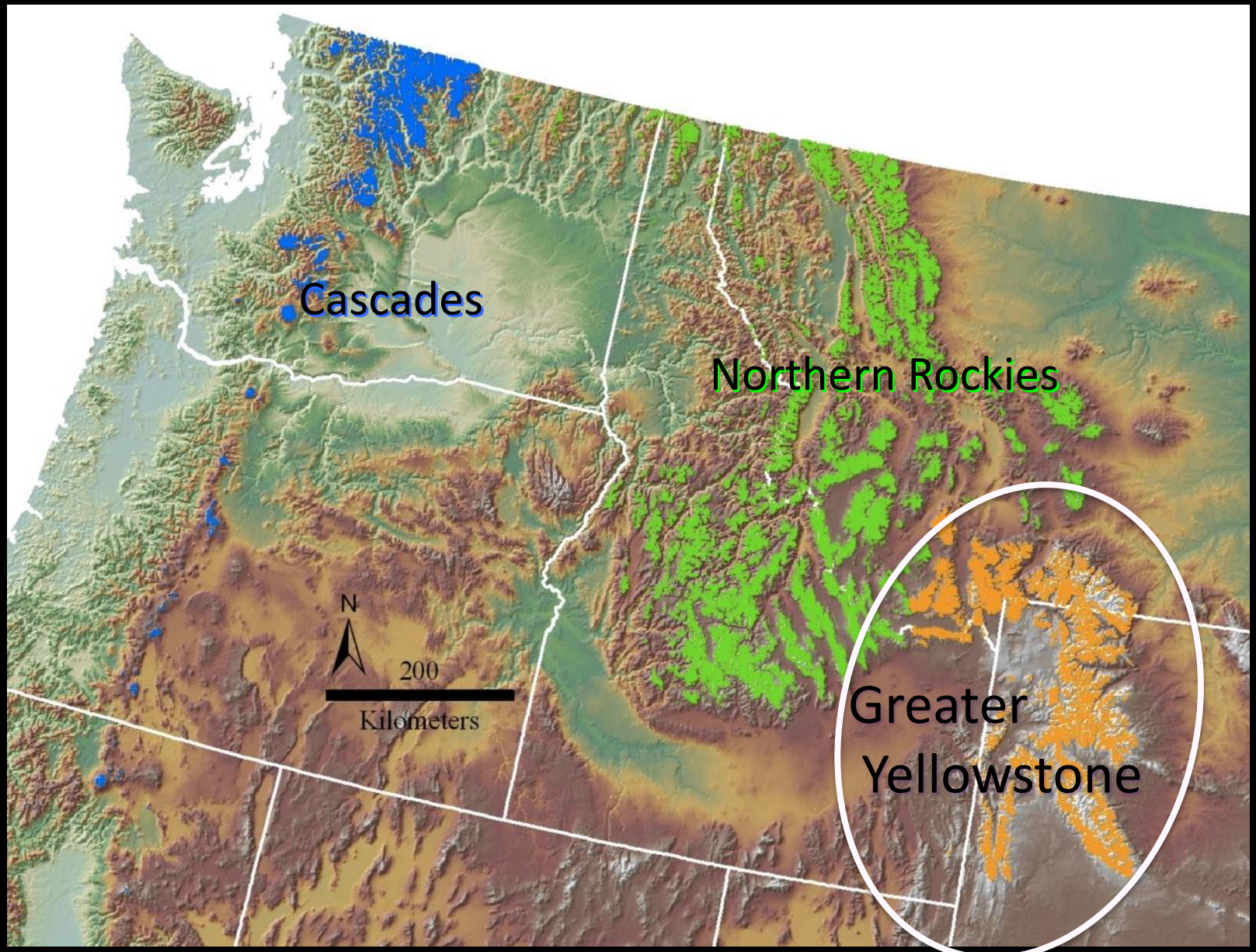
1. Quantify climate-beetle relationships in whitebark pine

2. Understand causes of the recent outbreak

3. Estimate historical, current, and future weather suitability for beetle attacks

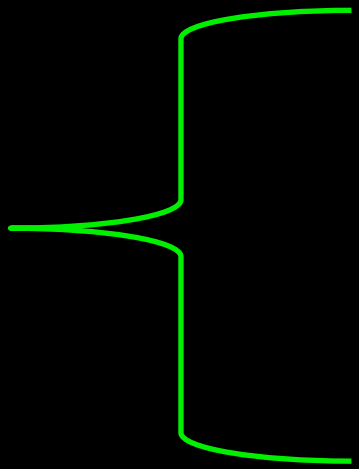

photo P. Buotte

Study area: three regions of whitebark pine range



Methods: Statistical modeling

Probability of tree mortality

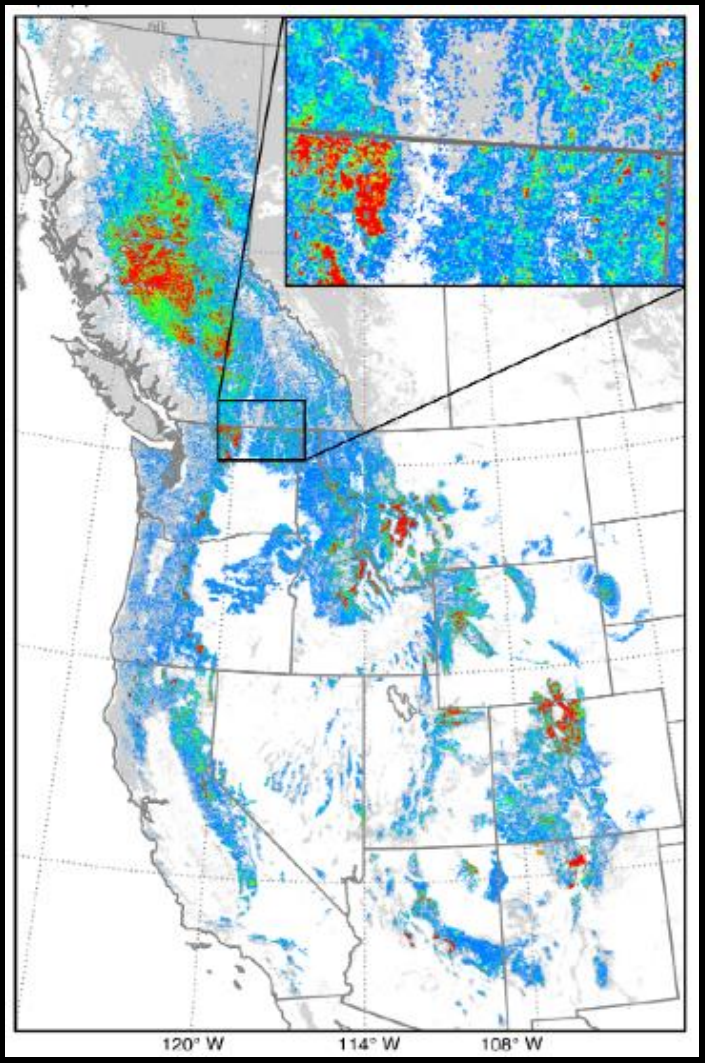


1. Beetle pressure
1. Stand structure
1. Climate

Response variable

Presence of whitebark pine mortality from mountain pine beetles

- from 1997-2010 Aerial Detection Surveys gridded to 1-km spatial resolution (Meddens et al. 2012)



Meddens et al. 2012, Eco. App.

Potential explanatory variables: Beetle pressure

local beetle pressure

trees killed last year within cell

dispersal beetle pressure

trees killed last year in 6-km radius

both from processed Aerial Detection Surveys (Meddens et al. 2012)

Potential explanatory variables: Stand structure

Remaining whitebark pine

100 - cumulative mortality area since 1997 (Meddens et al. 2012)

Percent whitebark pine in 1-km grid cell

30-m map for the Greater Yellowstone Area (Landenburger et al. 2008)

Biomass, diameter, basal area

data sets available but highly uncertain

Potential explanatory variables: Climate

Adaptive Seasonality

Mean Sept-Nov temp
Mean April-Aug temp
Mean Sept-Aug temp
Logan AS probability
Daily temperature metrics

0-1 year lags;
PRISM and BioSIM data

Potential explanatory variables: Climate

Beetle winter mortality

Minimum winter temp
Cold tolerance

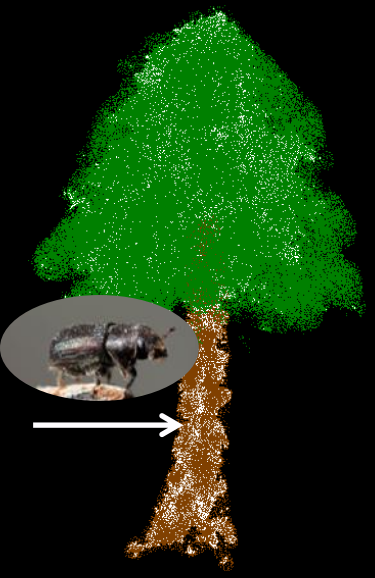
0-1 year lags;
PRISM and BioSIM data

Potential explanatory variables: Climate

Tree drought stress

Water year precip
Summer precip
Climatic Water Deficit
Vapor Pressure Deficit

} 0-5 year lags; PRISM data



Statistical model structure

logistic generalized additive model:
nonlinear relationships

all candidate models had:

