Can we forecast changes in the distribution and regeneration of conifers in the Inland Northwest?

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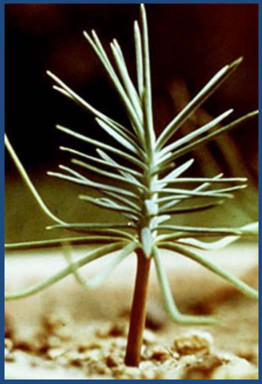
Presentation Overview

- Correlative models of adult vs. juvenile presence
- Incorporating future climate into fine-scale water balance estimates
- Potential shifts in future regeneration with future climate scenarios
- Future directions and needs

USFS outplanting activities in Region 1

- Average acres treated: ~ 9,000-12,000
- Cost per acre: $600-700
- 6.3-8.5 million dollars annually

- Success rate:
- 70% success by 3rd year



(cost estimates: Glenda Scott Region 1)

Climate Change?

- Broad agreement from models and historical observations that things are getting warmer
- Extensive evidence from paleoclimate records that shifts in climate were accompanied by shifts in vegetation
- Widely assumed that tree distribution will shift to higher elevations

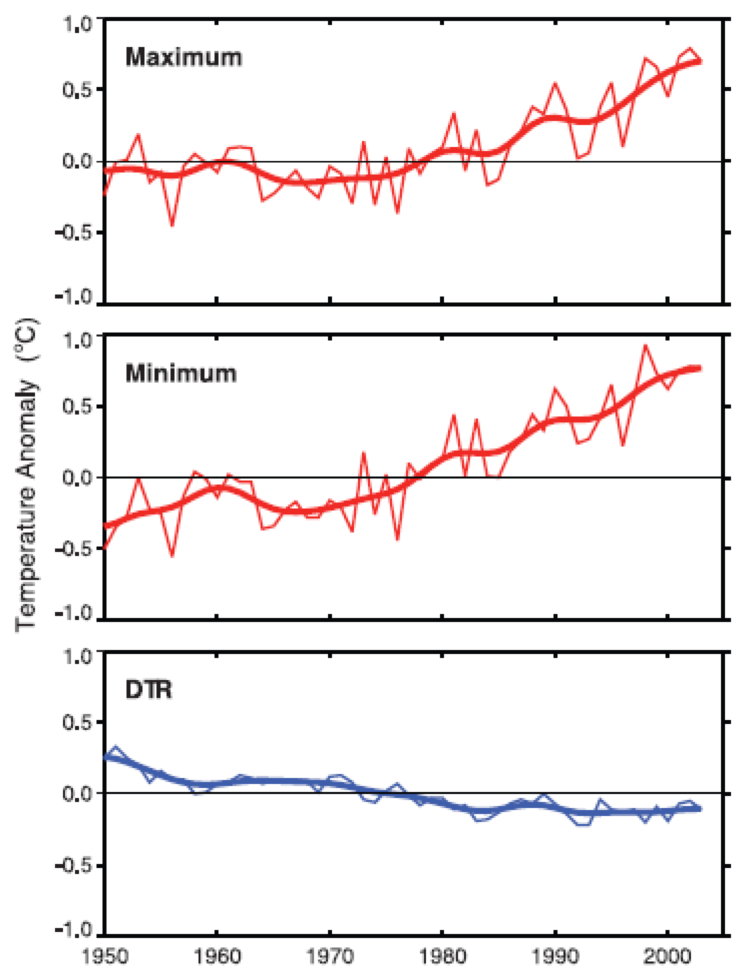


Figure 3.2. *Annual anomalies of maximum and minimum temperatures and DTR (°C) relative to the 1961 to 1990 mean, averaged for the 71% of global land areas where data are available for 1950 to 2004. The smooth curves show decadal variations (see Appendix 3.A). Adapted from Vose et al. (2005a).*

IPCC 2007

Implications for forest management

- a better understanding of bioclimatic controls on species occurrence and growth could save time and money
- Improve outplanting success
- Anticipate optimum locations for planting with projected warming
- Develop tools for near and long term forecasting of where and when to plant??

The cottage industry of modeling changes in species distributions with climate change

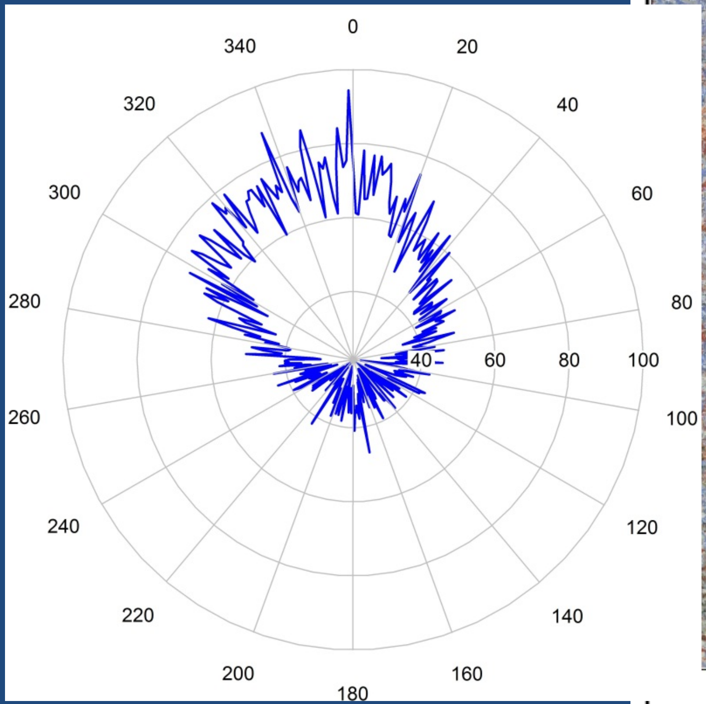
- It’s easy!
- Correlate species presence with climate variables
- Fit favorite model
- Project onto current/future climate space
- Things move around!

The challenge in mountains:

- All of the physical drivers that govern where species occur vary with terrain
- Temperature, radiation, wind, humidity
- Finer spatial resolution than available data

Larch basal area predicted from spring-fall Landsat change

Strong aspect dependence
Larch occurs primarily on North-facing slopes



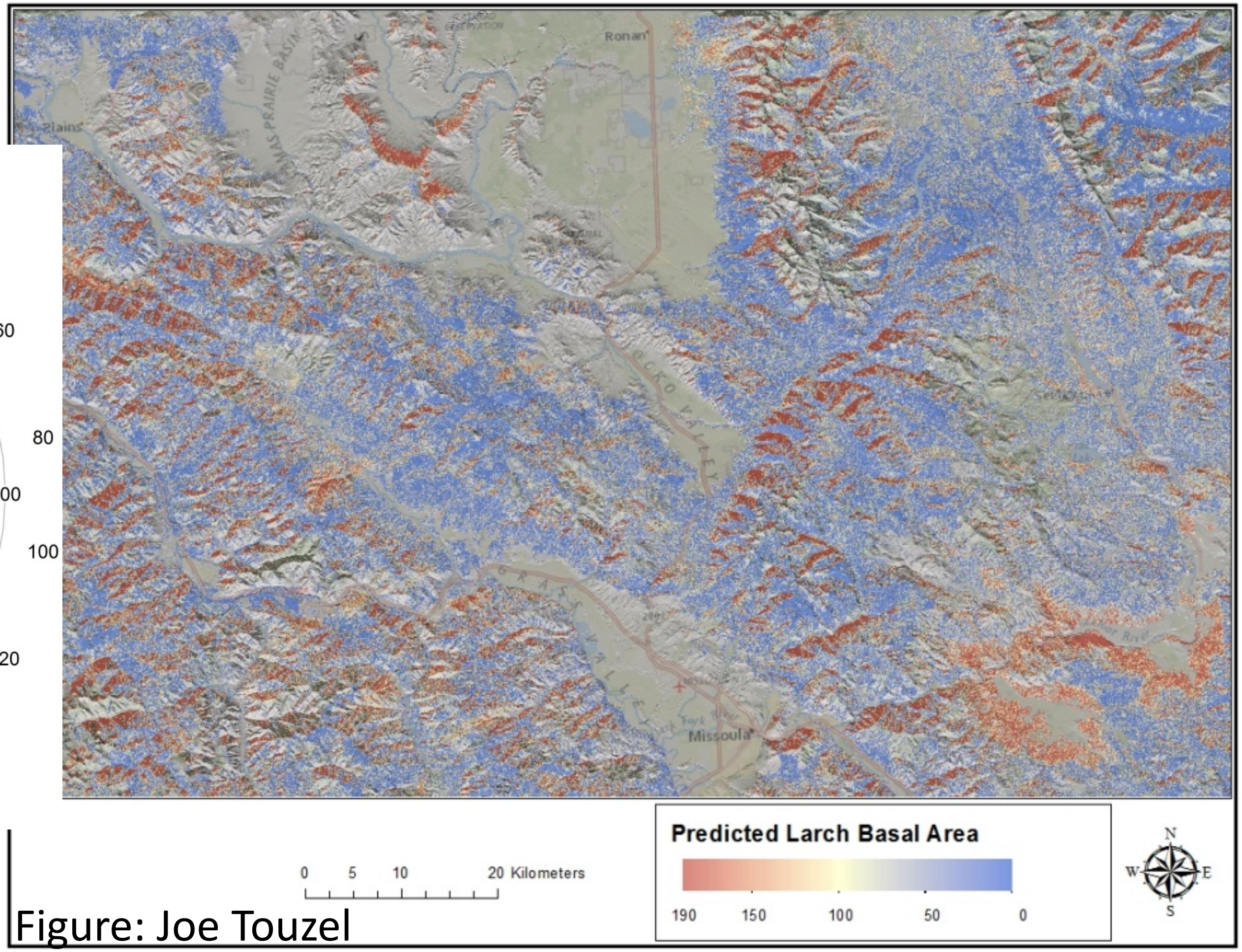


Figure: Joe Touzel

Toward Improved understanding of climate-vegetation dynamics: Development of high spatial resolution climatic water balance models

Penman-Montieth equation for evapotranspiration

Integrates climate and energy into mechanistic variables

Temperature

Radiation

Atmospheric Vapor Pressure (RH)

$$ET = \frac{\Delta\left(R_n - G\right) + \rho_a c_p (e_s - e_a)/r_a}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$$

Aerodynamic resistance (Wind)

Each aspect of the Penman-Monteith model varies with terrain

The climatic water balance

- PET = potential for a site to evaporate water
- AET = actual evaporation, given moisture. (Think productivity)

- Deficit= The difference.
- PET – AET = deficit.
- Unmet atmospheric demand

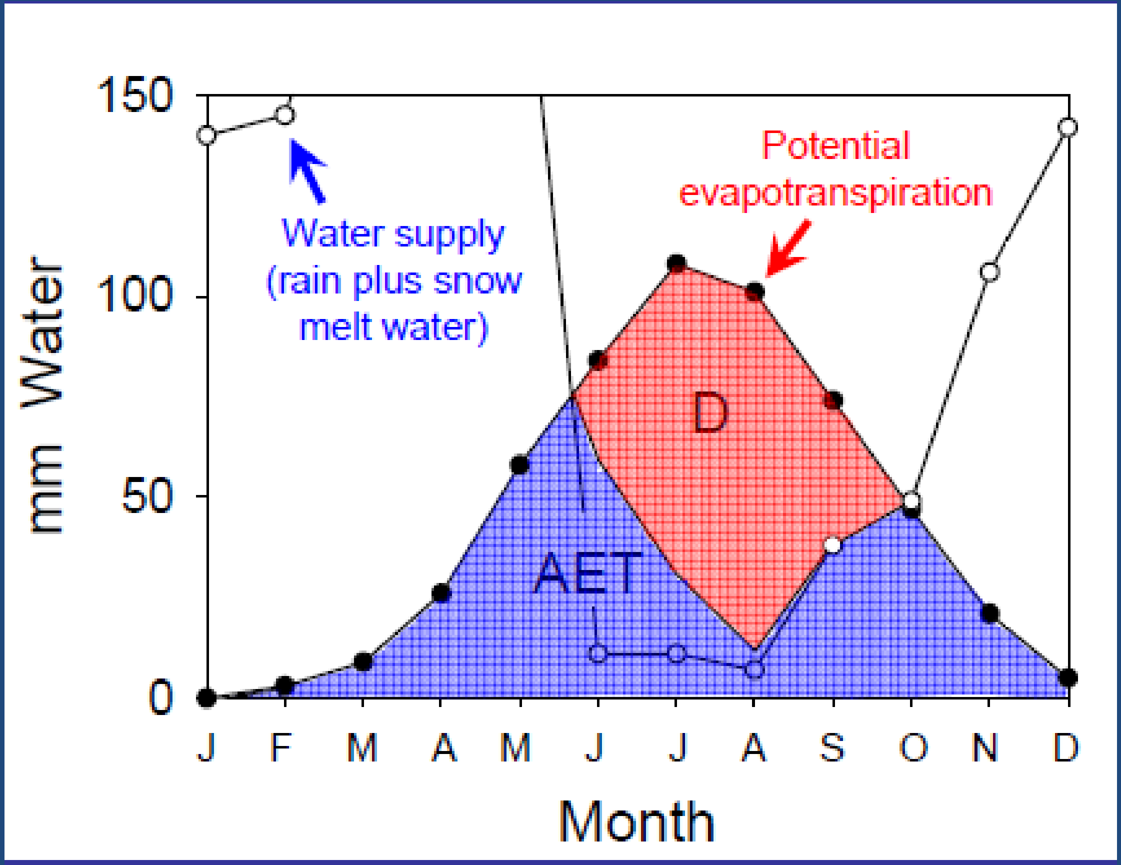


Figure from Nathan Stephenson, USGS, AGU presentation 2011

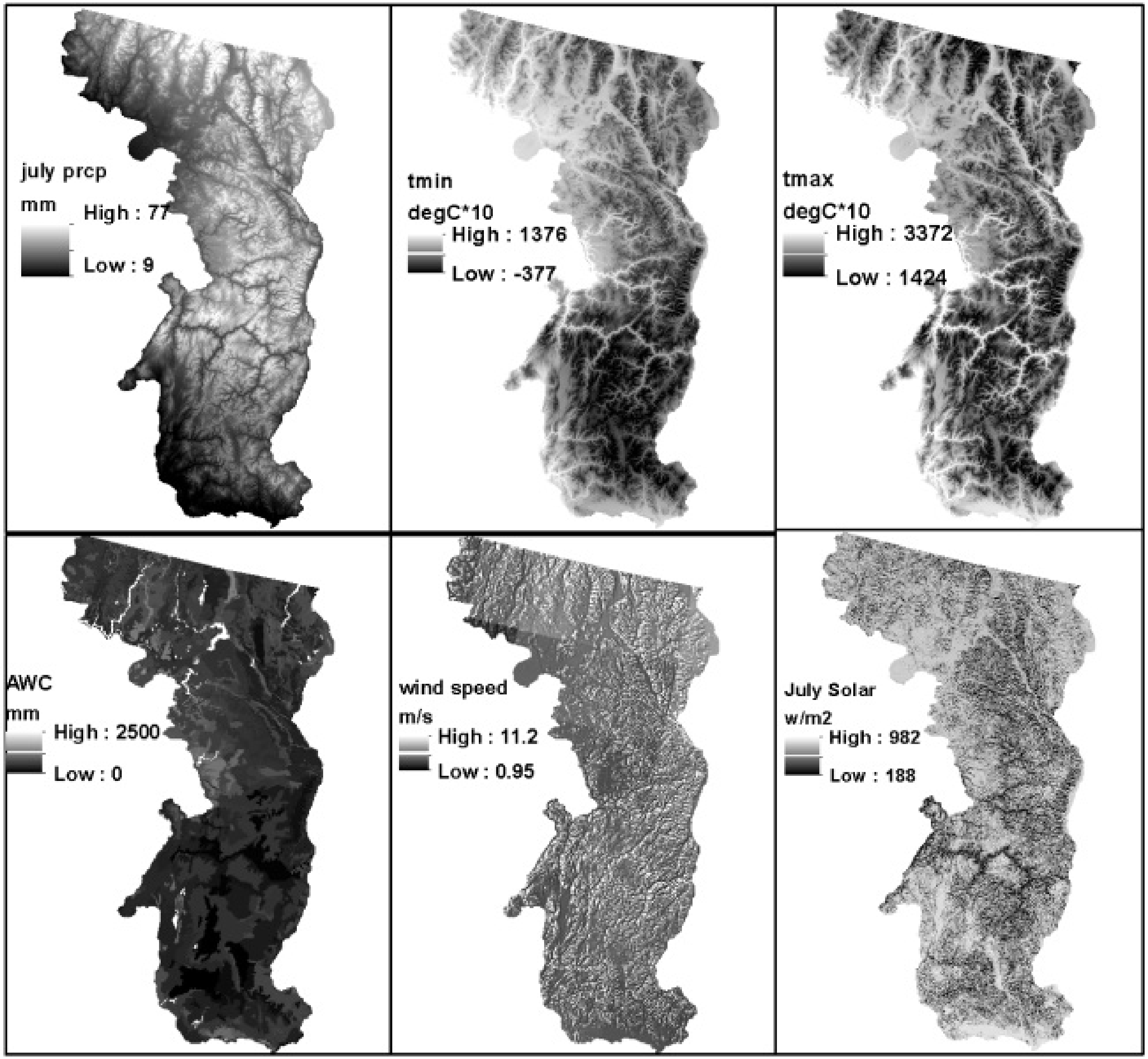
Water Balance Inputs (60m)

