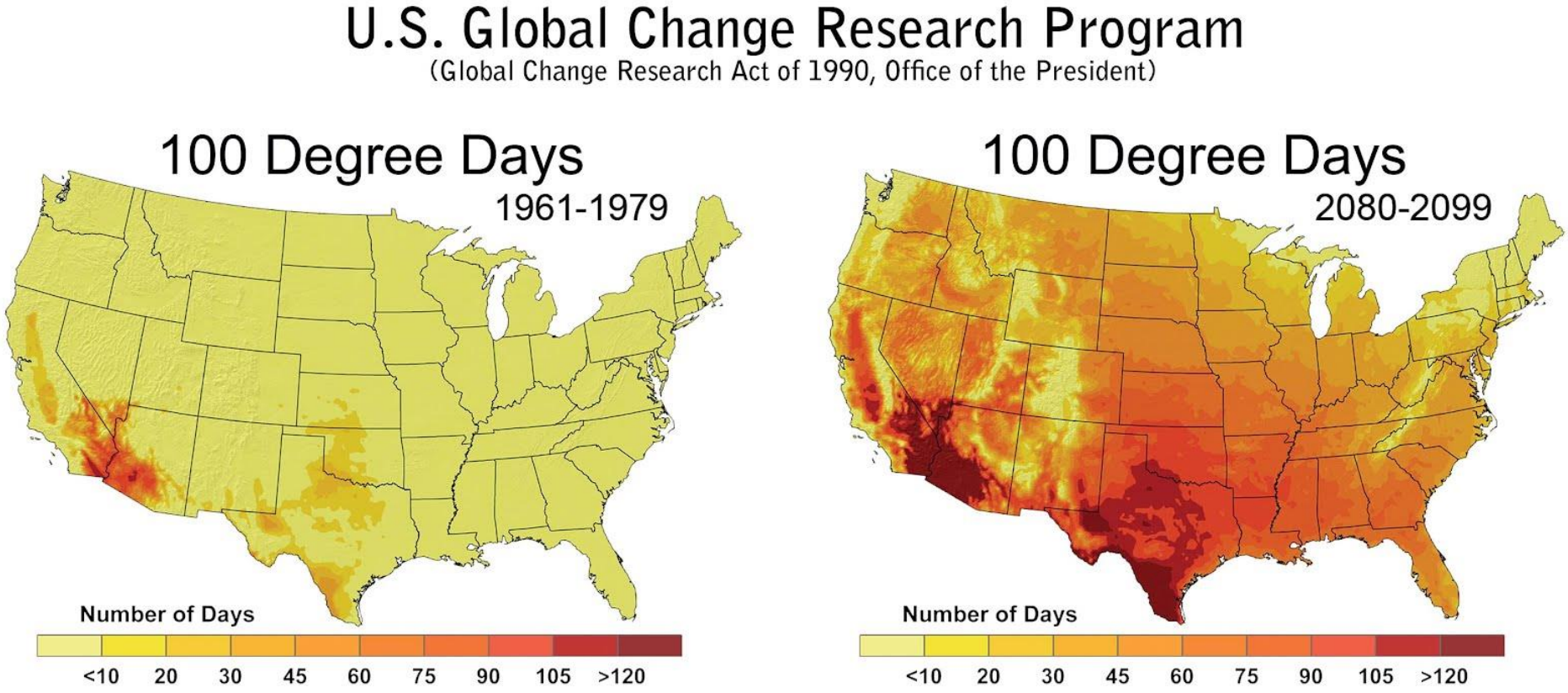
Frost, heatwaves and declining water tables: is there a super cottonwood genotype that can cope with all three?

Frost, heatwaves and declining water tables: is there a super cottonwood genotype that can cope with all three?

Future climate in the West…

- Is the population niche going to narrow?
- If so, can we identify genotypes within populations best suited to maximize fitness in a smaller niche?