- beetle pressure
- stand structure
- one variable representing each of:
  - adaptive seasonality
  - beetle winter mortality
  - tree drought stress

model selection: AIC

Estimating weather suitability: Model application

Best model

Historical weather
- Monthly PRISM data 1900 – 2009

Future projections
- 10 GCMs
- 3 emissions scenarios RCP 2.6, 4.5, 8.5

Weather suitability index
sum of the weather terms

Results: Best model

Probability of tree mortality

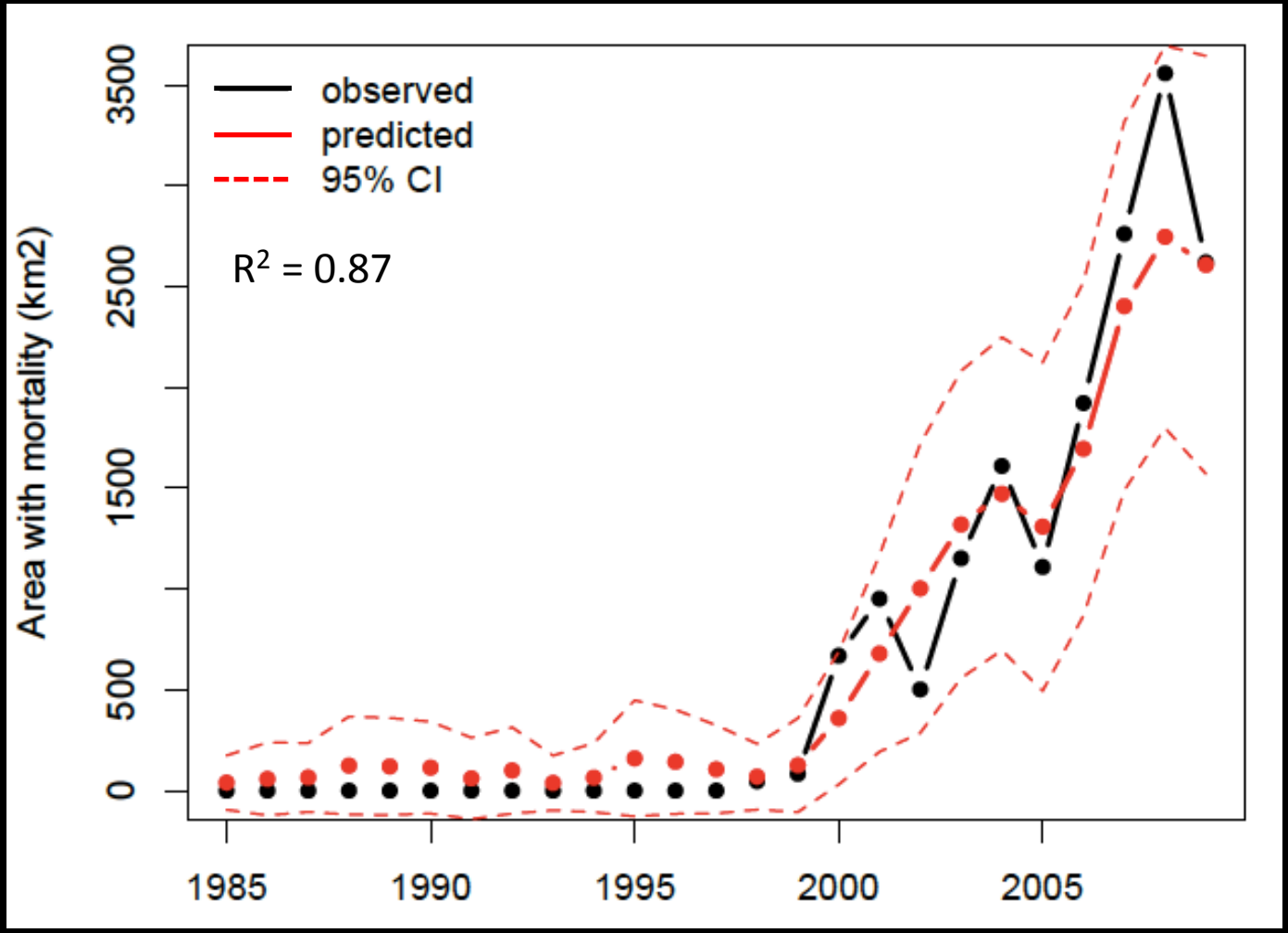
1. Beetle pressure
   - local
   - dispersal

1. Stand structure
   - % whitebark pine

1. Climate
   - adaptive seasonality:
     fall temp and spring-summer temp
   - beetle winter mortality:
     winter minimum temp
   - tree drought stress:
     cumulative 2-year summer precip