30 yr Monthly Average:

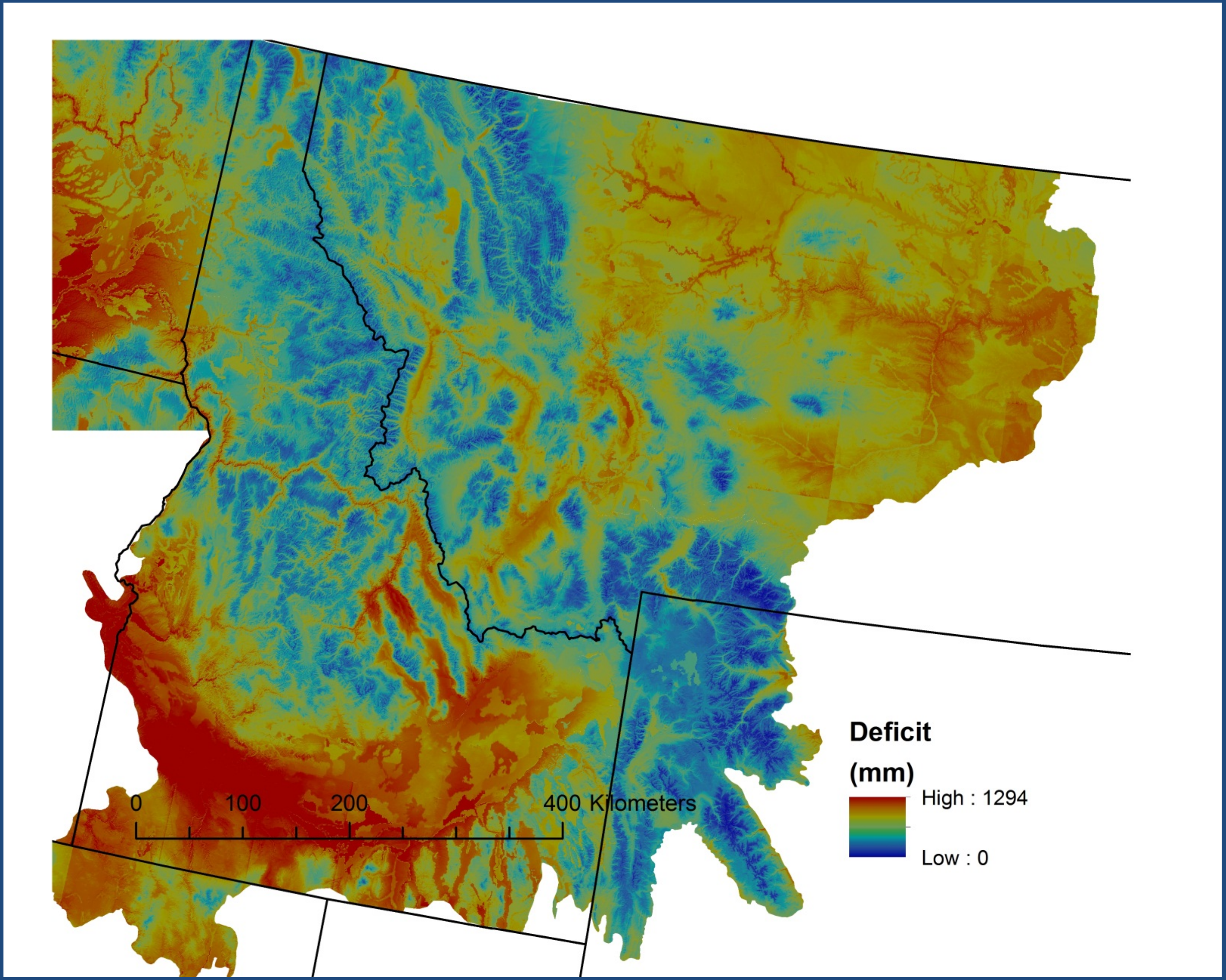
Min. Temperature
Max. Temperature
Solar Radiation
Precipitation

Wind Speed (windninja)

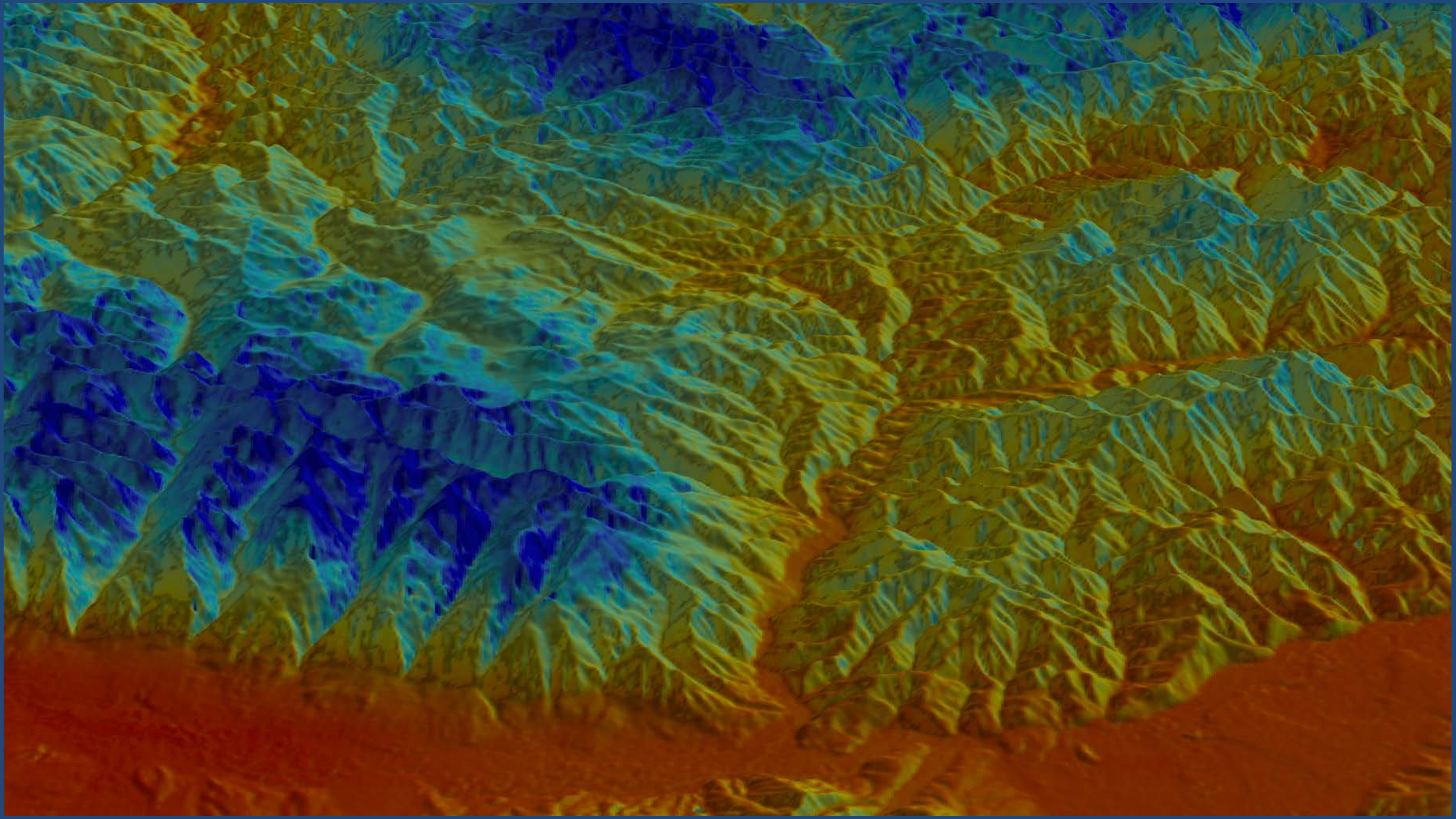
Soil water capacity



30 year (1971-2000) Deficit

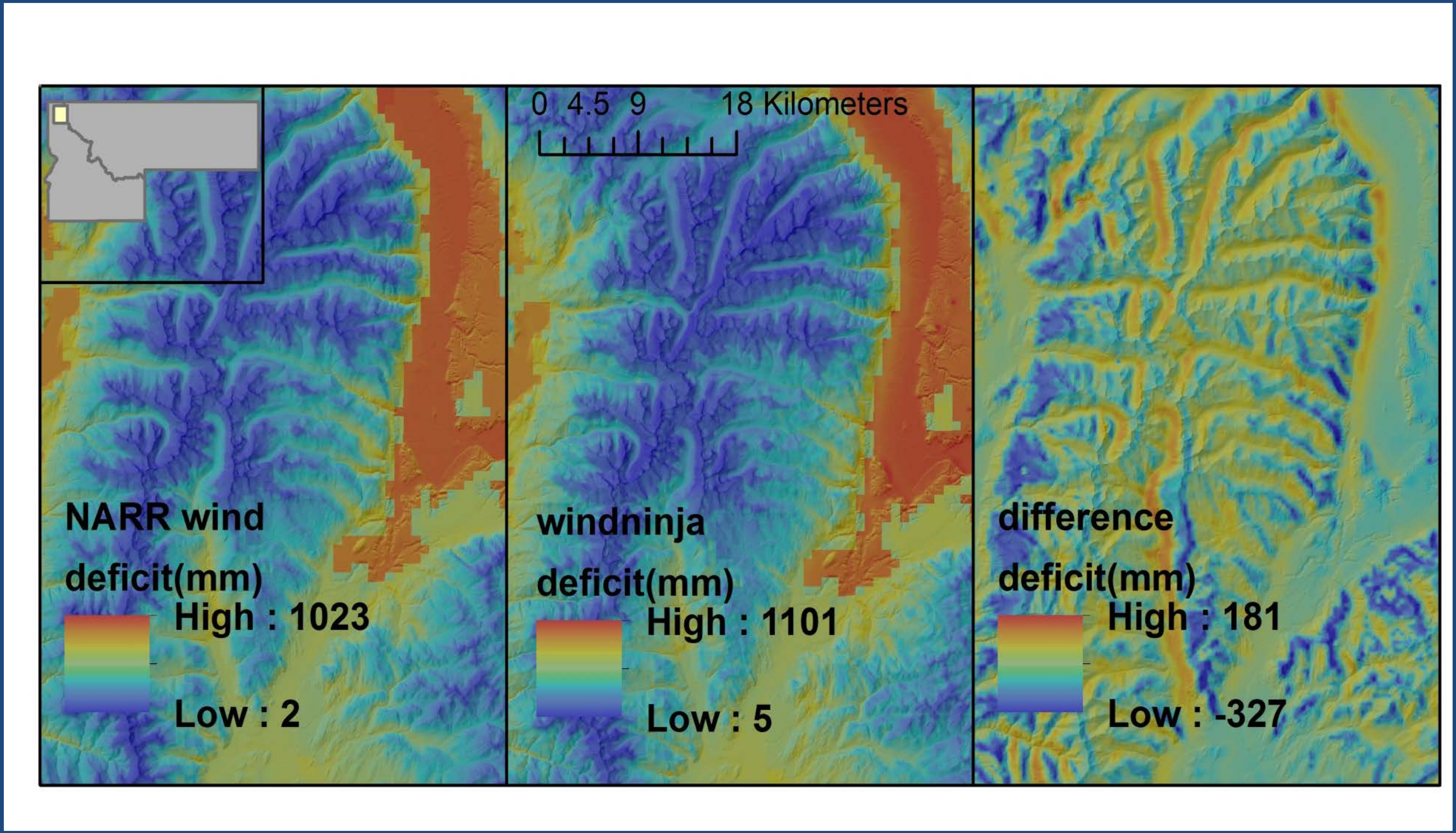


Using high resolution solar radiation grids, we can capture some aspect-scale variation in water balance



Modeling the influence of wind on evapotranspiration

- Selkirk mountains

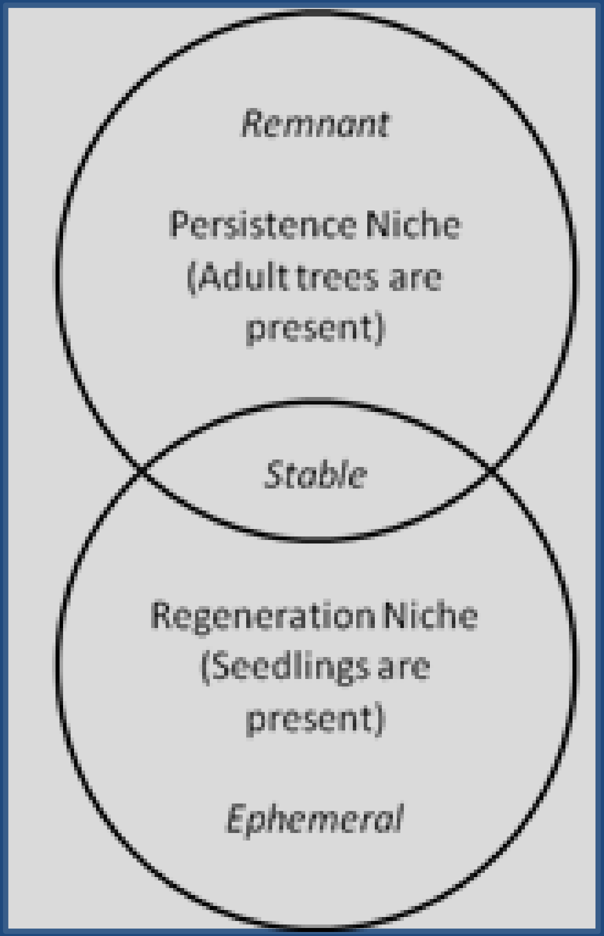


Modeling adult vs regeneration niche

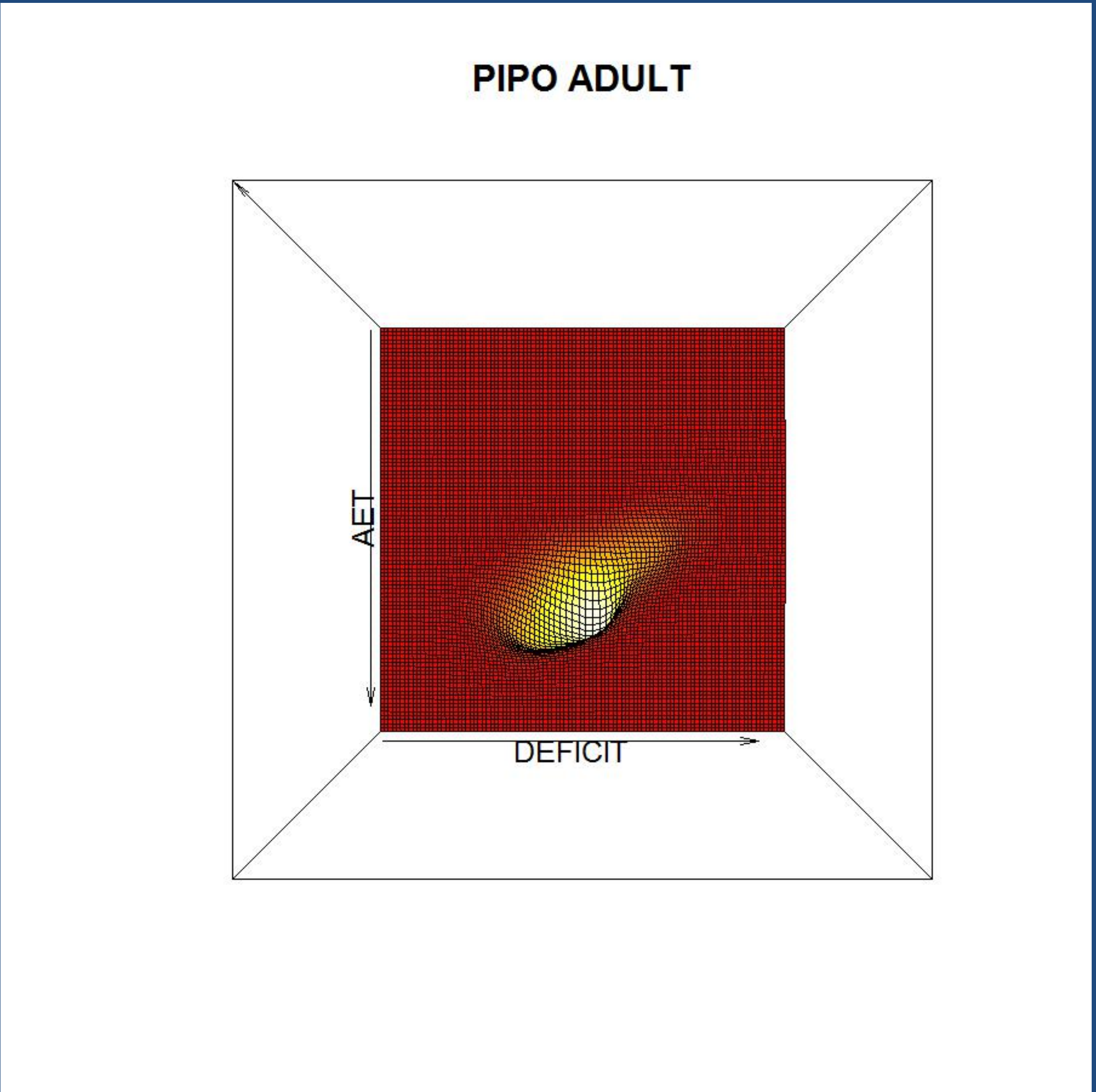
Most SDM studies focus on presence of adults