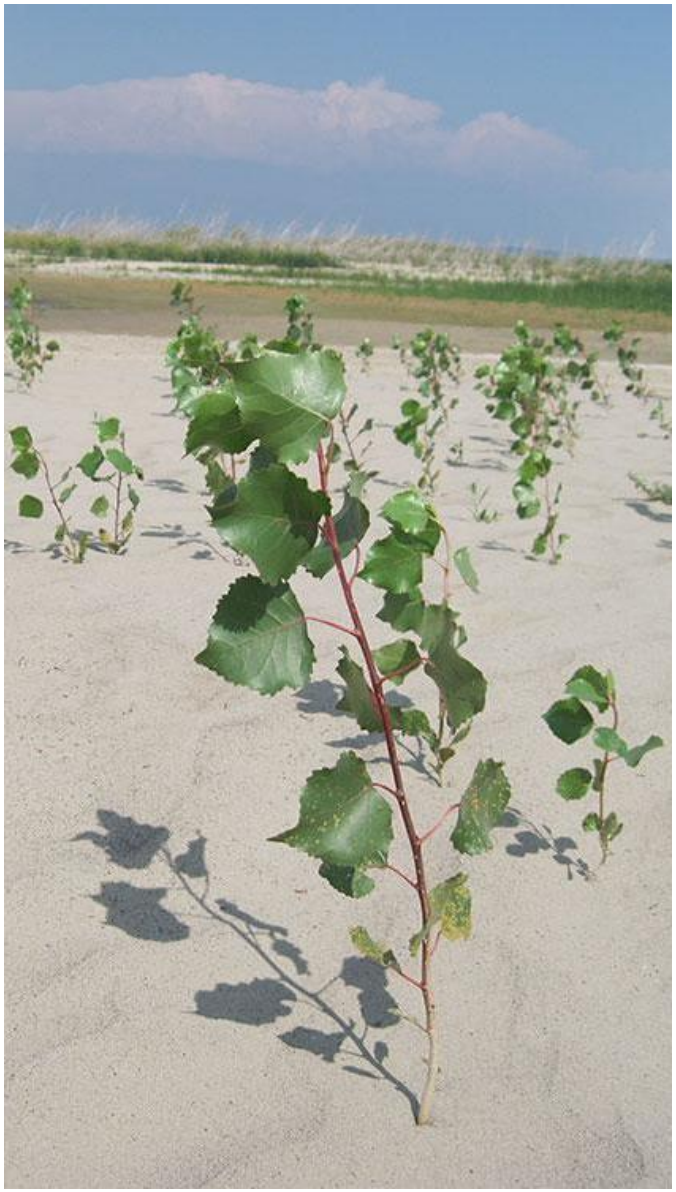
Economics 101

- **Supply / demand**: Ex. Sapwood (supply) to leaf area (demand)

- **Cost / benefit**: Ex. Leaf construction (cost), photosynthetic carbon gain (benefit)

Risk / reward: Ex. Early leaf flush (Risk), photosynthetic carbon gain (benefit)