Model goodness-of-fit

predictions similar to observations



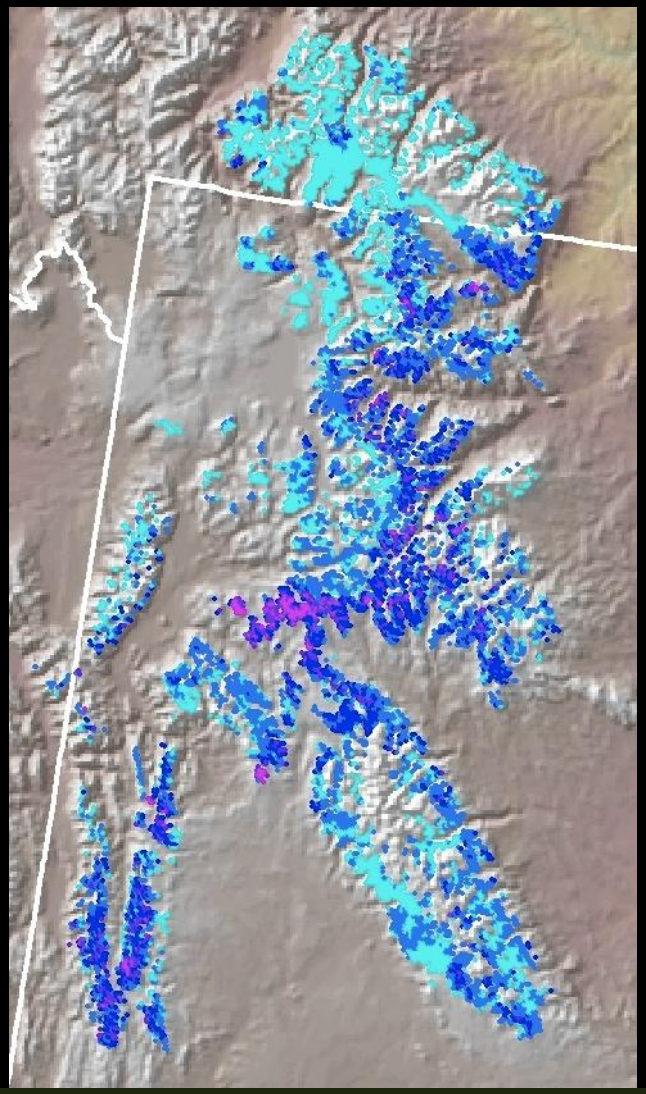
Model goodness-of-fit

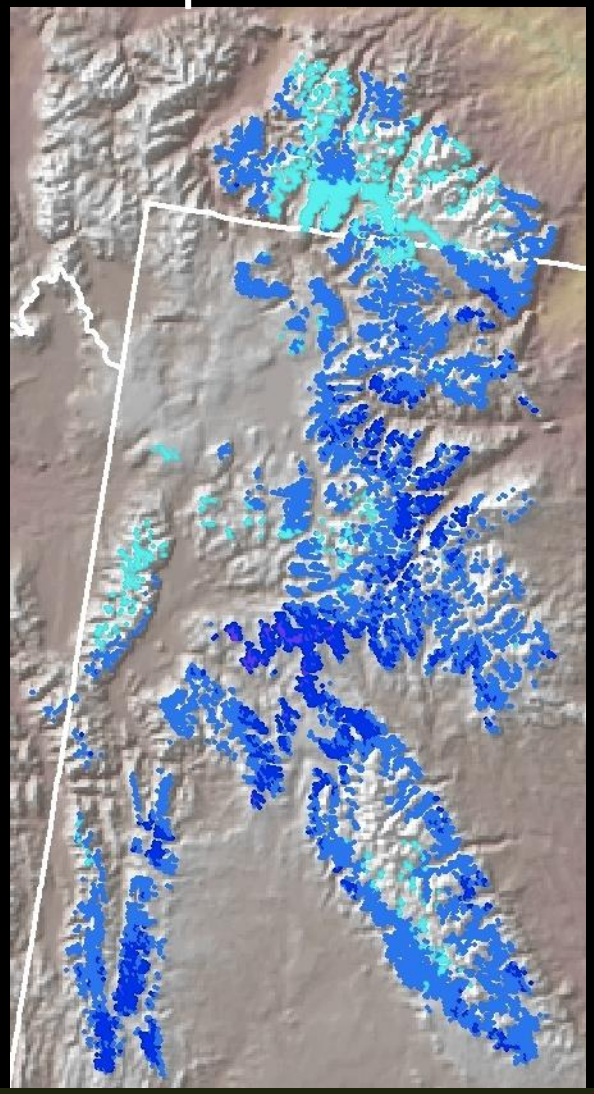
predictions similar to observations

observed

predicted

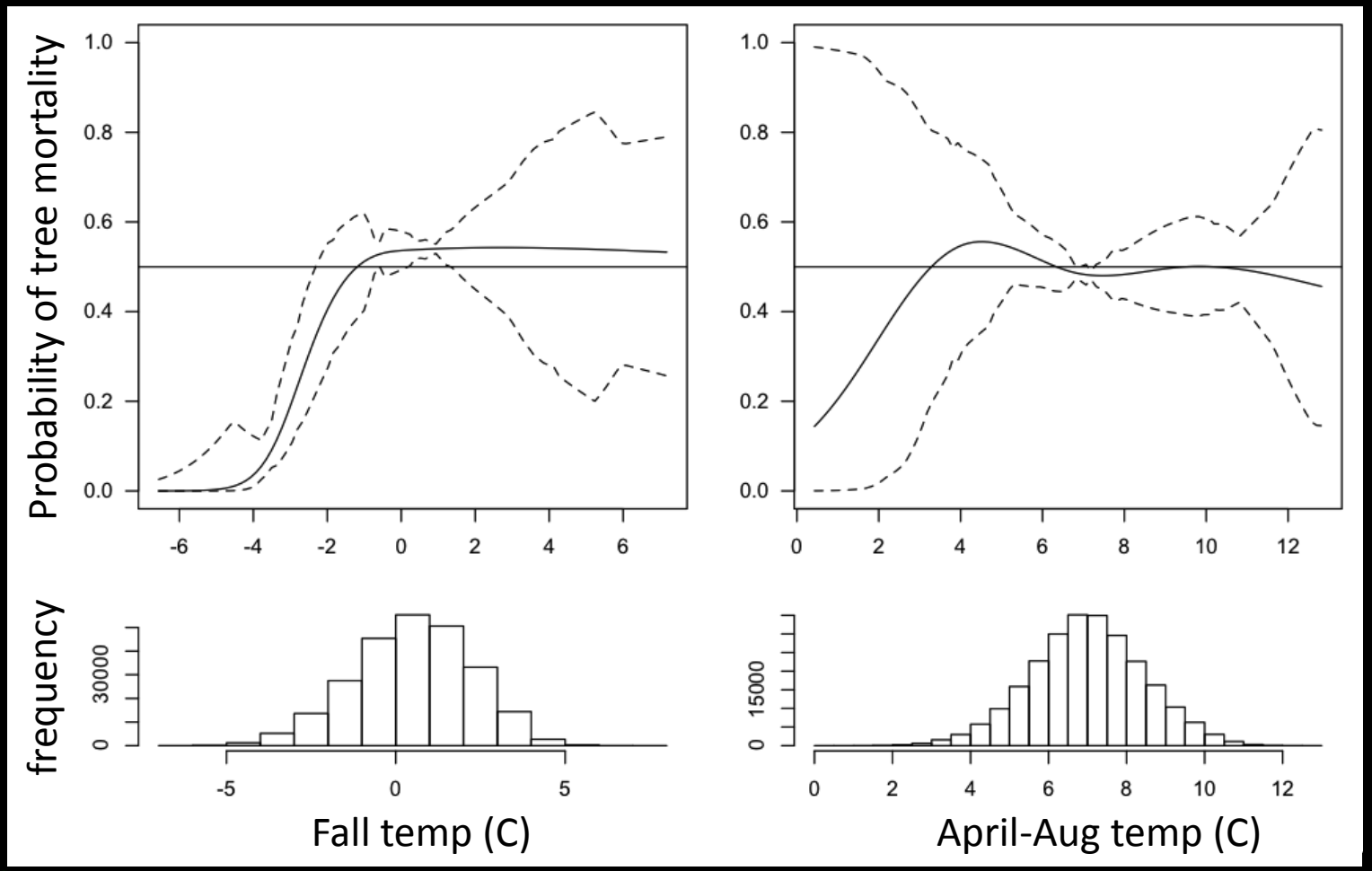
cumulative years with mortality





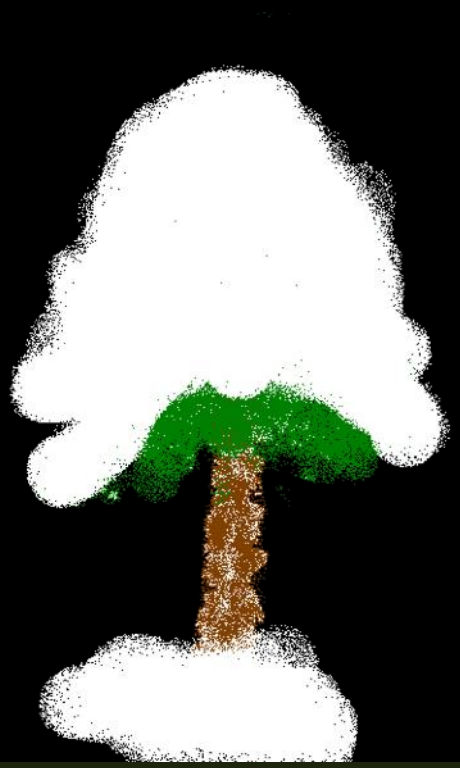
Climate-beetle relationships