Many age cohorts representing large range of climatic conditions

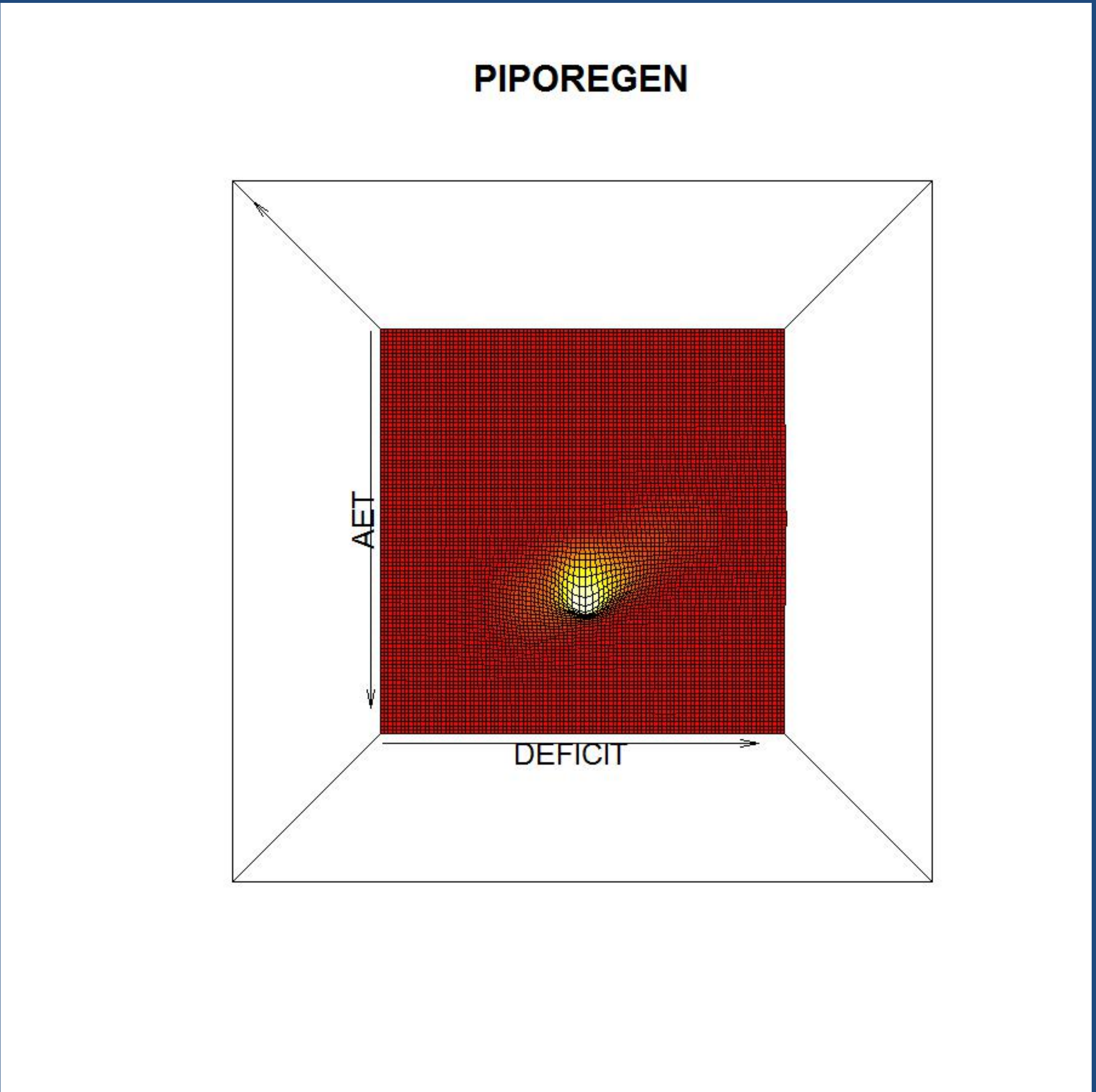
Presence of juveniles may better represent contemporary climate