A theoretical super genotype…

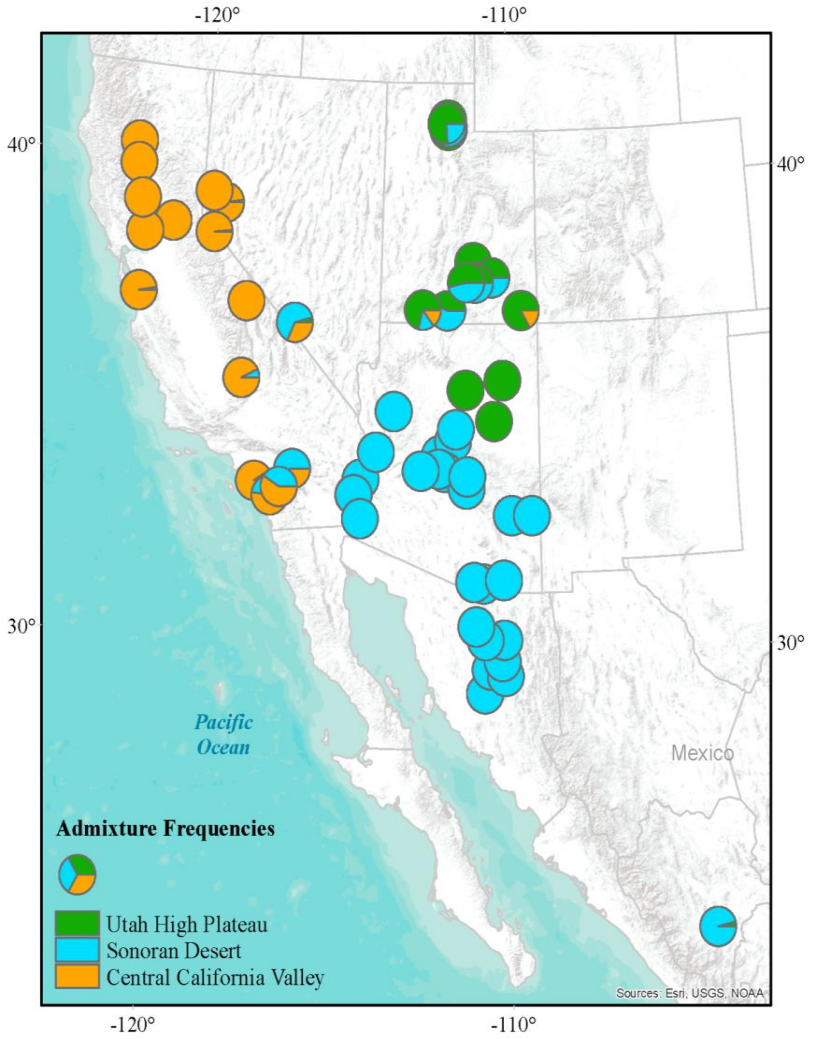


- Thermal stress avoidance: Early leaf flush, high maximum conductivity, high sapwood / root area to leaf area, low stomatal control (high risk)
- Frost tolerance / avoidance: Late leaf flush, small diameter xylem vessels
- Drought tolerance / avoidance: High sapwood / root area to leaf area, high stomatal control (low risk)

- High degree of phenotypic plasticity

Fremont cottonwood populations are distributed across discrete ecoregions

The expression of traits should follow a predictable pattern as a function of climate constraints