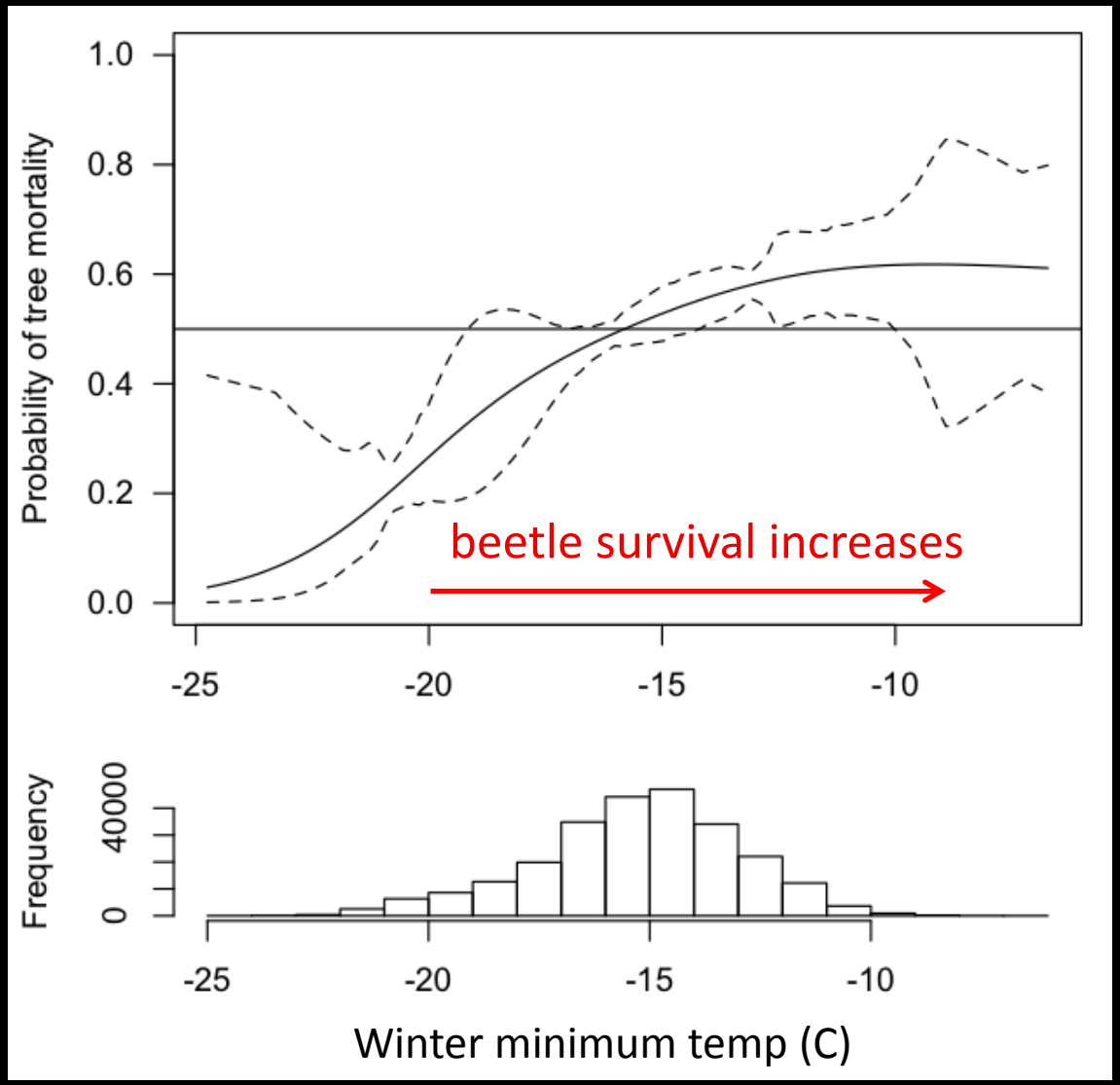
Adaptive Seasonality



Climate-beetle relationships

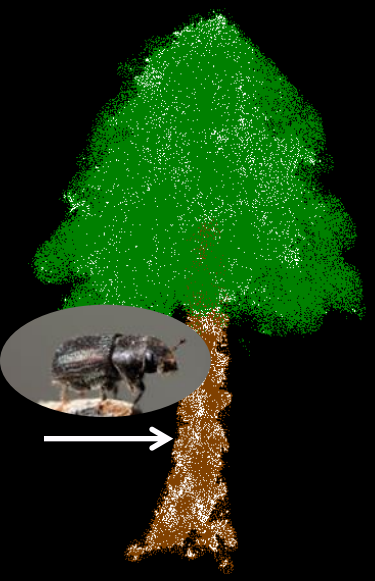
Beetle winter mortality

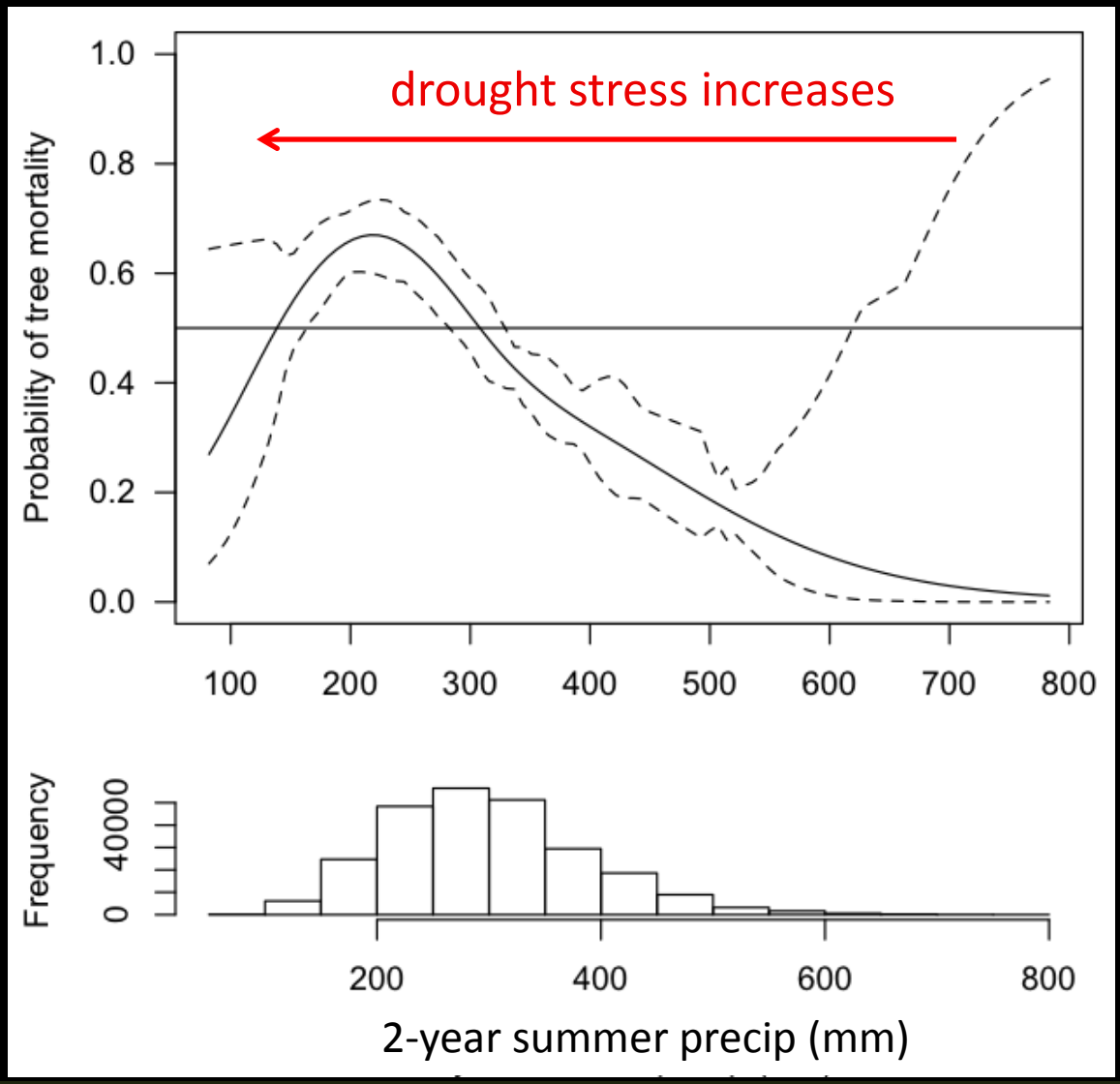




Climate-beetle relationships

Tree drought stress





Model application

Best model

Historical weather

- Monthly PRISM data 1900 – 2009

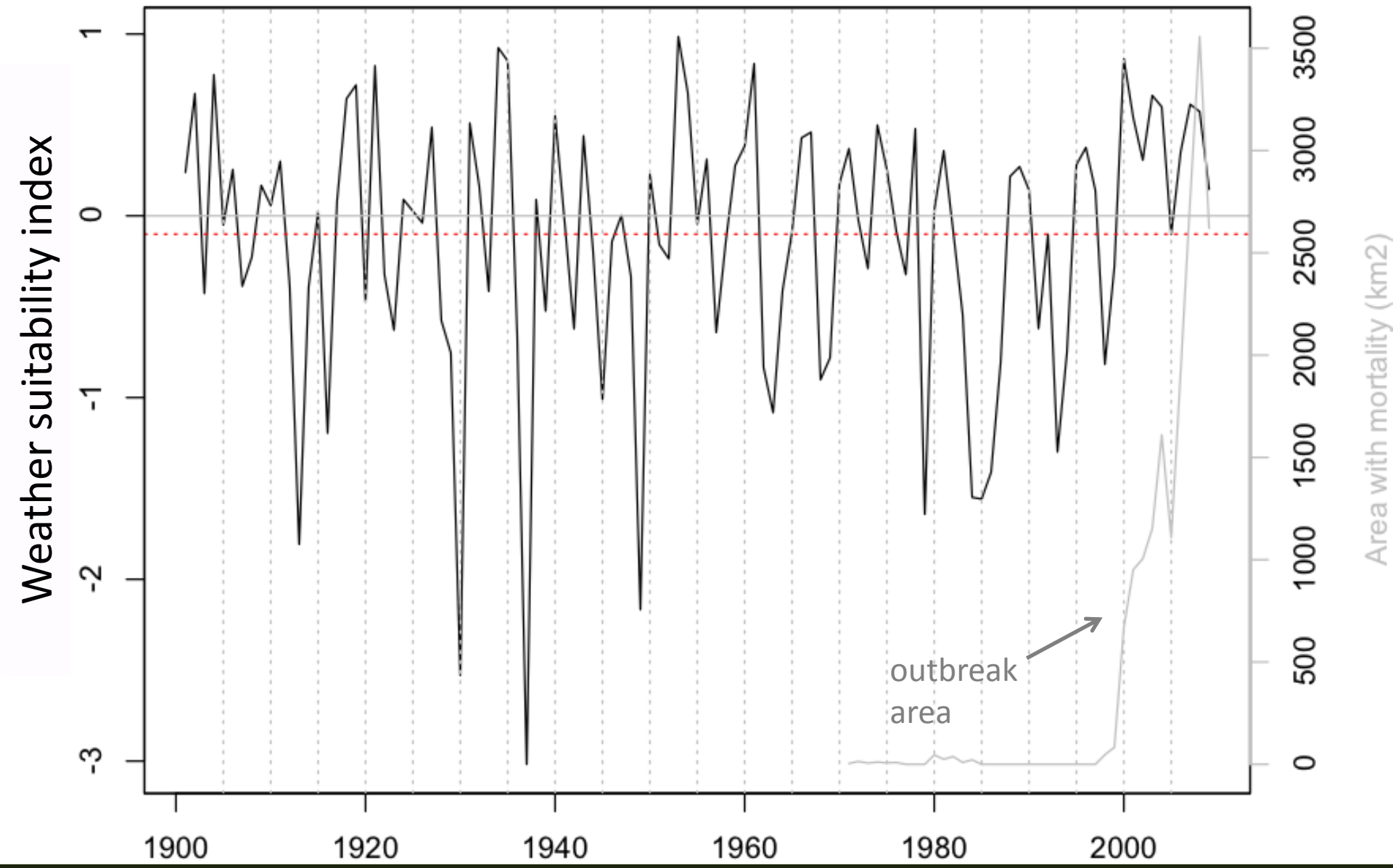