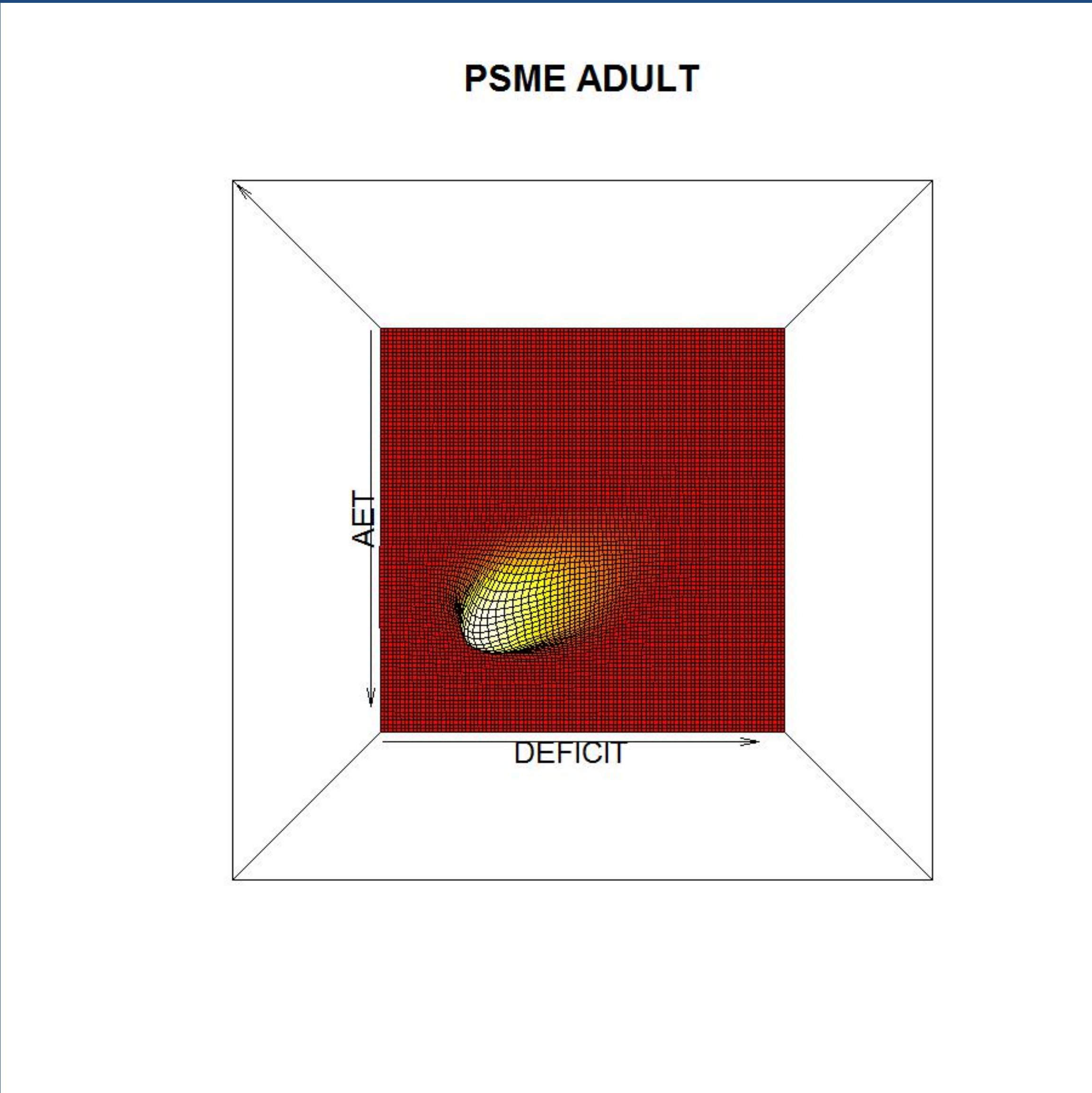
Ponderosa Pine adult niche



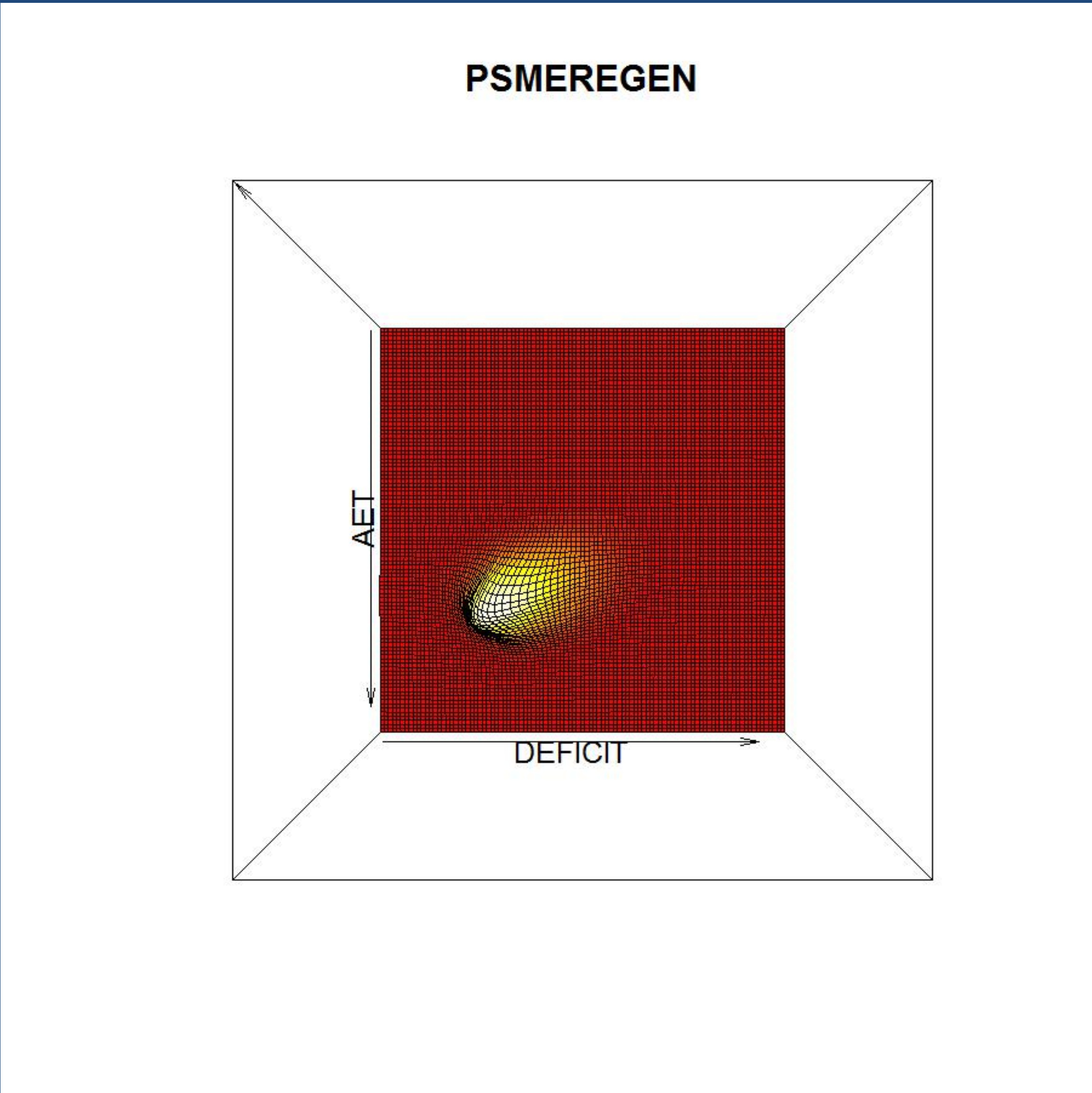
Ponderosa Pine regeneration niche



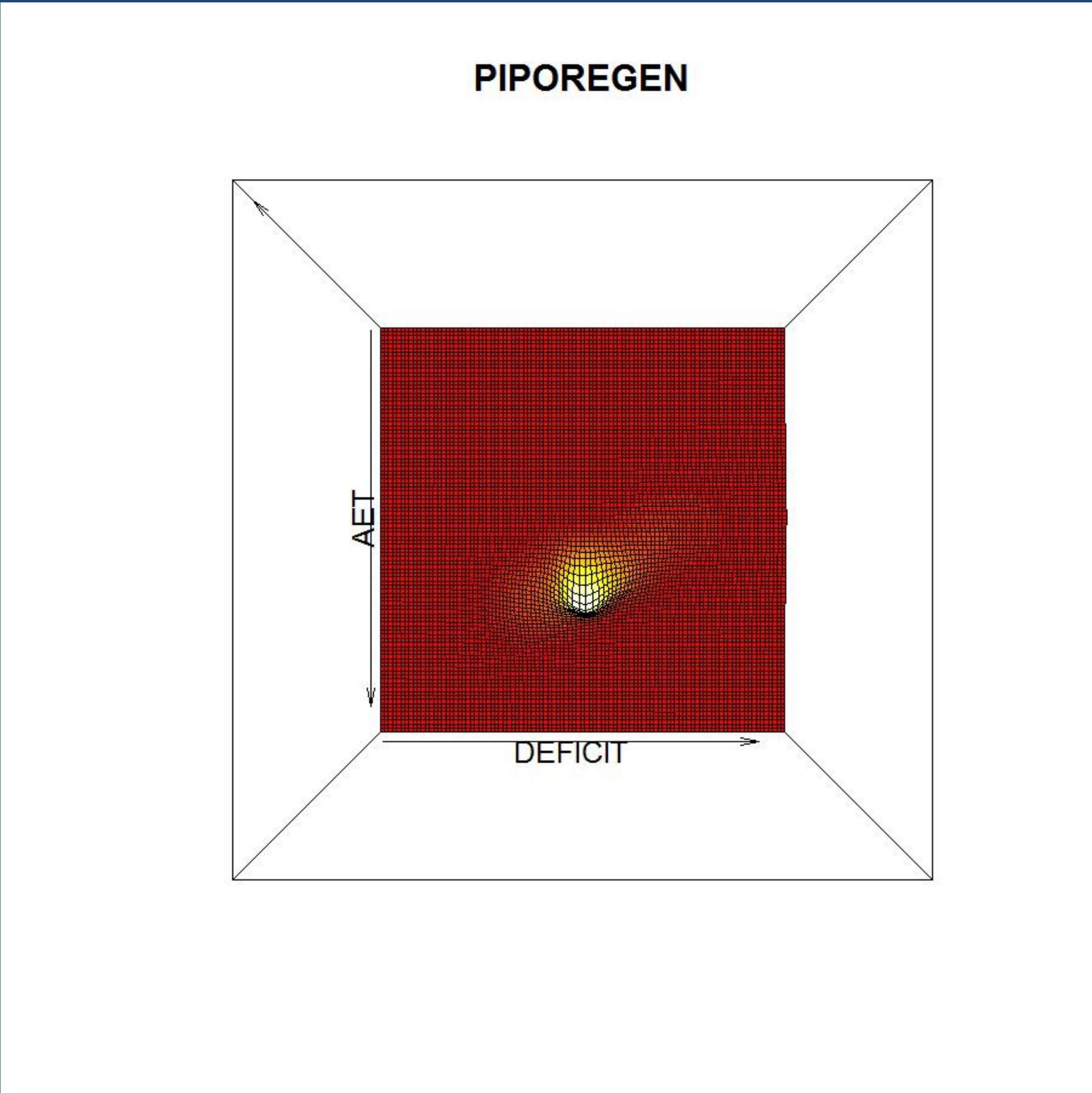
Douglas fir adult niche



Douglas fir regeneration niche



Ponderosa regeneration

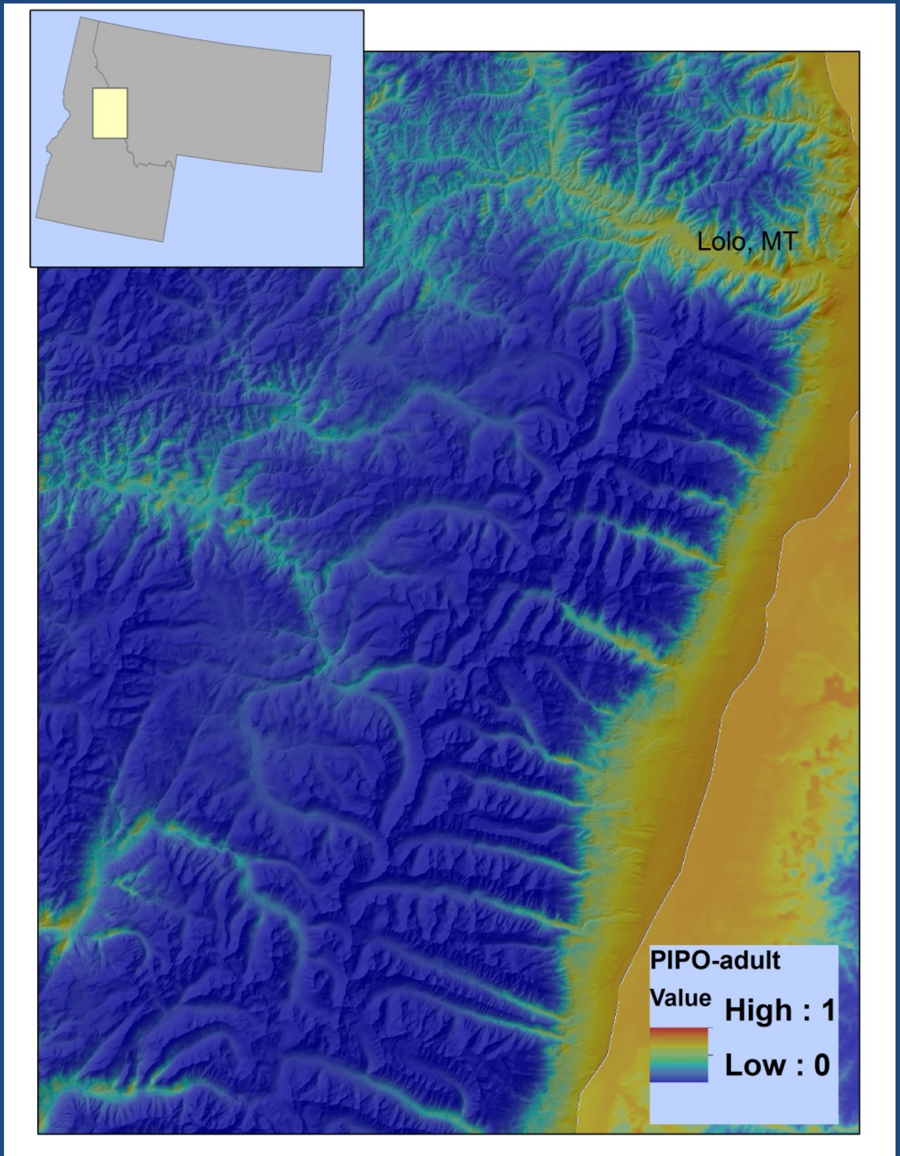


Modeling species occurrence using a water balance approach

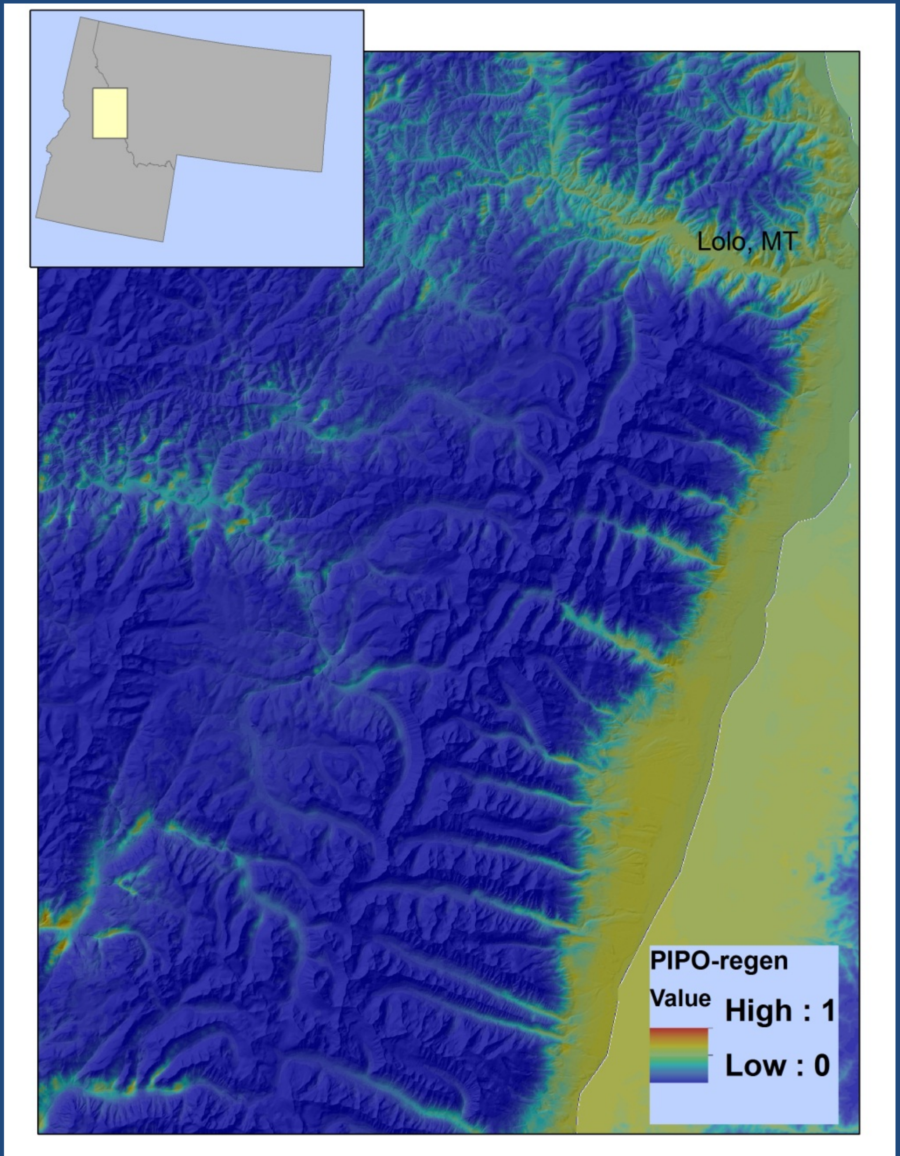
- Presence/Absence data from FIA
- GLM: PIPO ~ AET + poly(DEFICIT) + TMIN
- Limiting factors (energy, water, temperature)

Adult

Regen



Lolo, MT
PIPO-adult
Value
High : 1
Low : 0

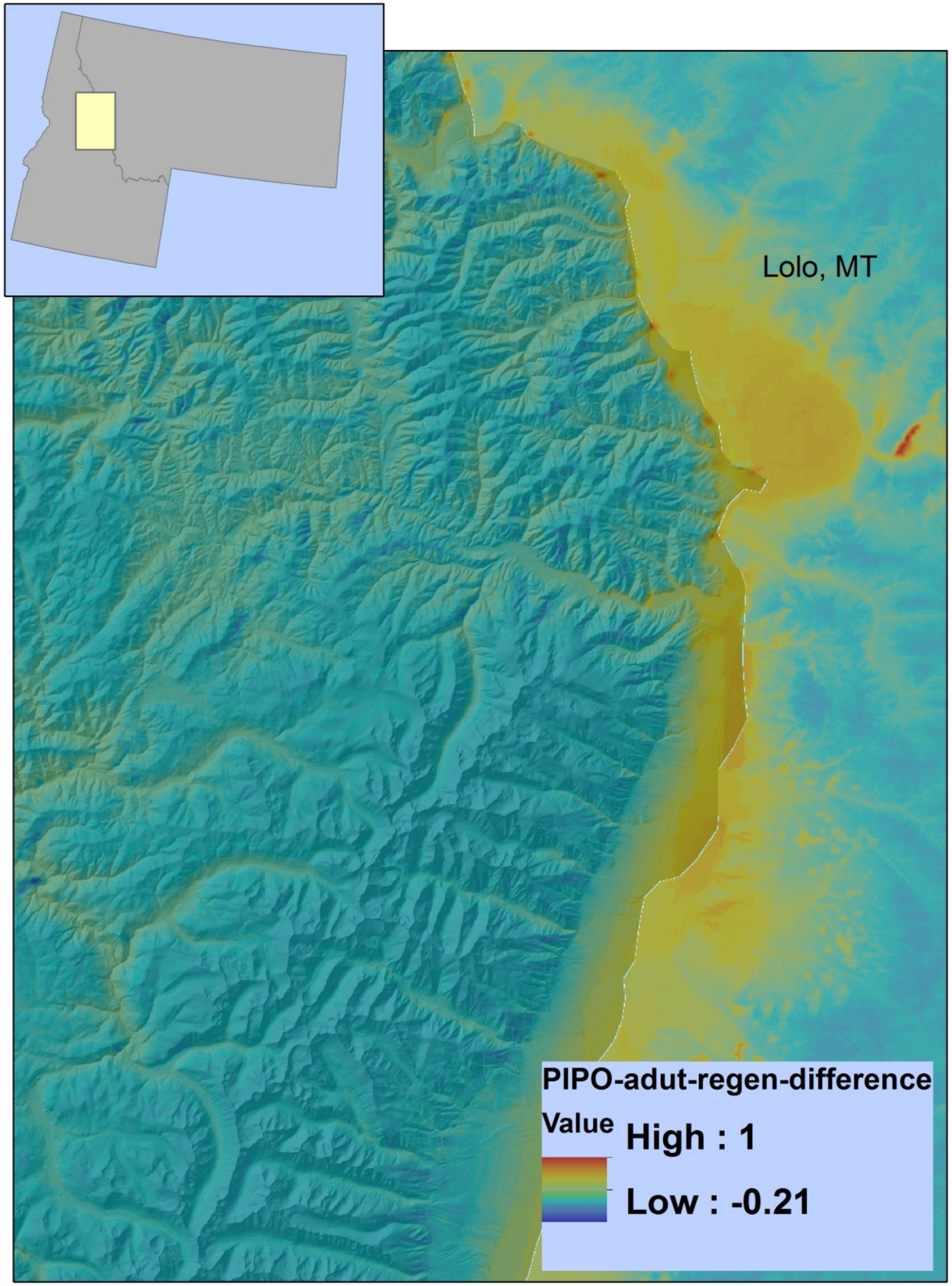


Lolo, MT
PIPO-regen
Value
High : 1
Low : 0

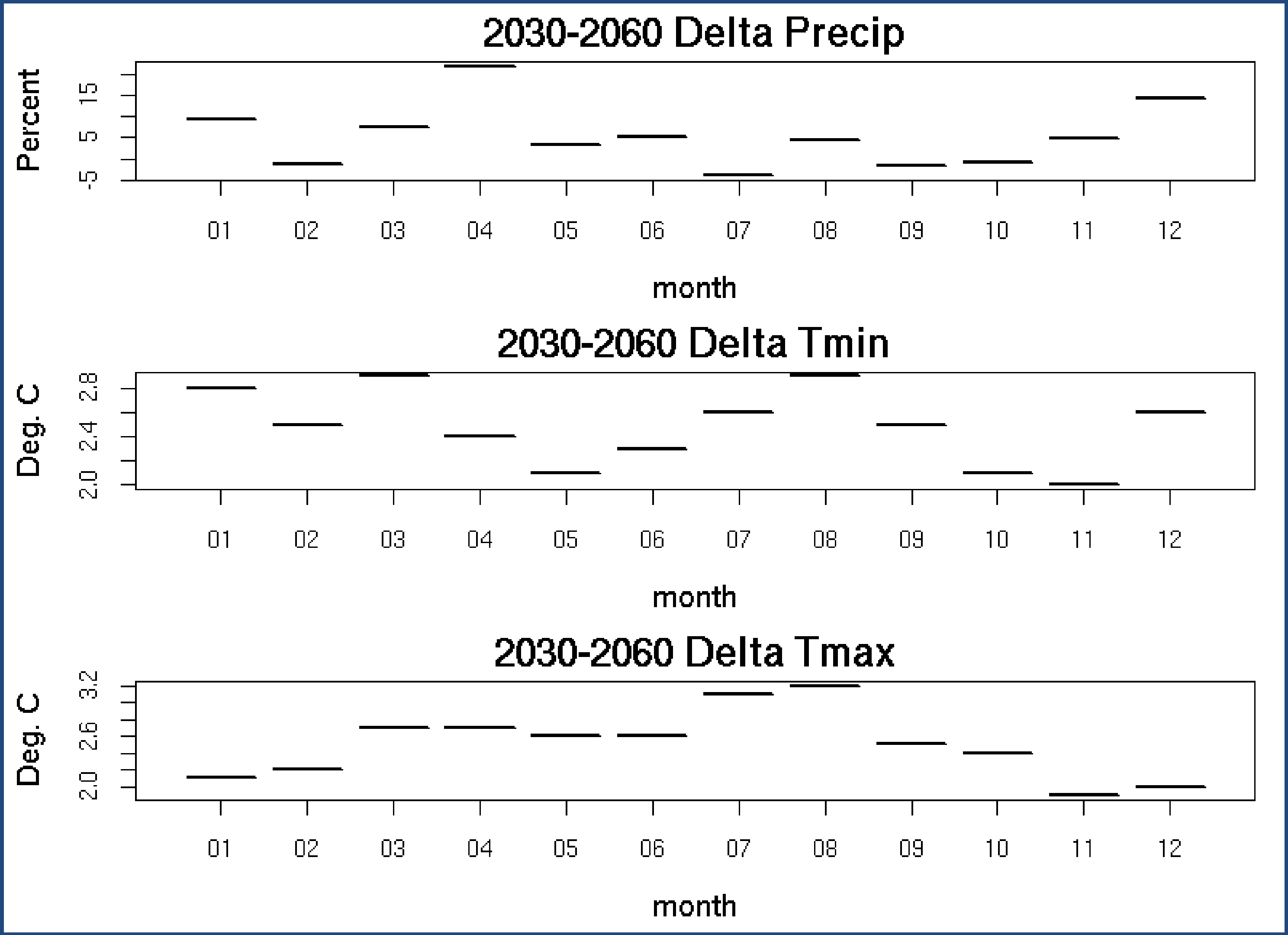
Difference in adult and regeneration niche

Lower probability for regeneration at lower elevations

Suggests contraction of range for Regenerating PIPO compared with adult size class