Future projections

- 10 GCMs
- 3 emissions scenarios RCP 2.6, 4.5, 8.5

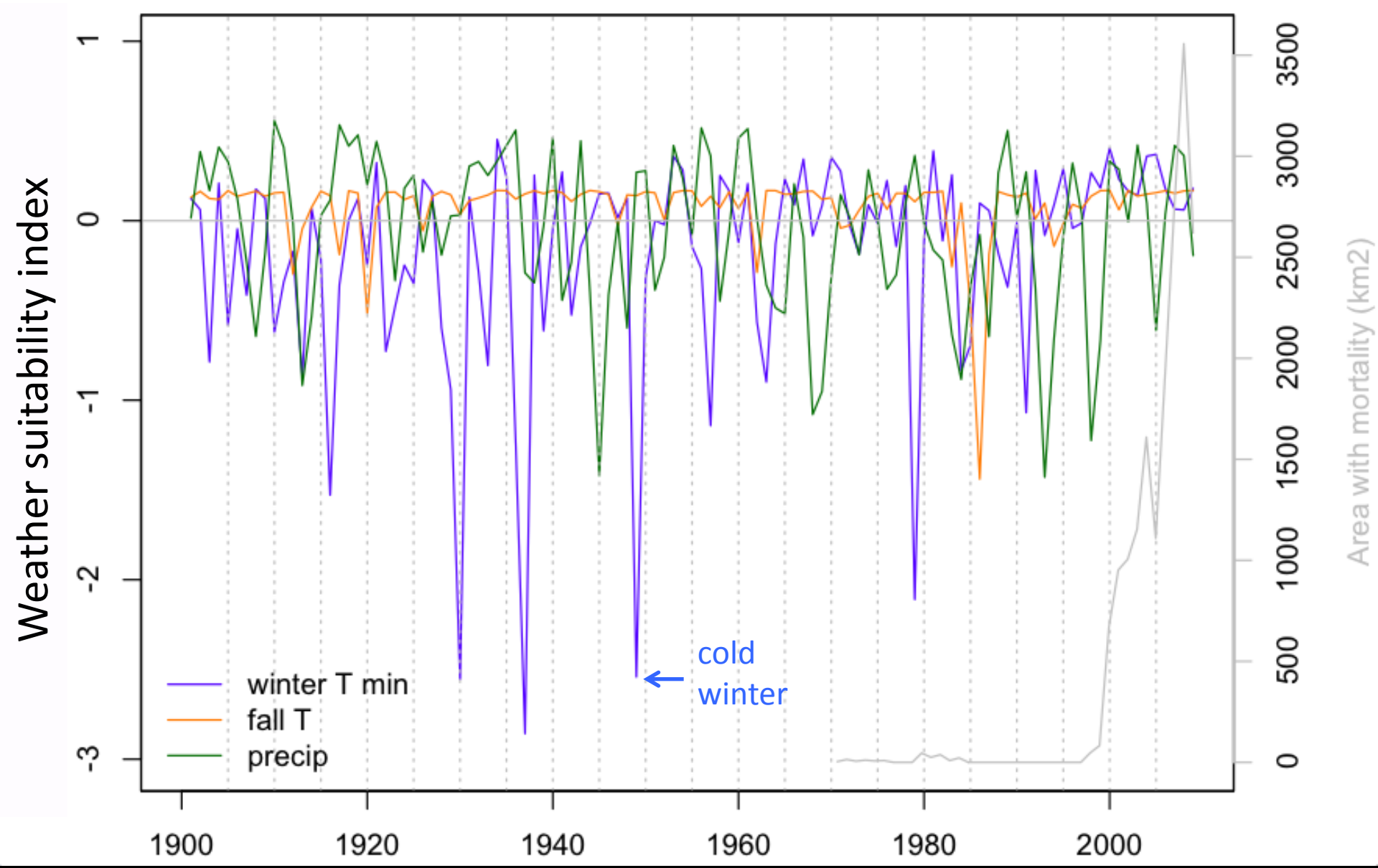
Weather suitability index

sum of the weather terms in the model

Weather was consistently suitable during recent outbreak



Lack of cold winters



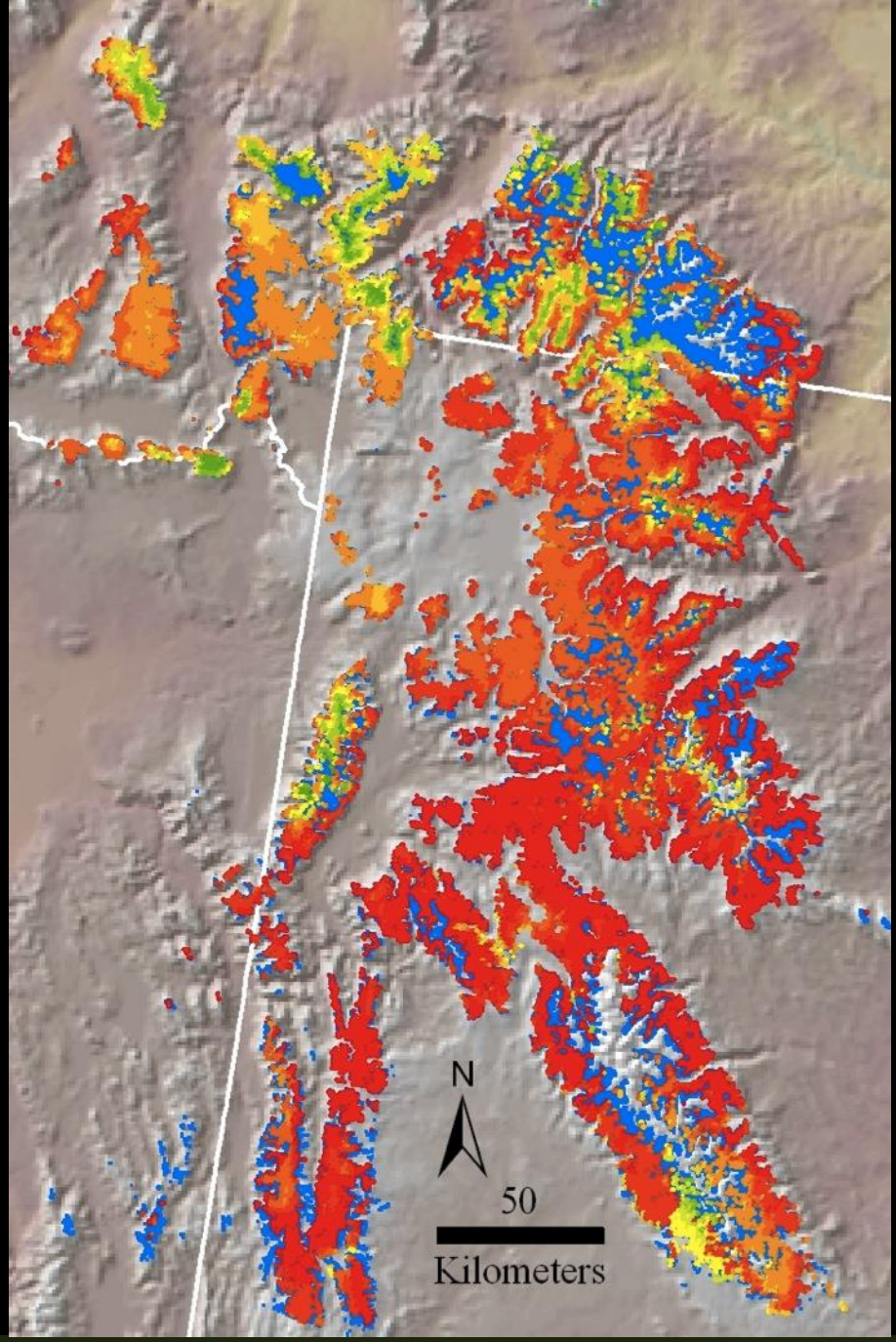
Weather suitability for beetle attack varies across the region