Projected monthly changes in climate
14 GCM average

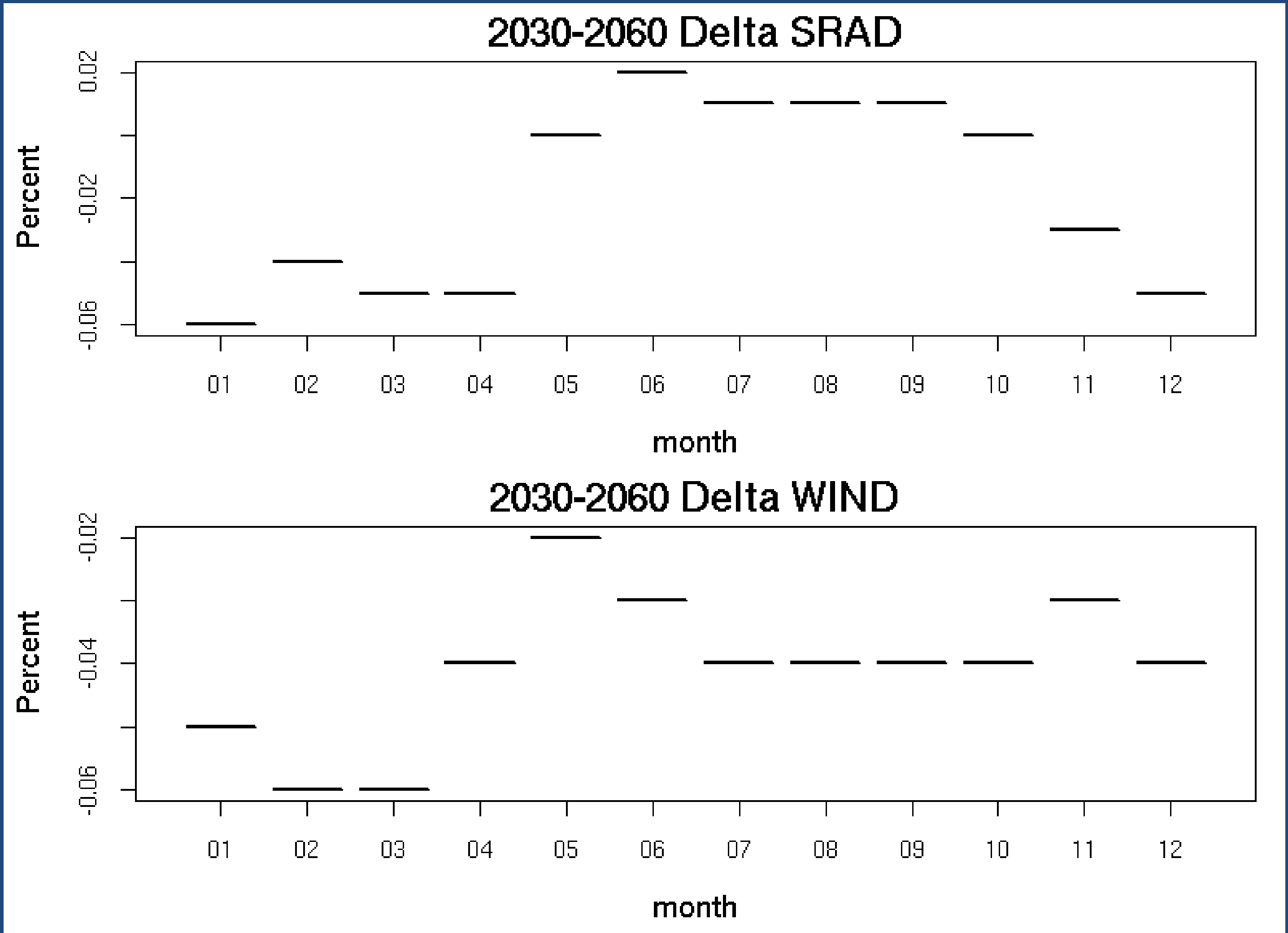


Wind and Radiation

More frequent persistent high pressure systems

Higher July-August temperatures

Decreased wind speeds



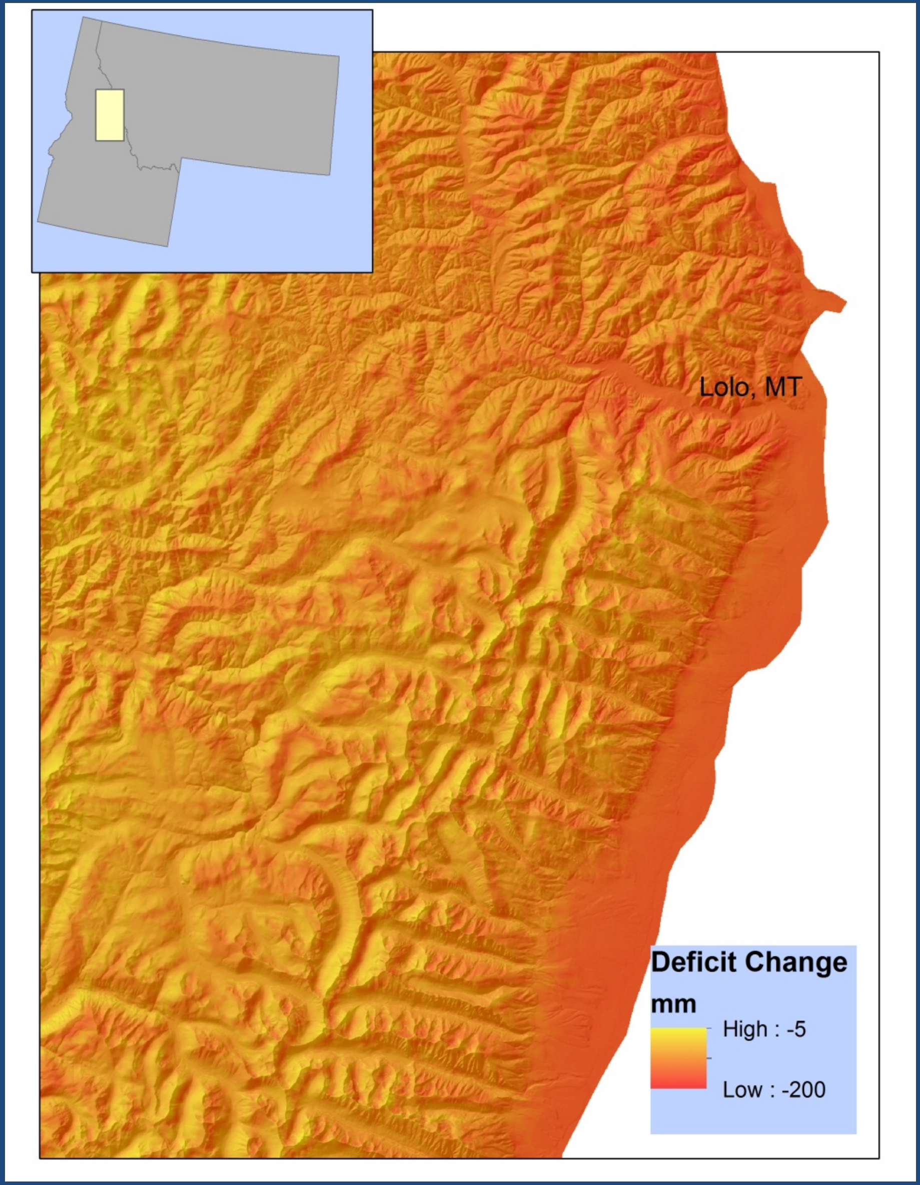
Modeled change in water balance for 2030

- > 15 cm increase in moisture deficit
- Complex patterns of relative change in Moisture availability:

-Warmer temperatures = increased evapotranspiration

-Lower wind speeds = decreased evapotranspiration at exposed sites

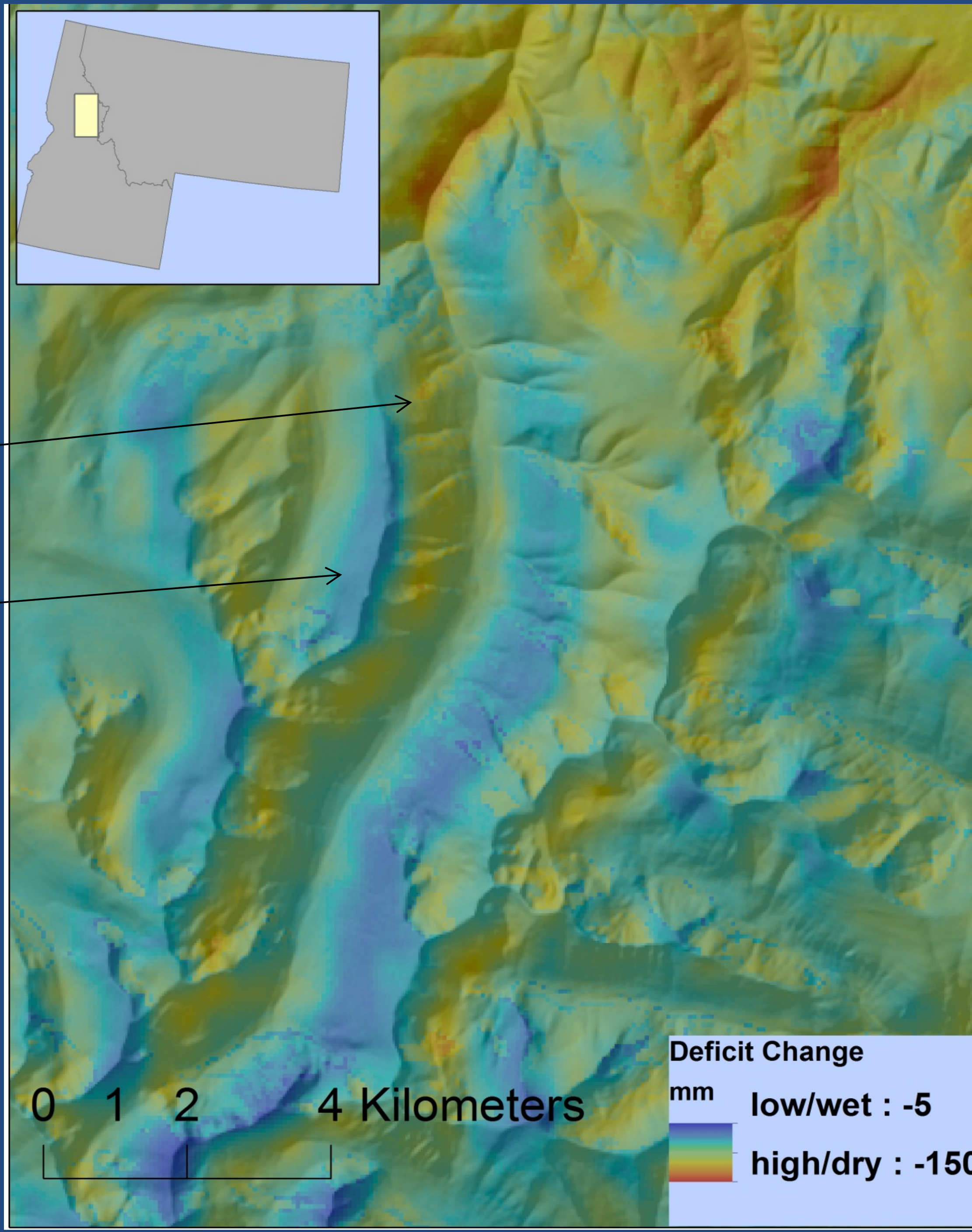
-Changes in cloud cover influence relative Change on shaded vs exposed slopes



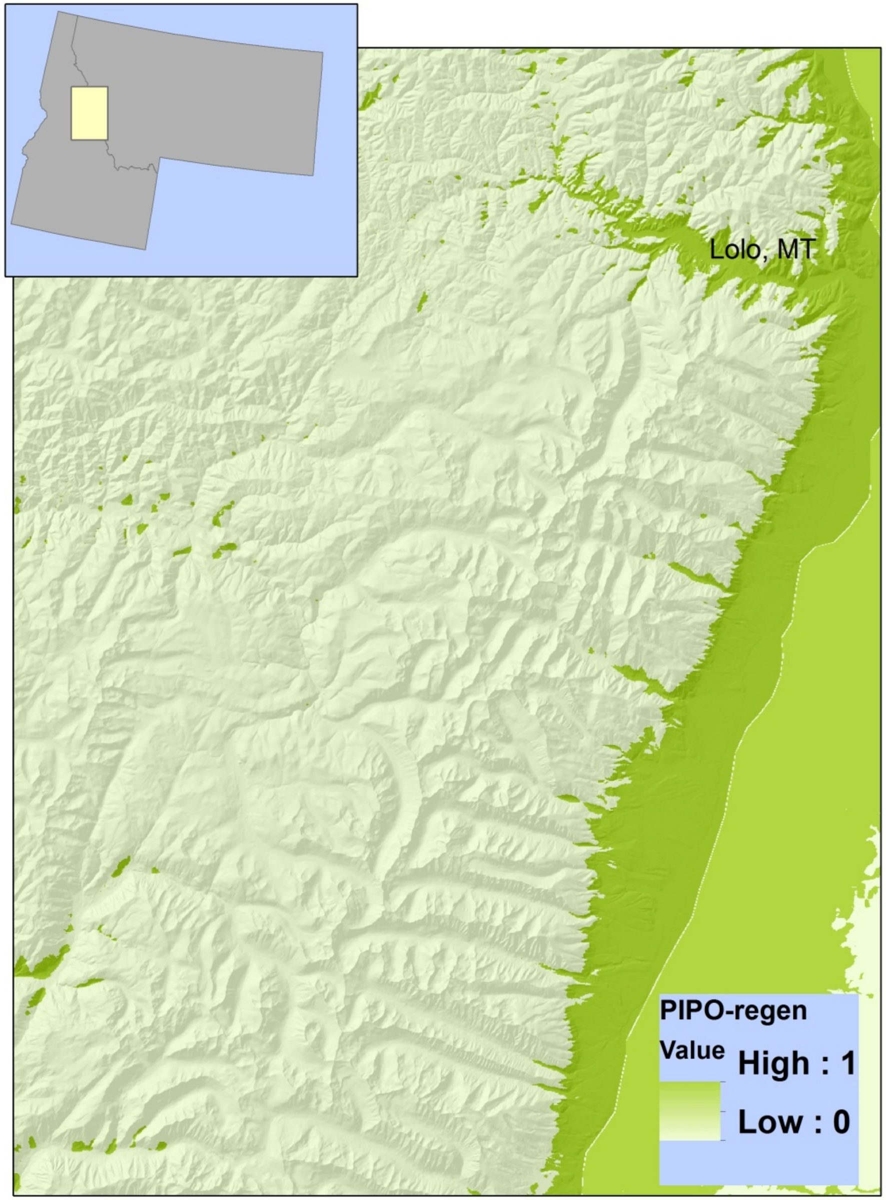
Sheltered leaward slope
(historically low wind speed)

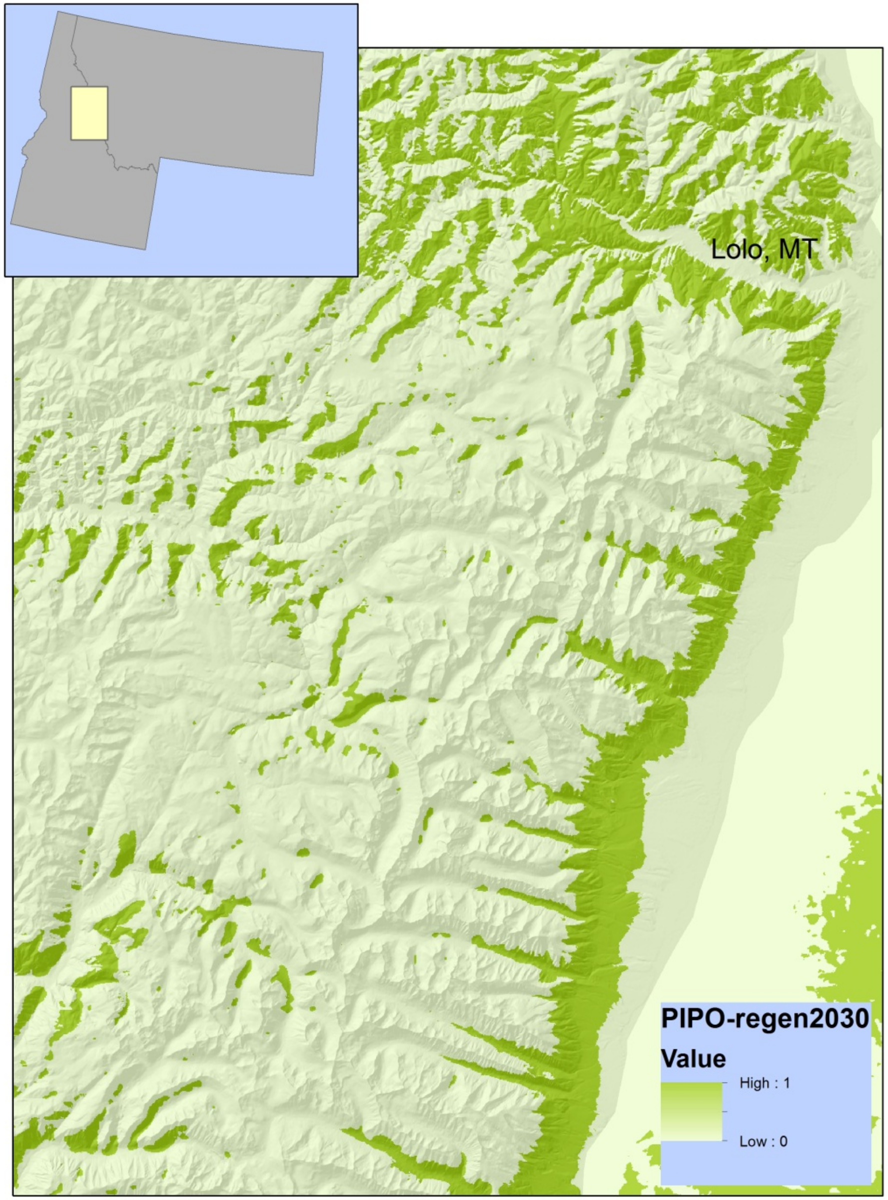
Ridgetop exposed to prevailing wind
(historically high wind speed)

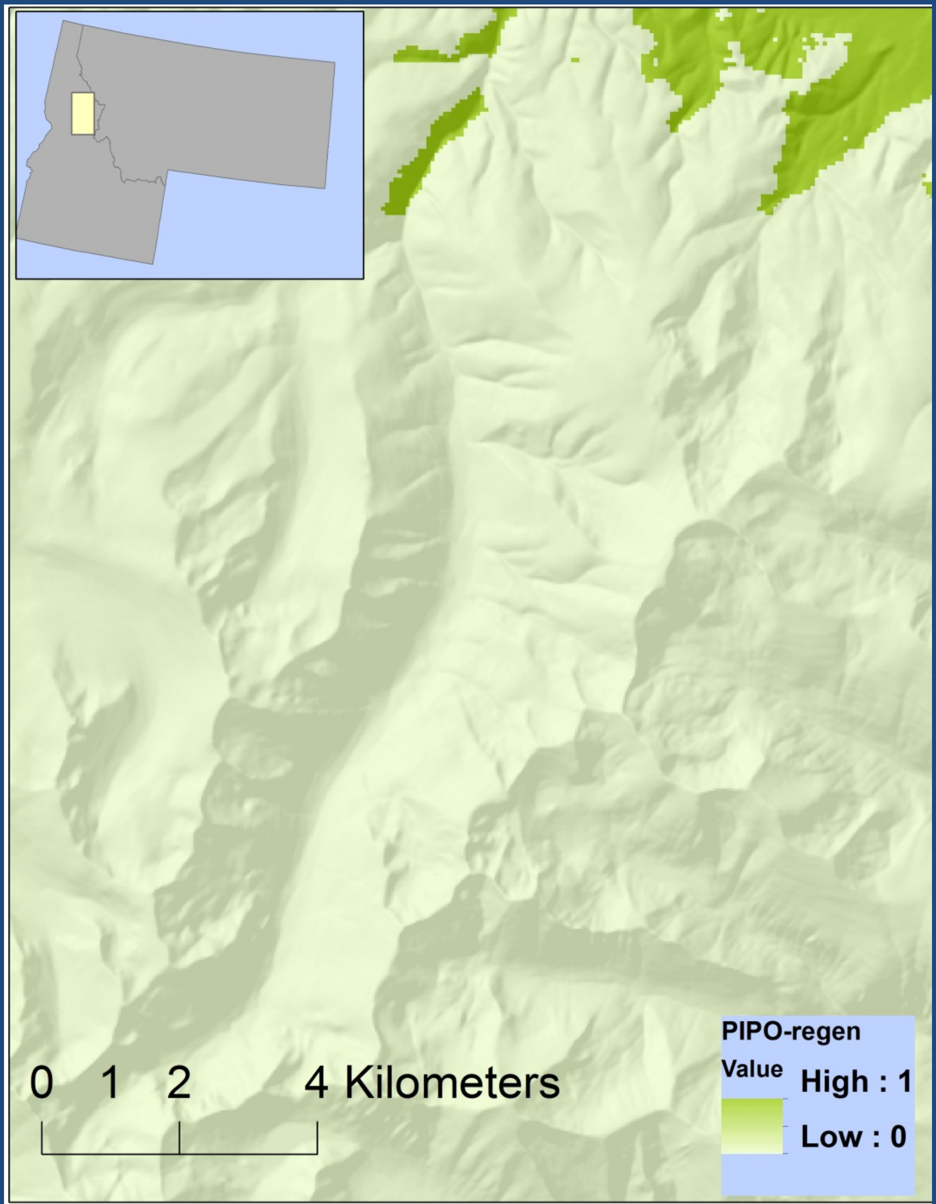
Global stilling mediates wind-driven patterns in evapotranspiration