0 → 10

cumulative years with suitable weather

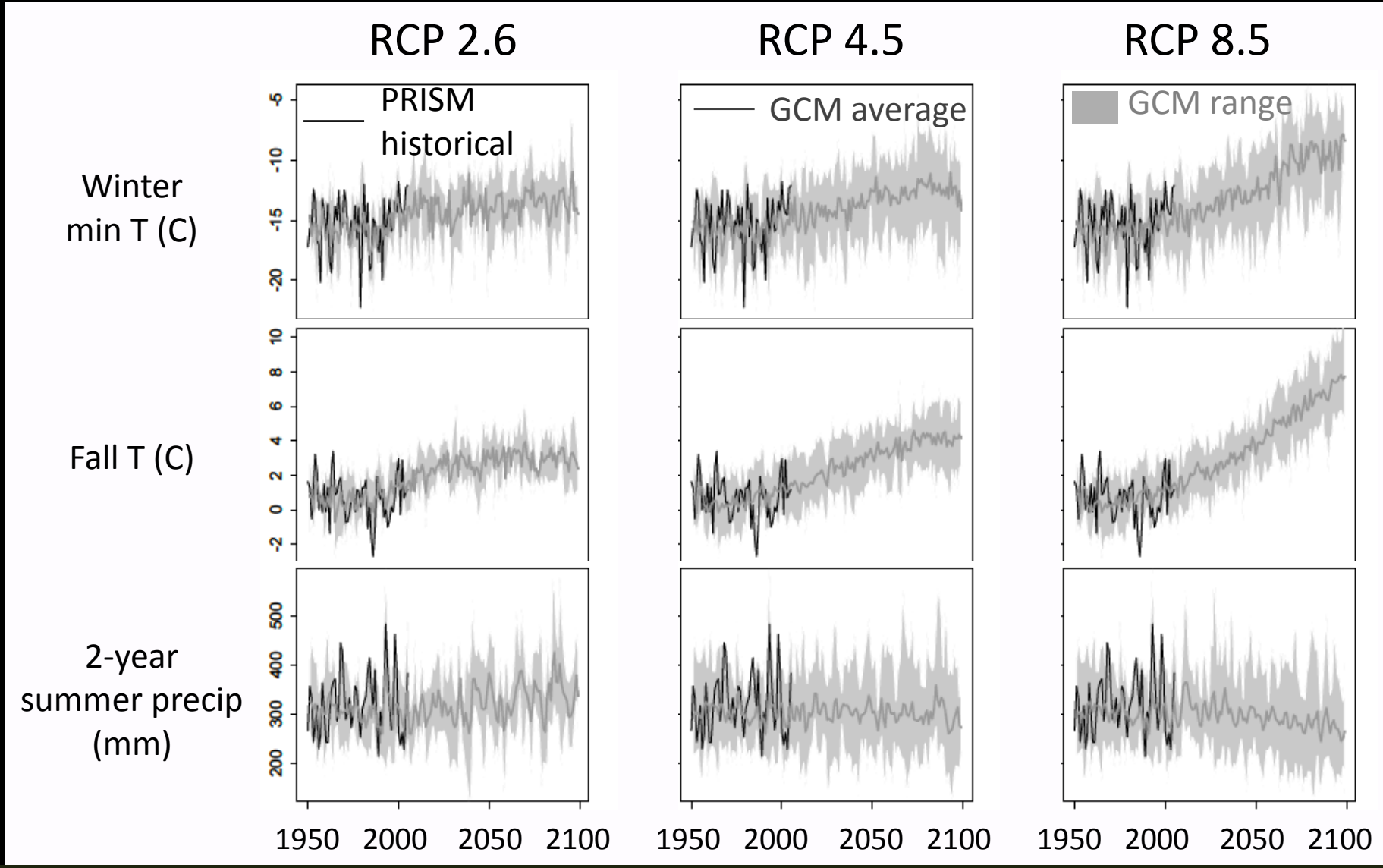
Based on:

2000-2009 weather for the range of WBP

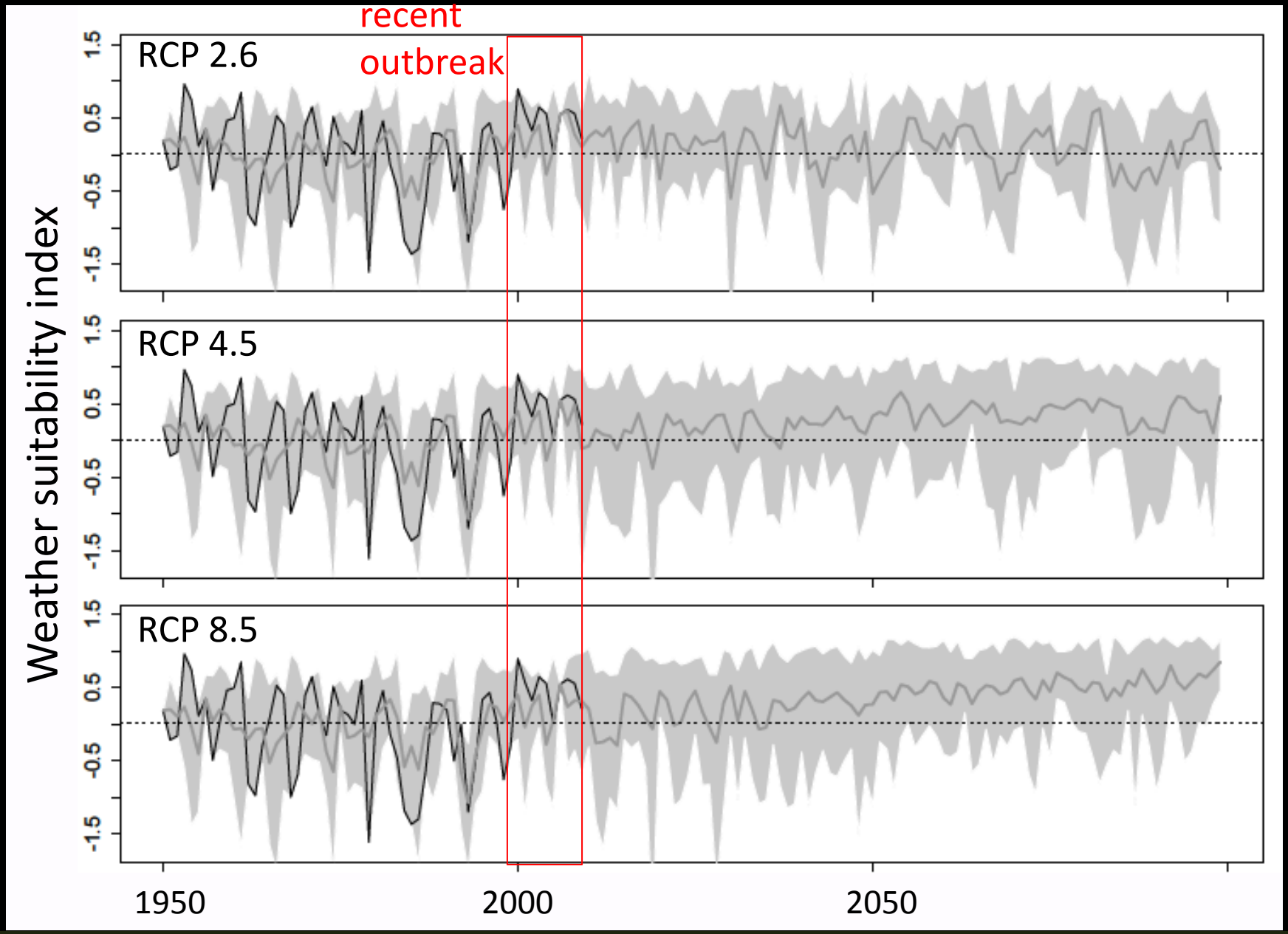


Future warming in winter and fall

Future precipitation is less certain

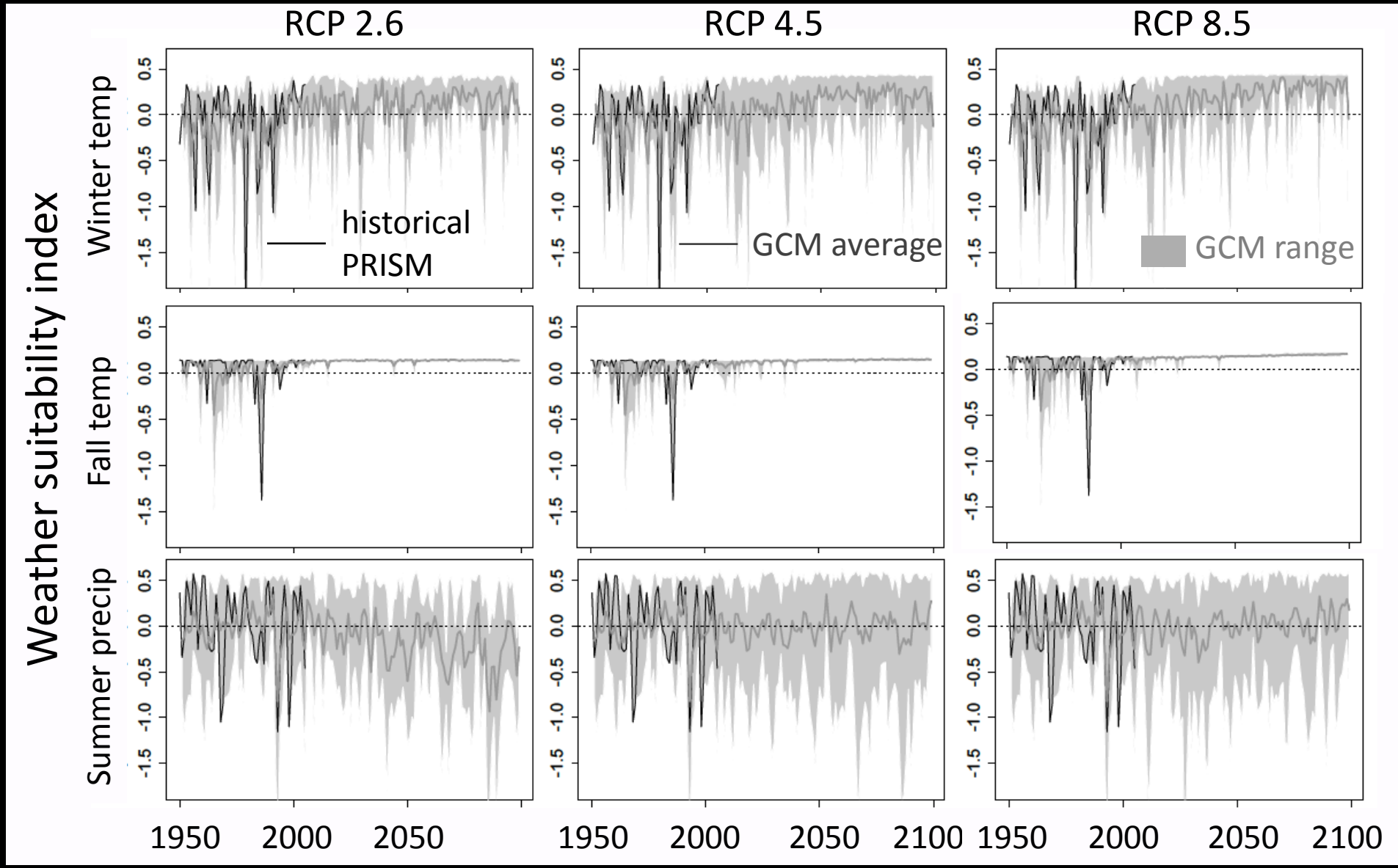


Future weather suitability for attacks is mostly higher



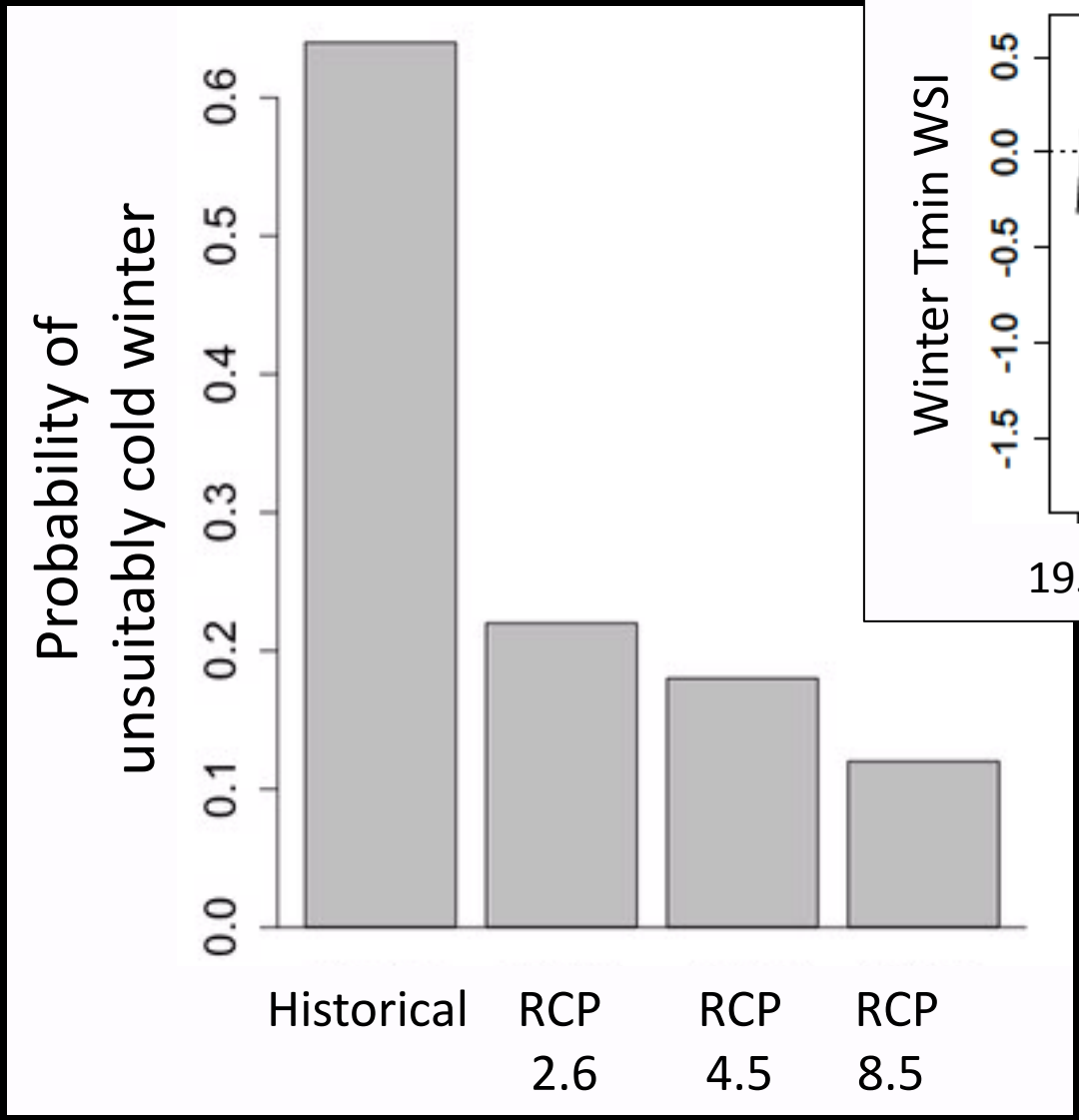
Future temperatures becoming more suitable

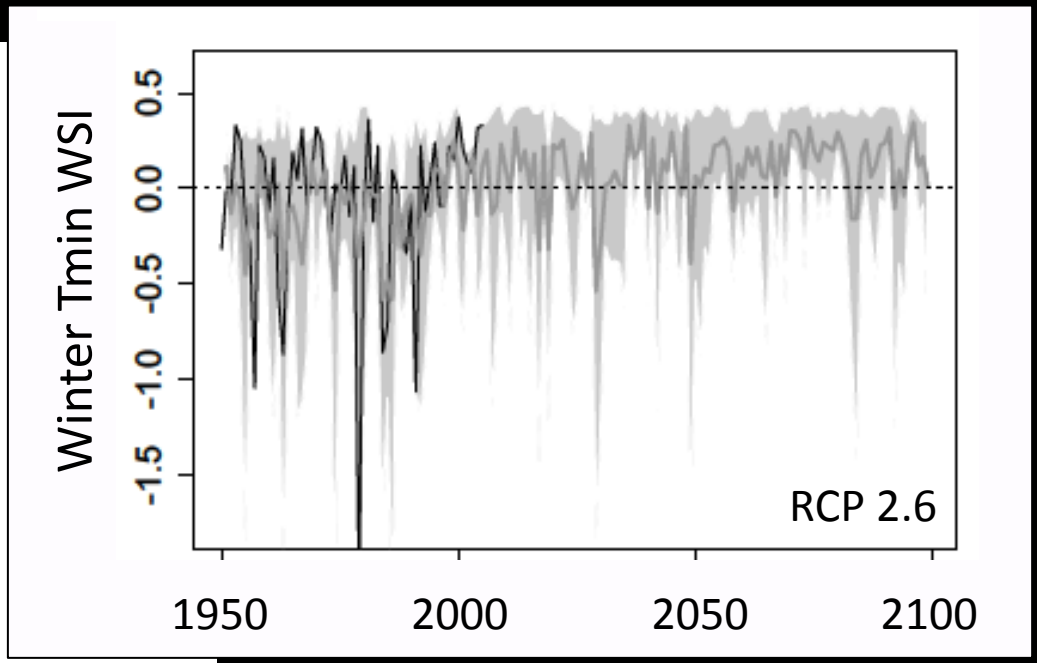
Future precipitation suitability varies



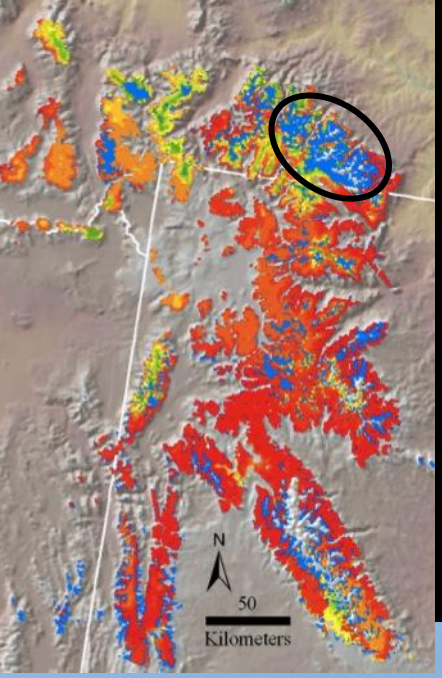
Probability of unsuitably cold winters is lower in the future

Cold winters limited outbreaks in the past





Current beetle activity on the Beartooth Plateau



developing beetles

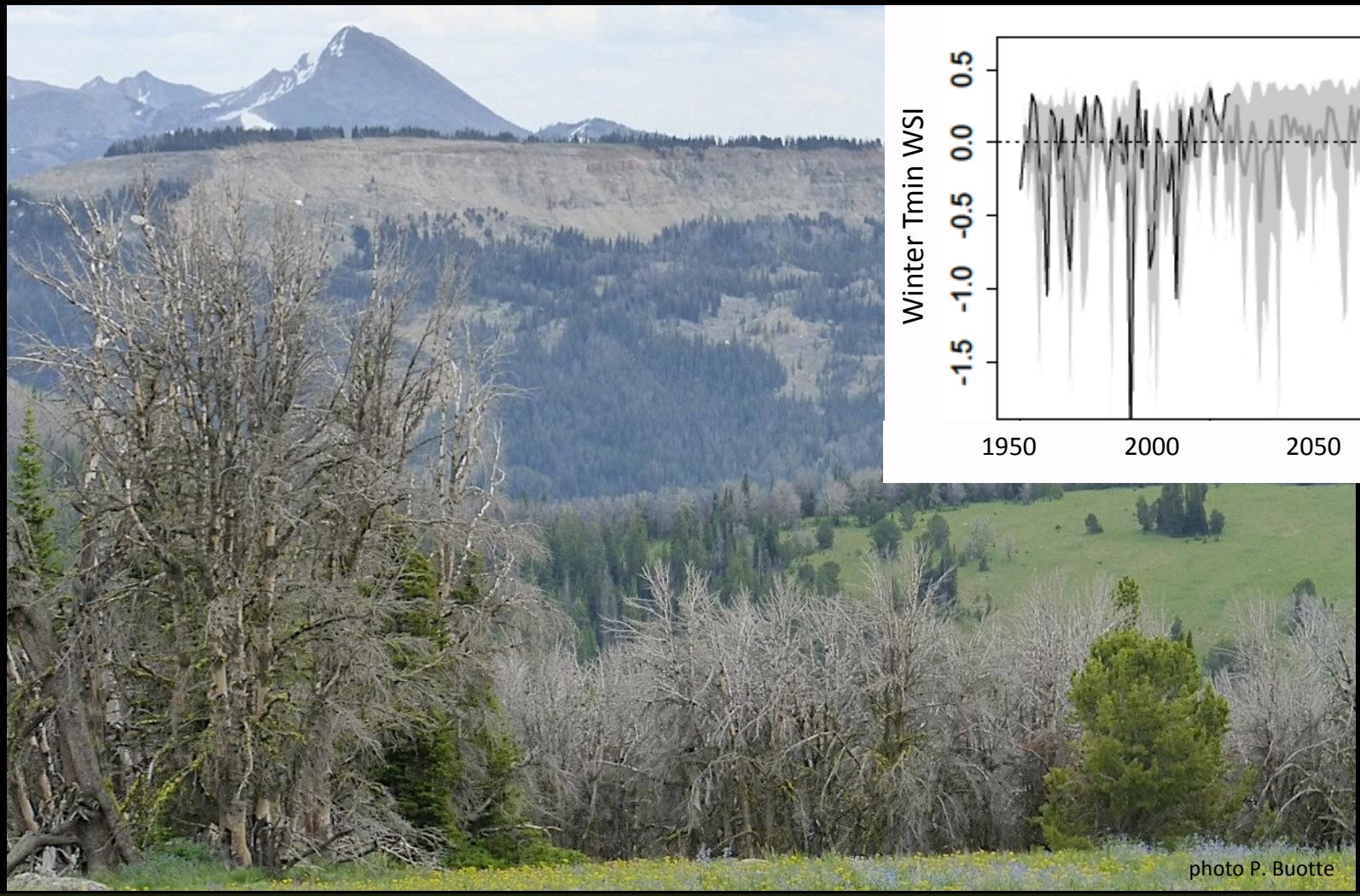
Caveats

- reliance on aerial surveys

- lack of meaningful stand structure data
  - previous work indicates beetles select larger whitebark pines

Whitebark pine persistence

Intersection of time to cone bearing age and time between cold winters



Planting efforts should focus on high-elevation areas

Most likely places to experience cold winters

We need to reduce global carbon emissions

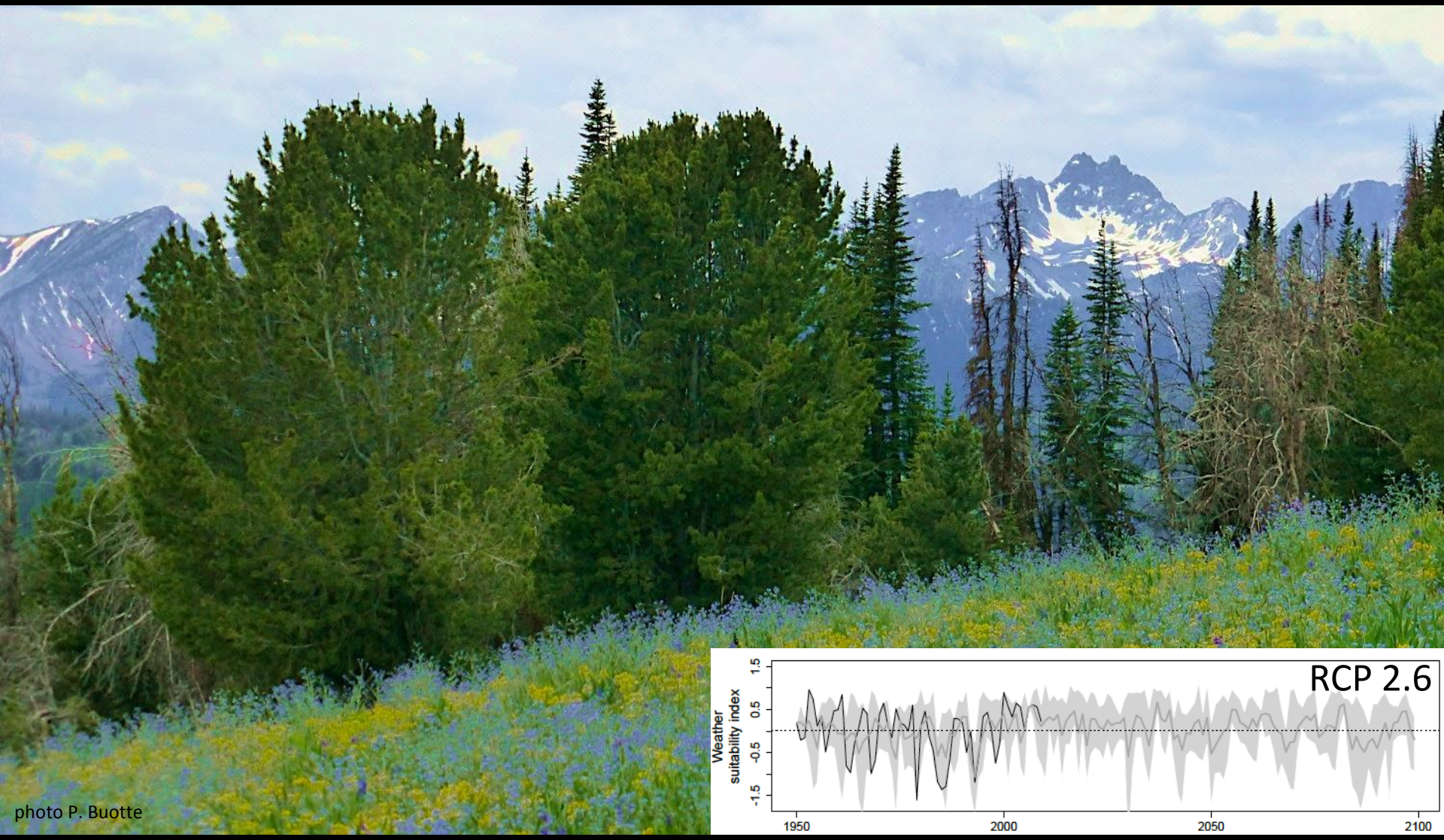


photo P. Buotte

Summary

1. Tree mortality from beetle attacks increases with:
    - higher fall and winter temperatures
    - increasing summer drought

2. Recent outbreak initiated by warm winters and summer drought
    - lack of cold winters the most noticeable change over the last century

3. Future weather suitability for beetle attacks is mostly higher
    - reduced suitability with greater precipitation
    - lower probability of cold winters

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