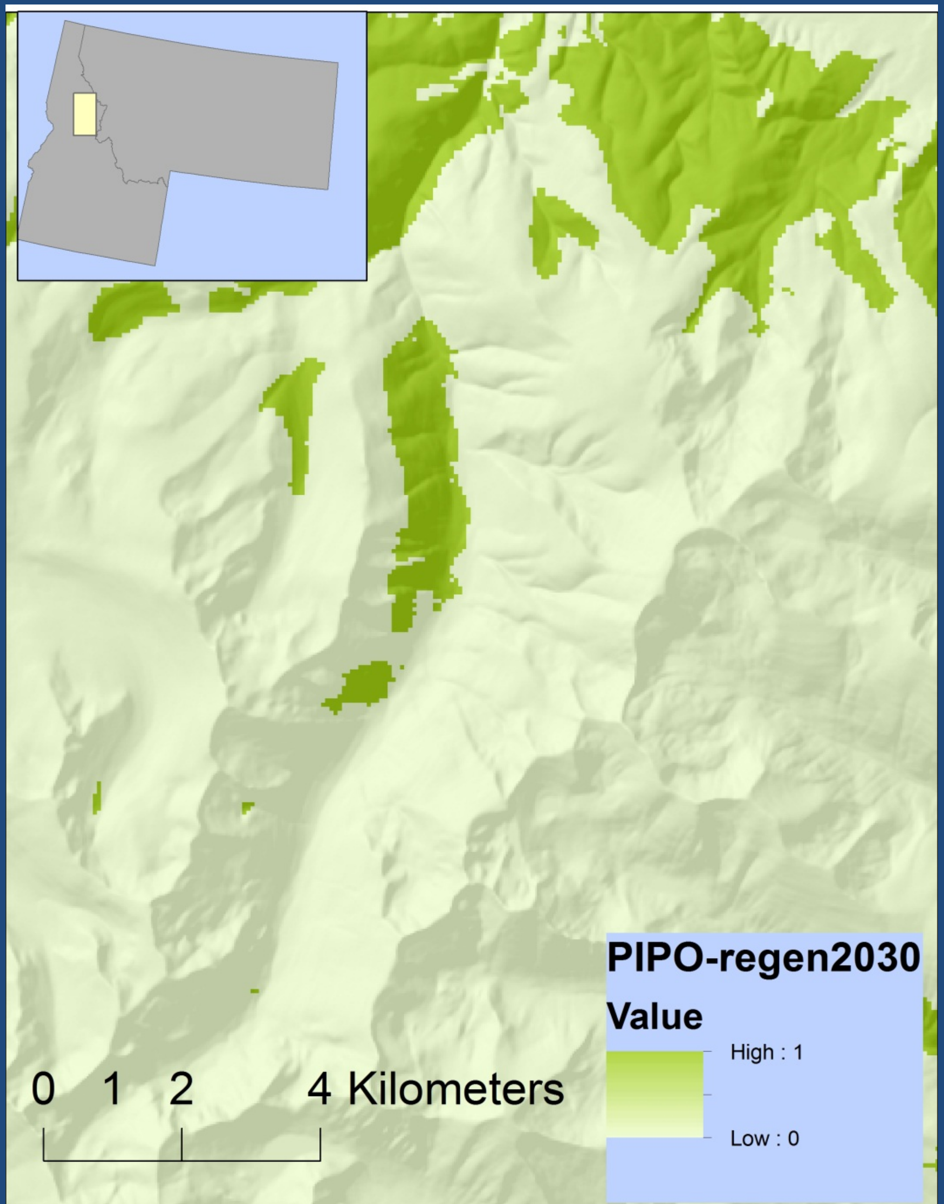


Ponderosa pine predicted regeneration: Adult vs 2030



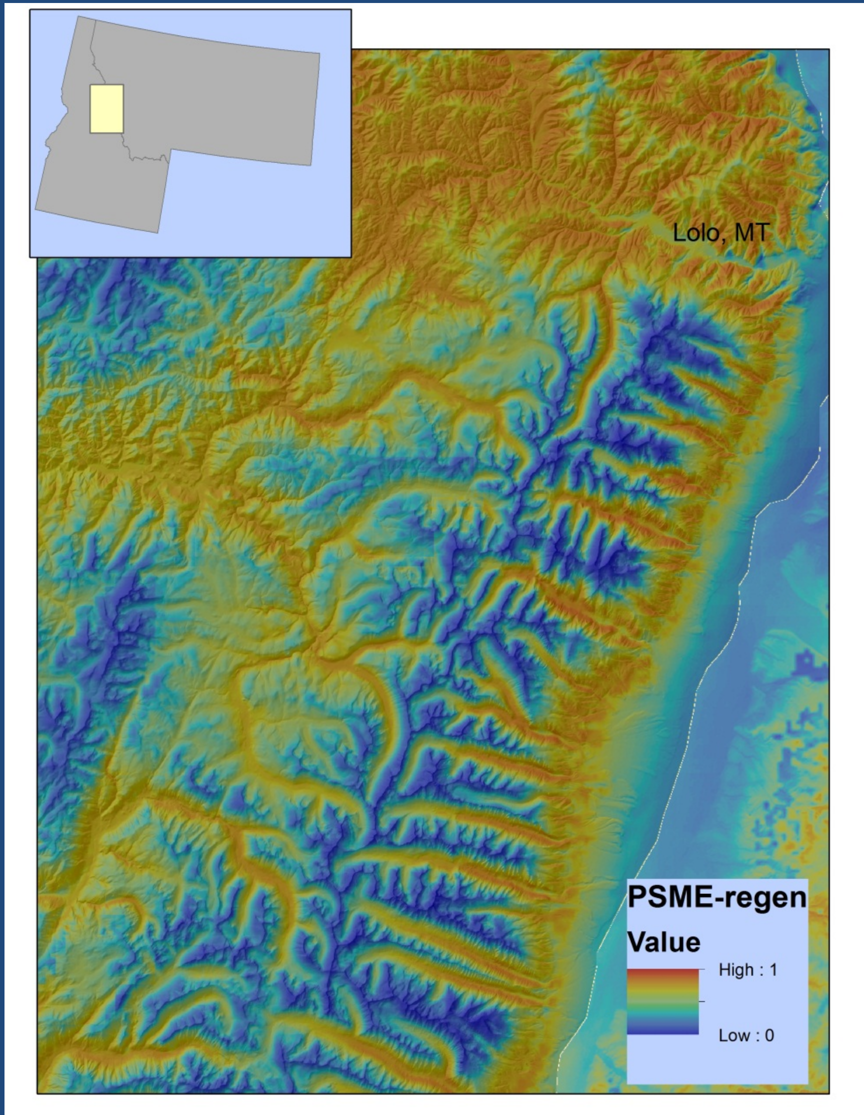



PIPO-regen
Value
High : 1
Low : 0
0 1 2 4 Kilometers

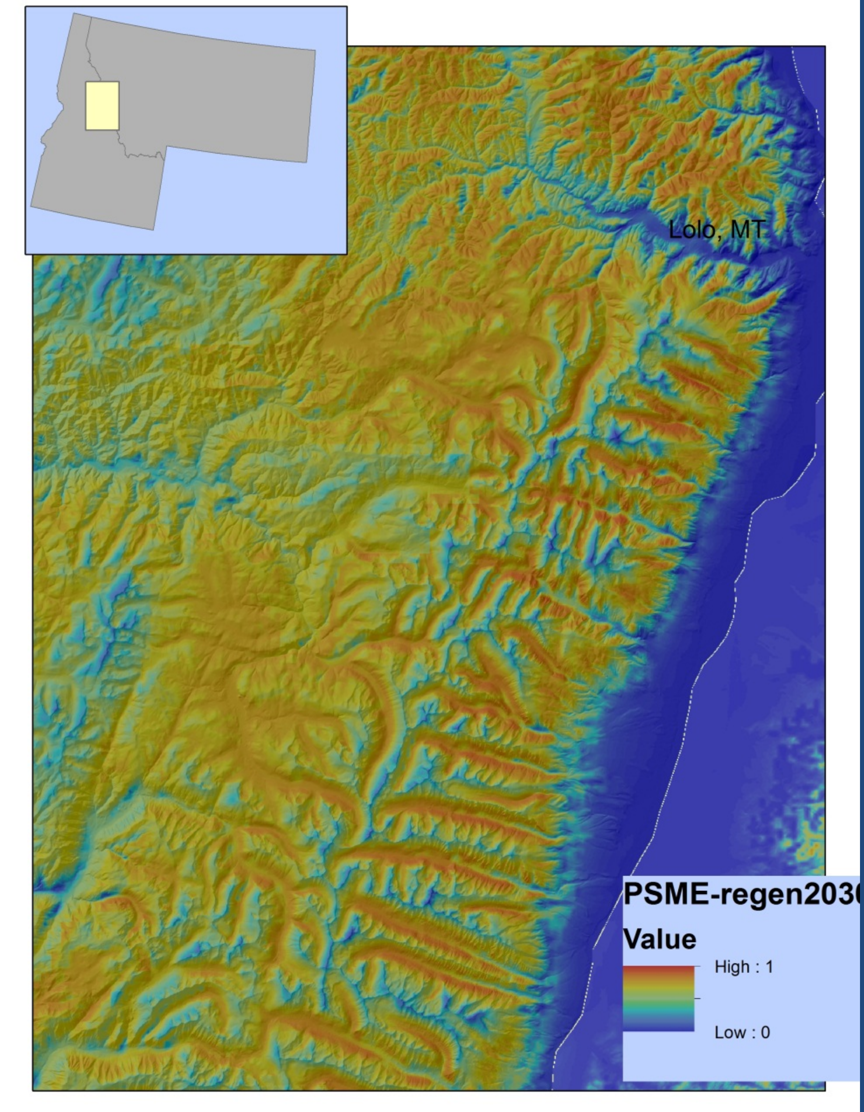

PIPO-regen2030
Value
High : 1
Low : 0
0 1 2 4 Kilometers

Douglas fir

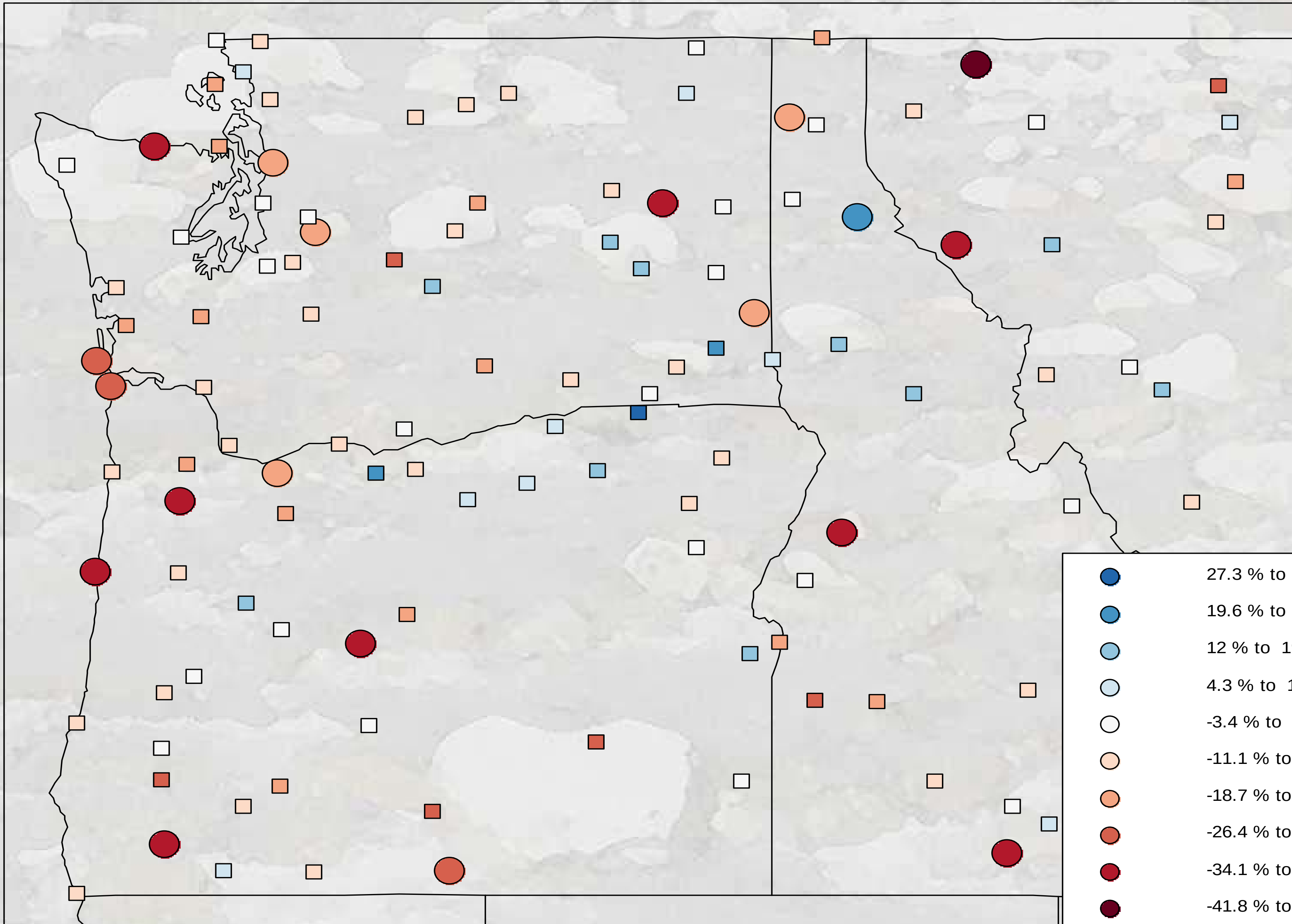
current regen



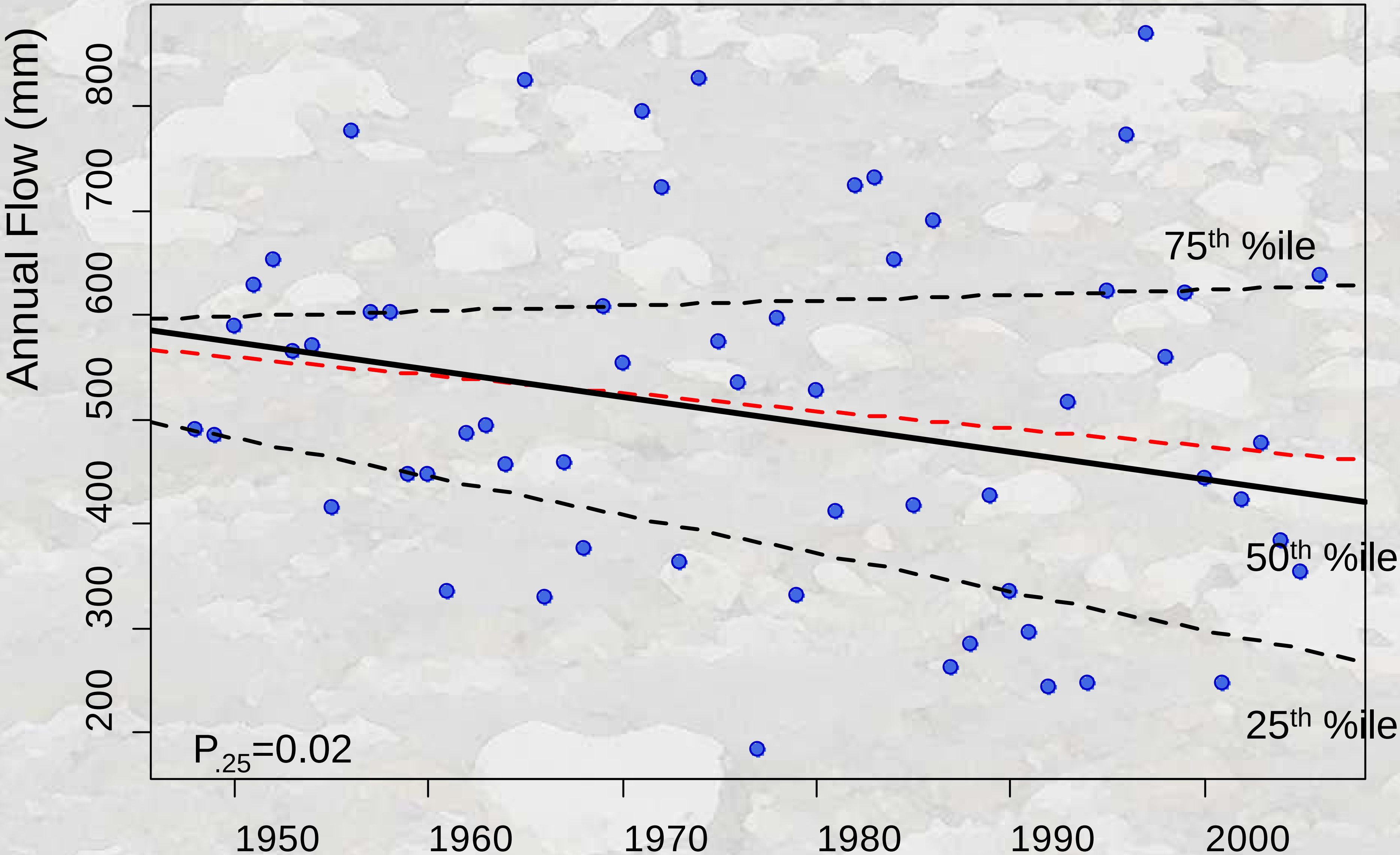
future regen



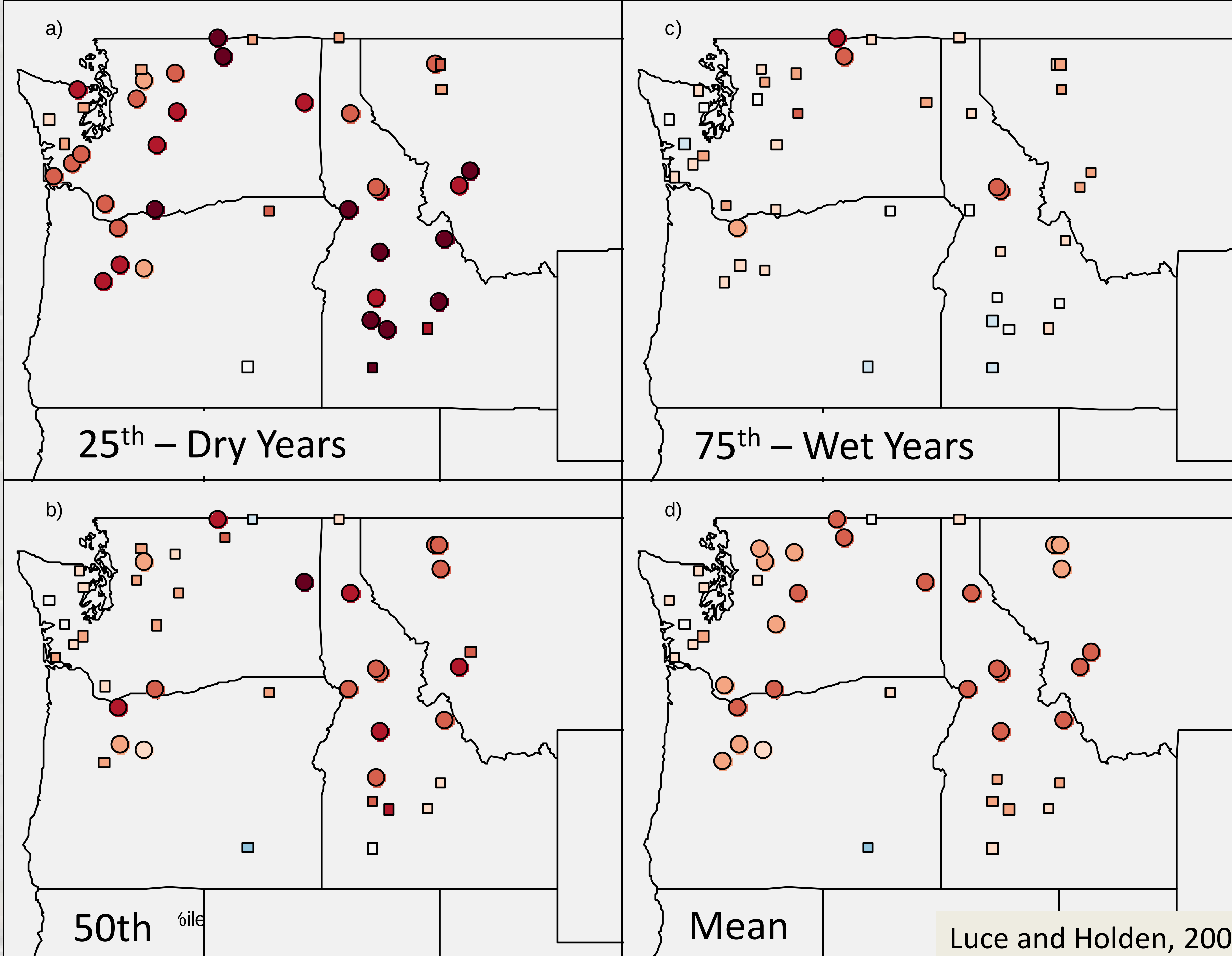
Trends in HCN2 Precipitation (% change in 25th %ile)



Middle Fork Boise – Trend in Water Yield Quantiles

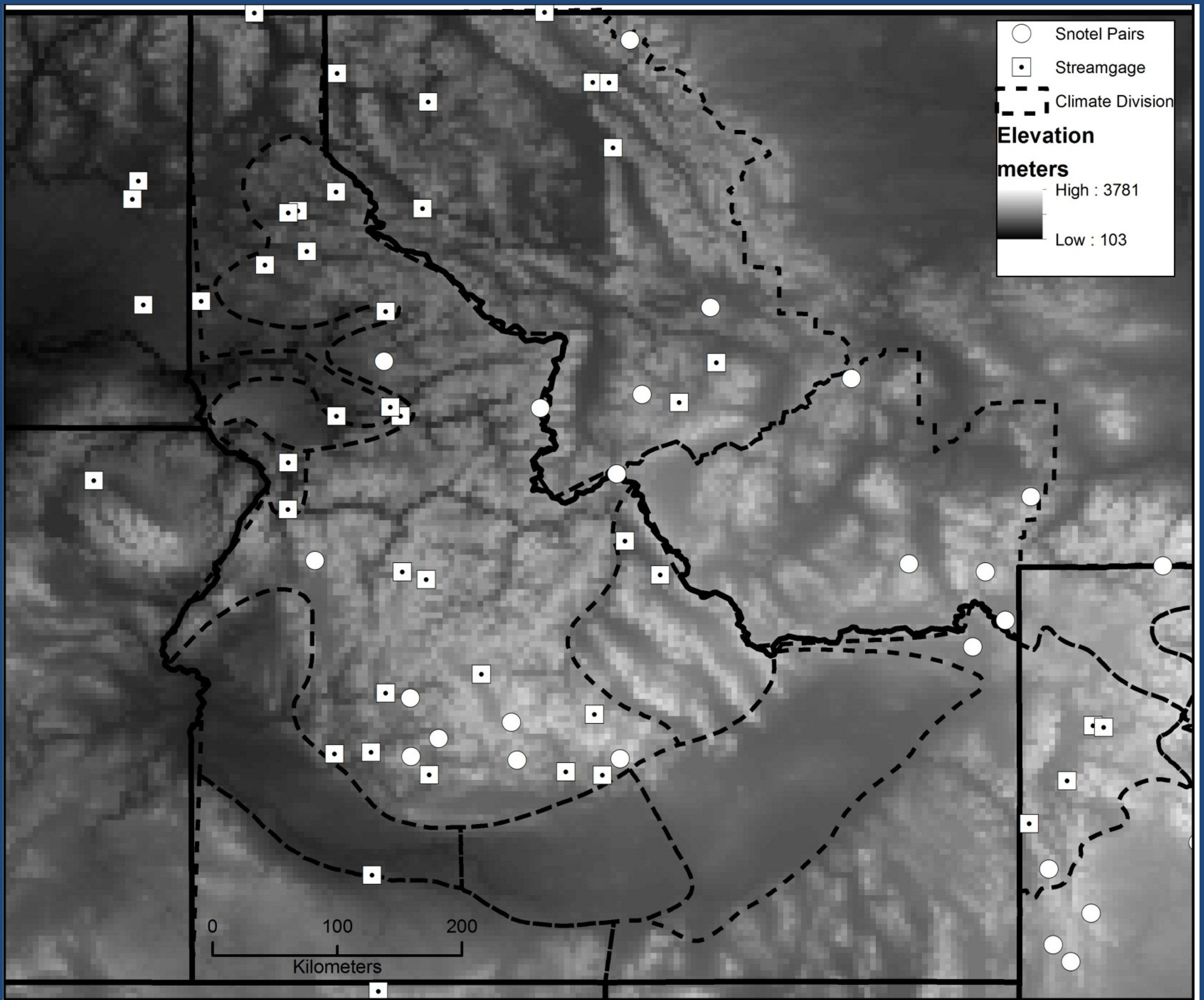


Luce and Holden, 2009



Luce and Holden, 2009

Snotel-HCN station pairs < 20km apart

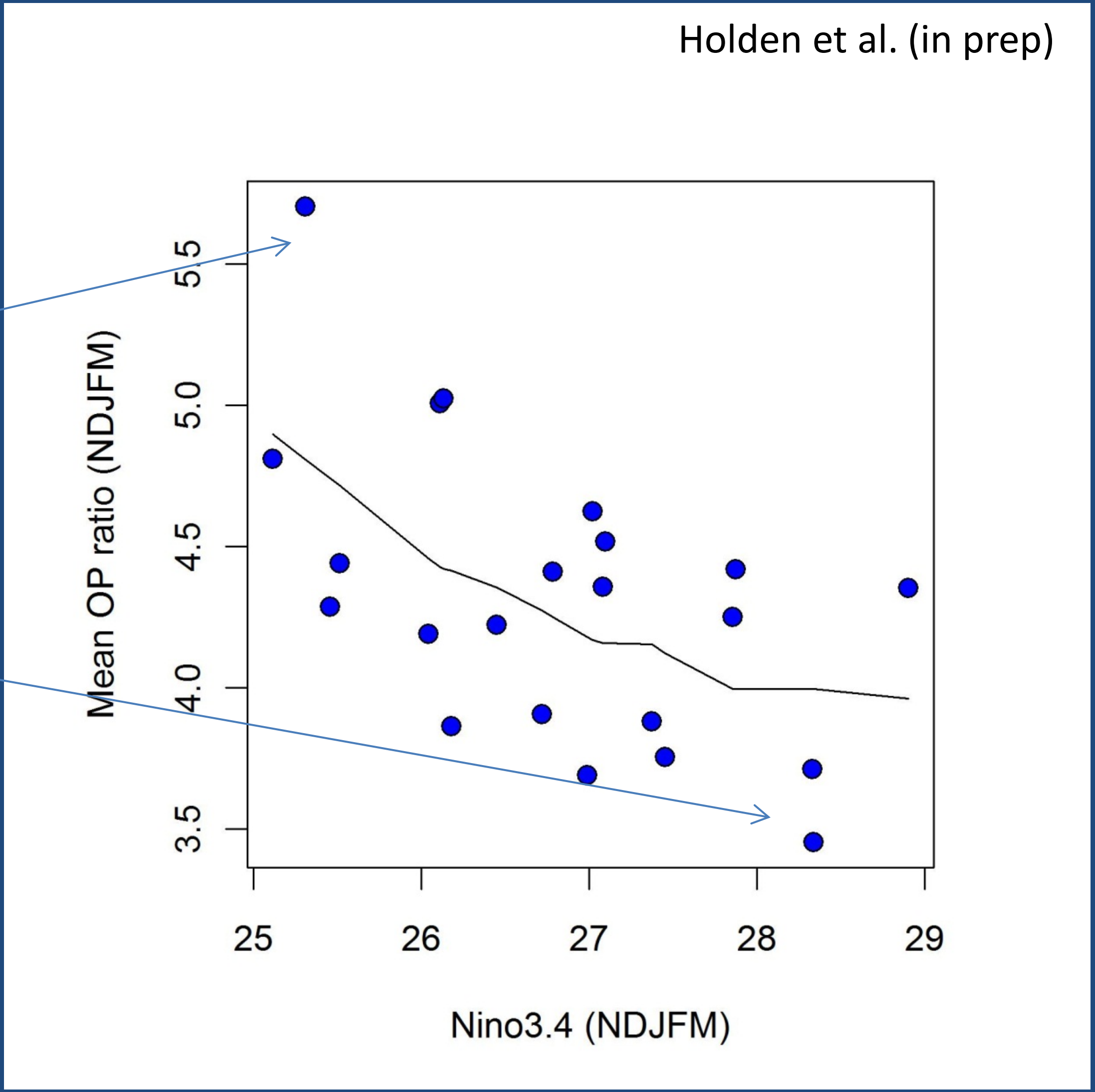


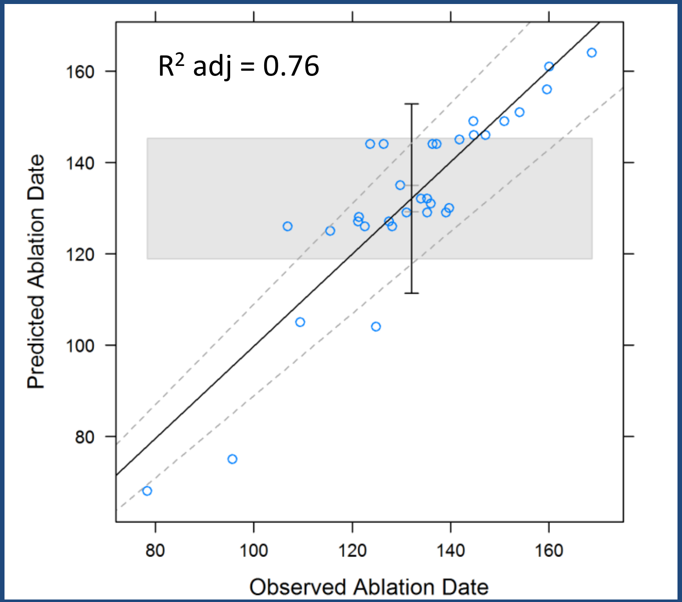
Changing patterns in orographic enhancement (the distribution of precipitation with elevation)

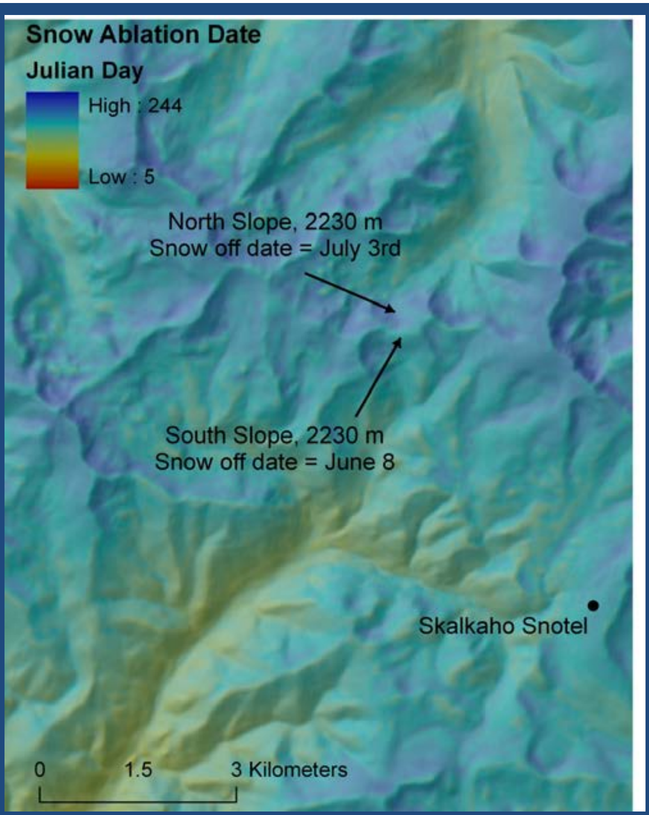
La Nina (wet) years have relatively
Higher amounts of high elevation
Precipitation

El Nino (dry) years have relatively
Less precipitation falling at high
Elevations

Trends detected at low elevation
Stations may be amplified in mountains





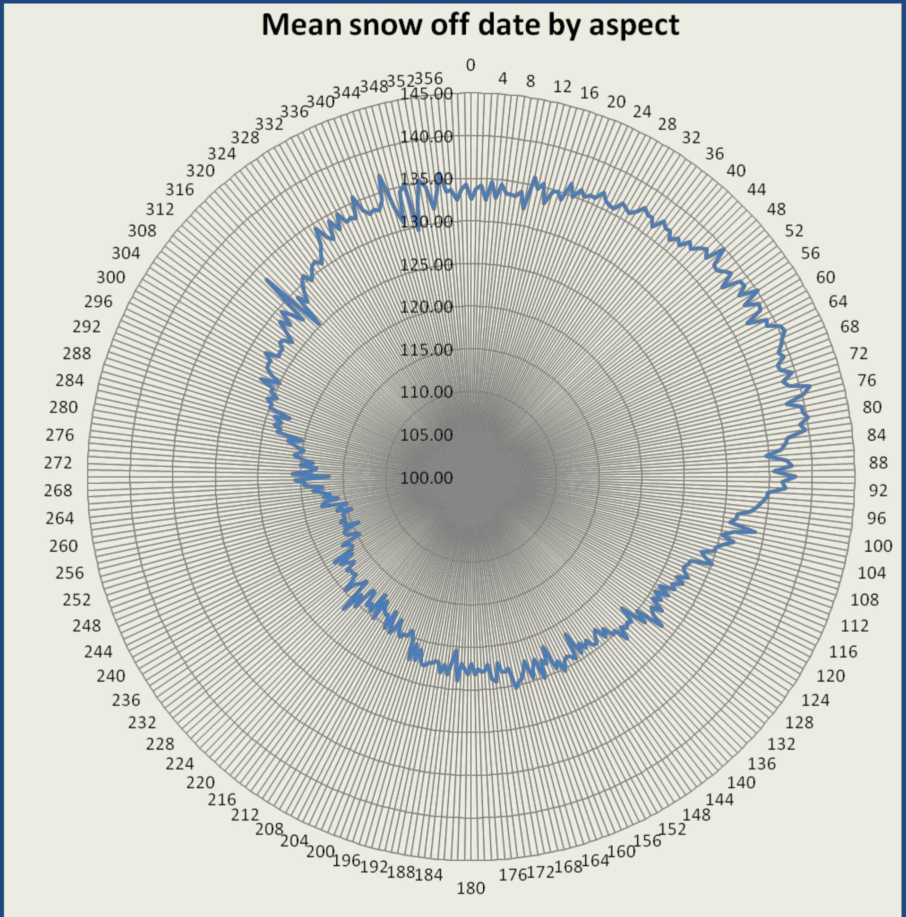


A simple empirical model of snow ablation date
Using distributed temperature sensors

Captures physics of snow accumulation and melt

Earliest melt on Southwest-facing slopes (interaction betweeen radiation and temperature)

4 week delay on high elevation North slopes



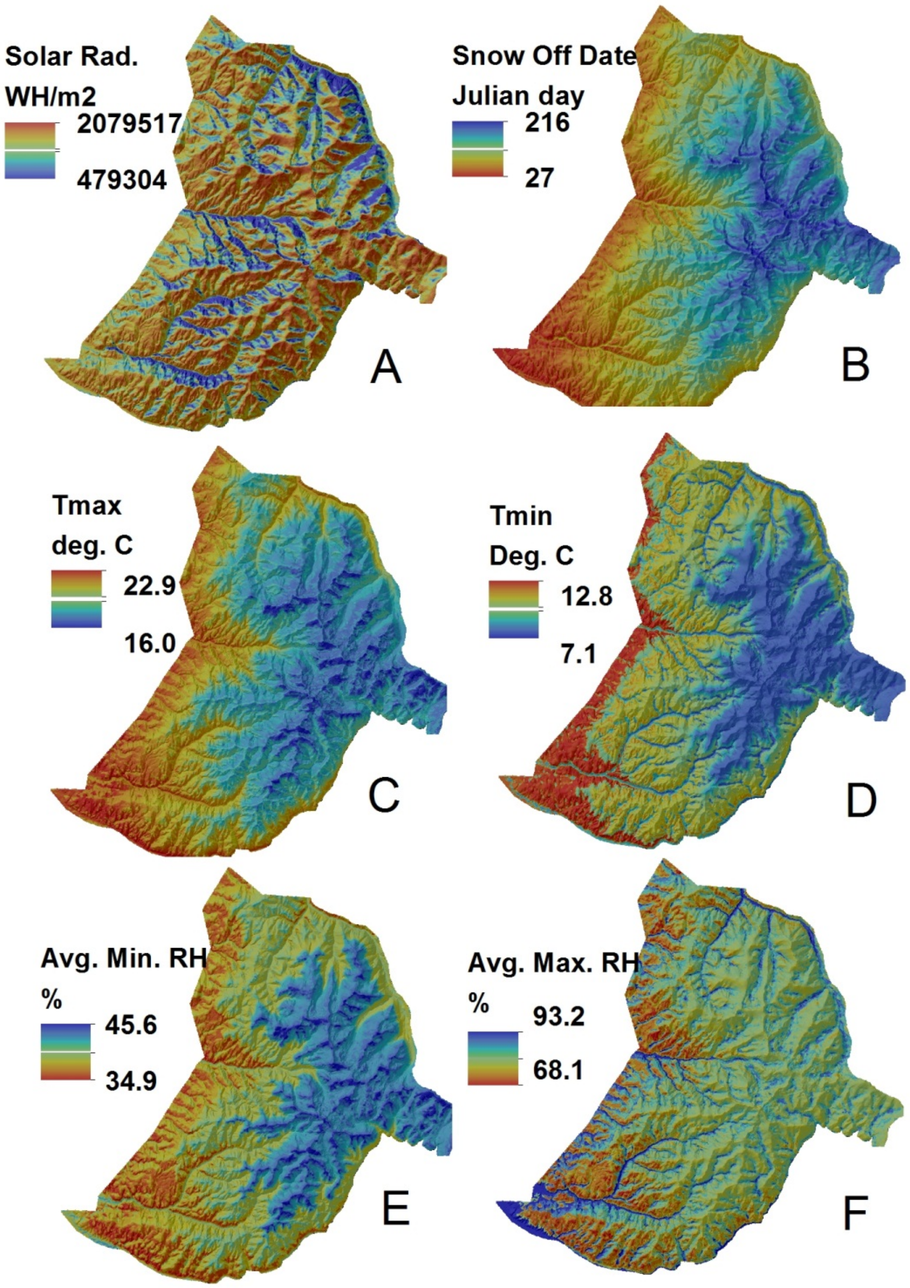
climatic and biophysical variation in complex terrain

Tmin, Tmax, Rhmin, Rhmax modeled using PCA and networks of ibuttons

Lower maximum temperatures and Higher RH on north slopes

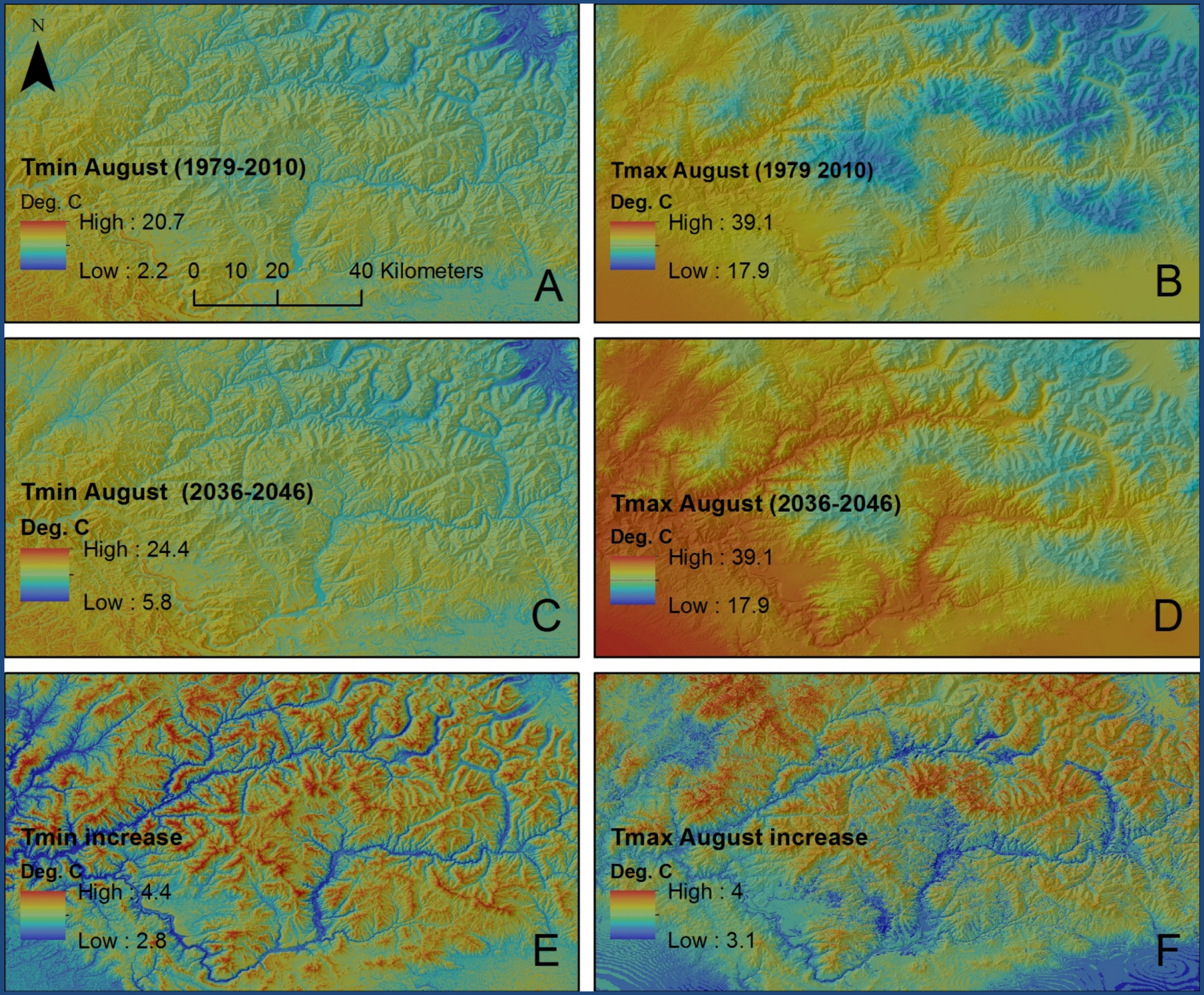
Delayed snowmelt timing on high Elevation north slopes

Lower minimum temperatures and higher RH in valley bottoms



Holden and Jolly (2011)

Fine-scale heterogeneous changes in air temperature warming rates

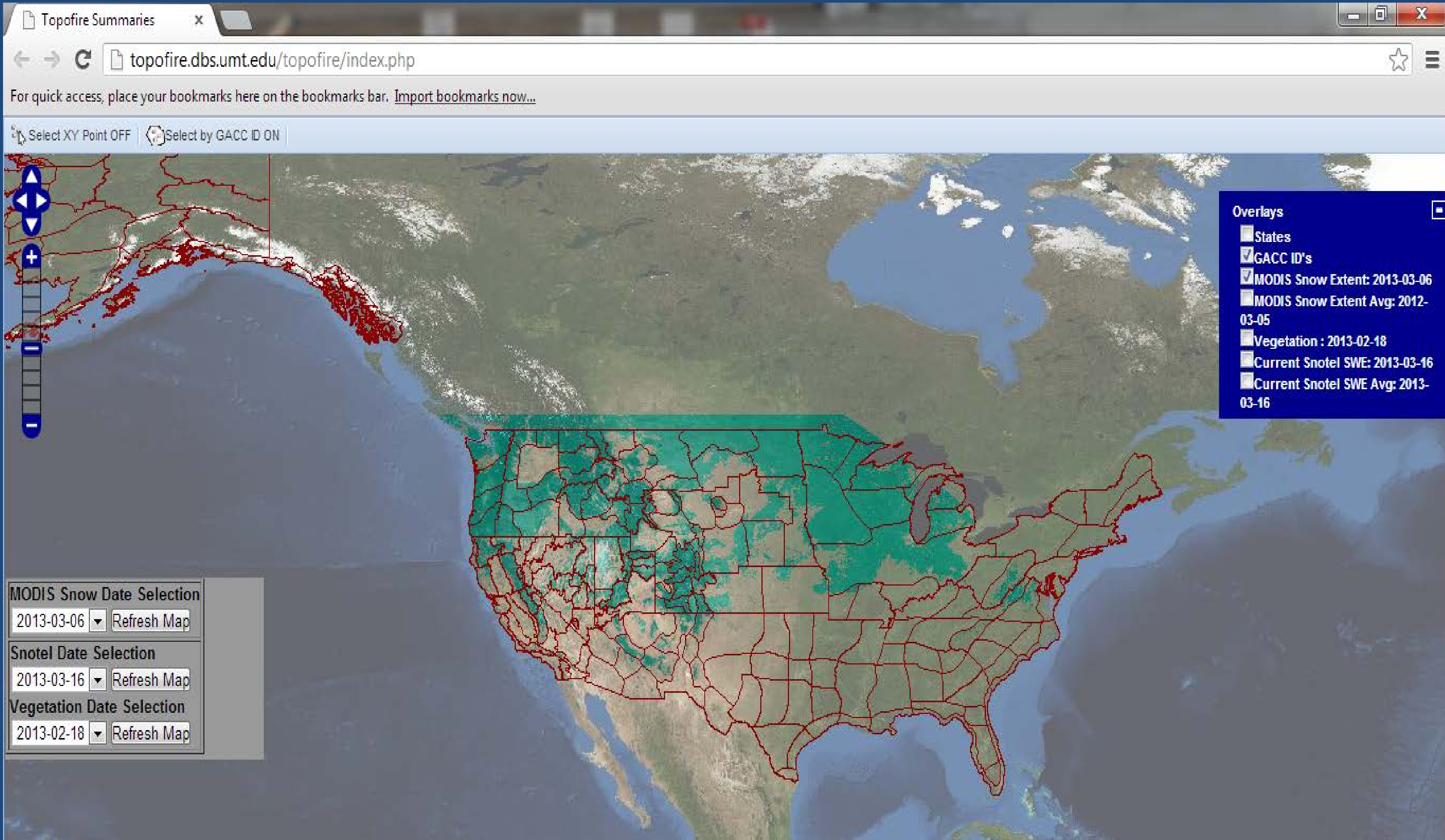


What we can expect in a warming world:

- Heterogeneous fine-scale changes in:
  - surface air temperature warming with aspect
  - changes in inversion patterns/cold air pooling
  - relative changes in snowmelt timing with aspect?
  - changes in distribution of precipitation?

Potential for complex *fine scale* changes in where/how species grow

TOPOFIRE: An interactive web system for monitoring disturbance and climatic influences on soil and fuel moisture in complex terrain



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questions