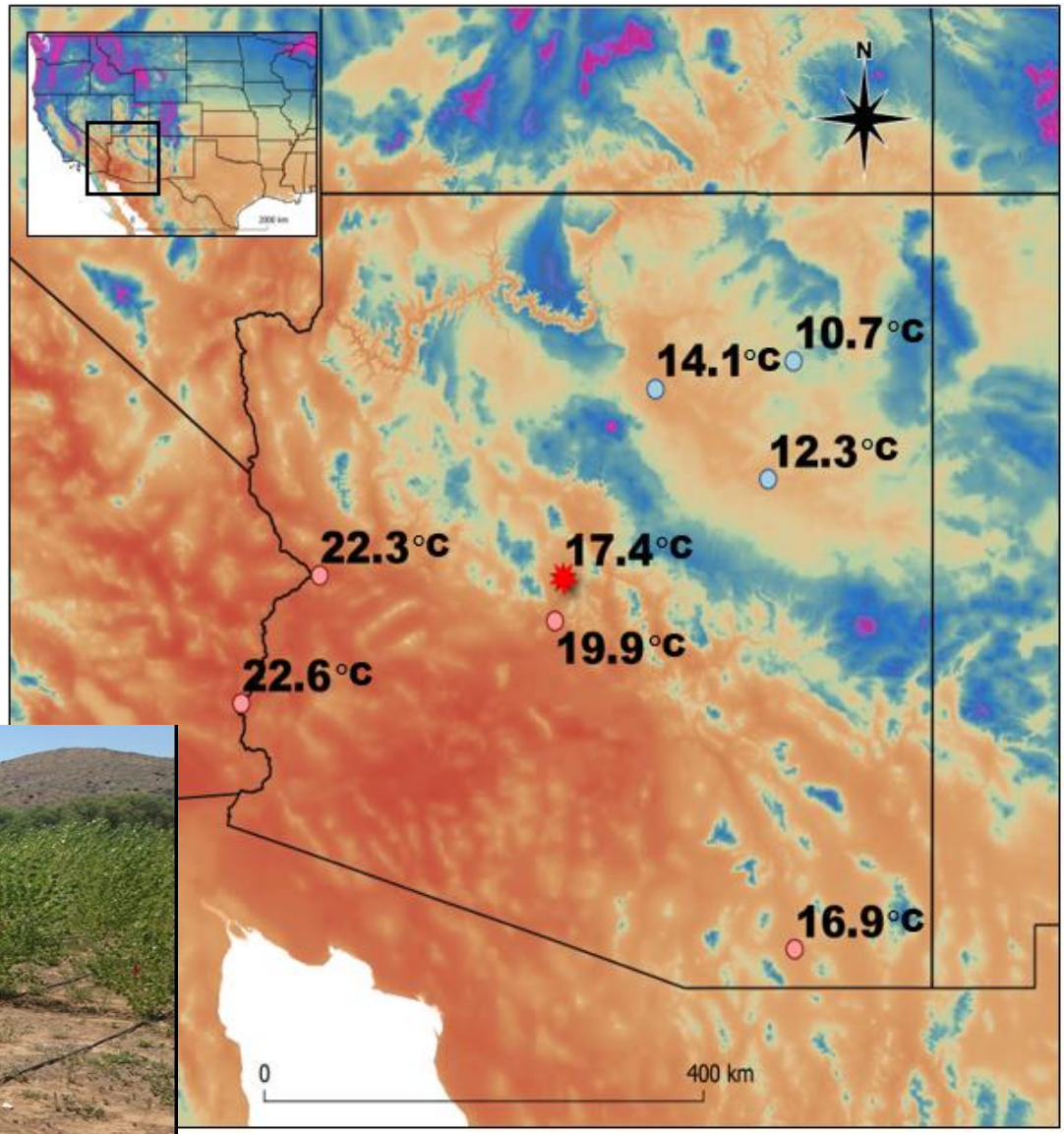


- Foliage phenology
- Leaf traits
- Wood / hydraulic traits
- Above ground architecture

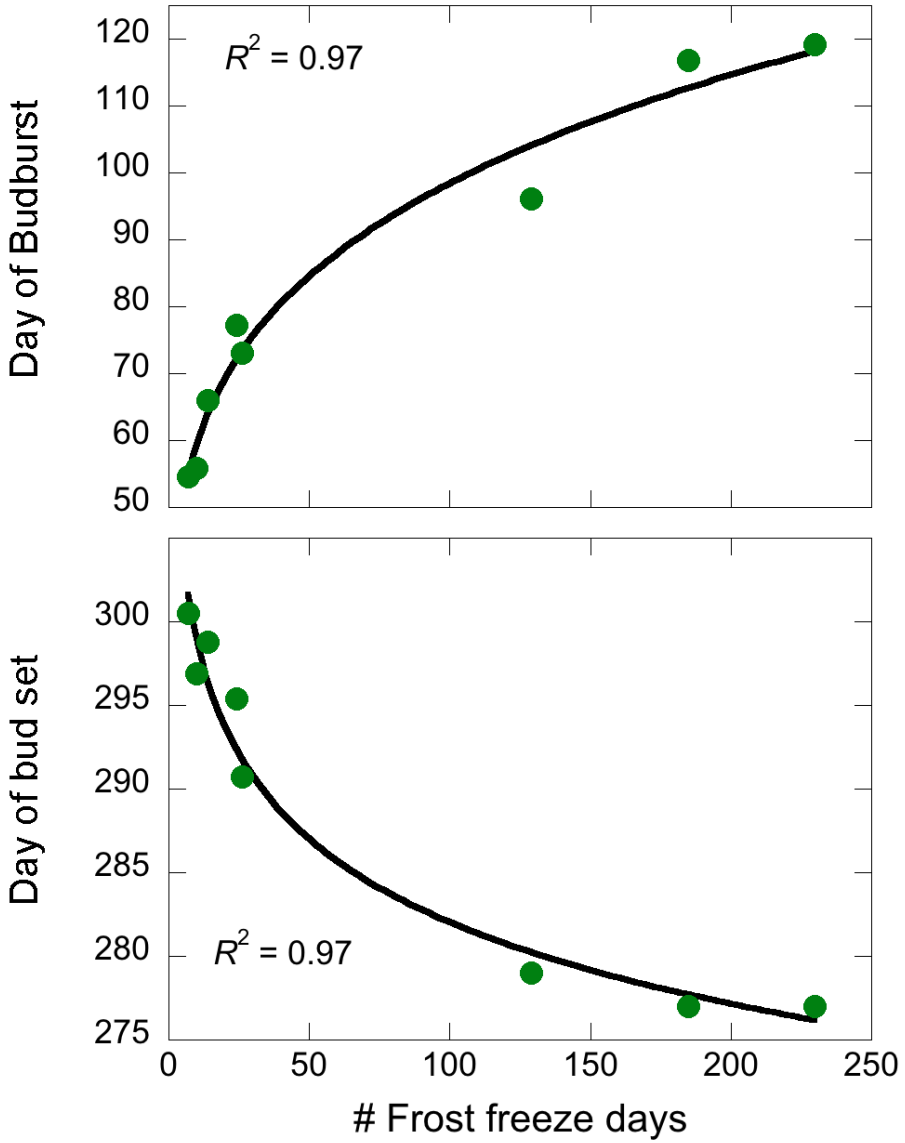
Bothwell et al. (in prep)

Common garden experiment to study trait variability

Eight populations spanning two Ecoregions and a MAT range of ~ 12 °C



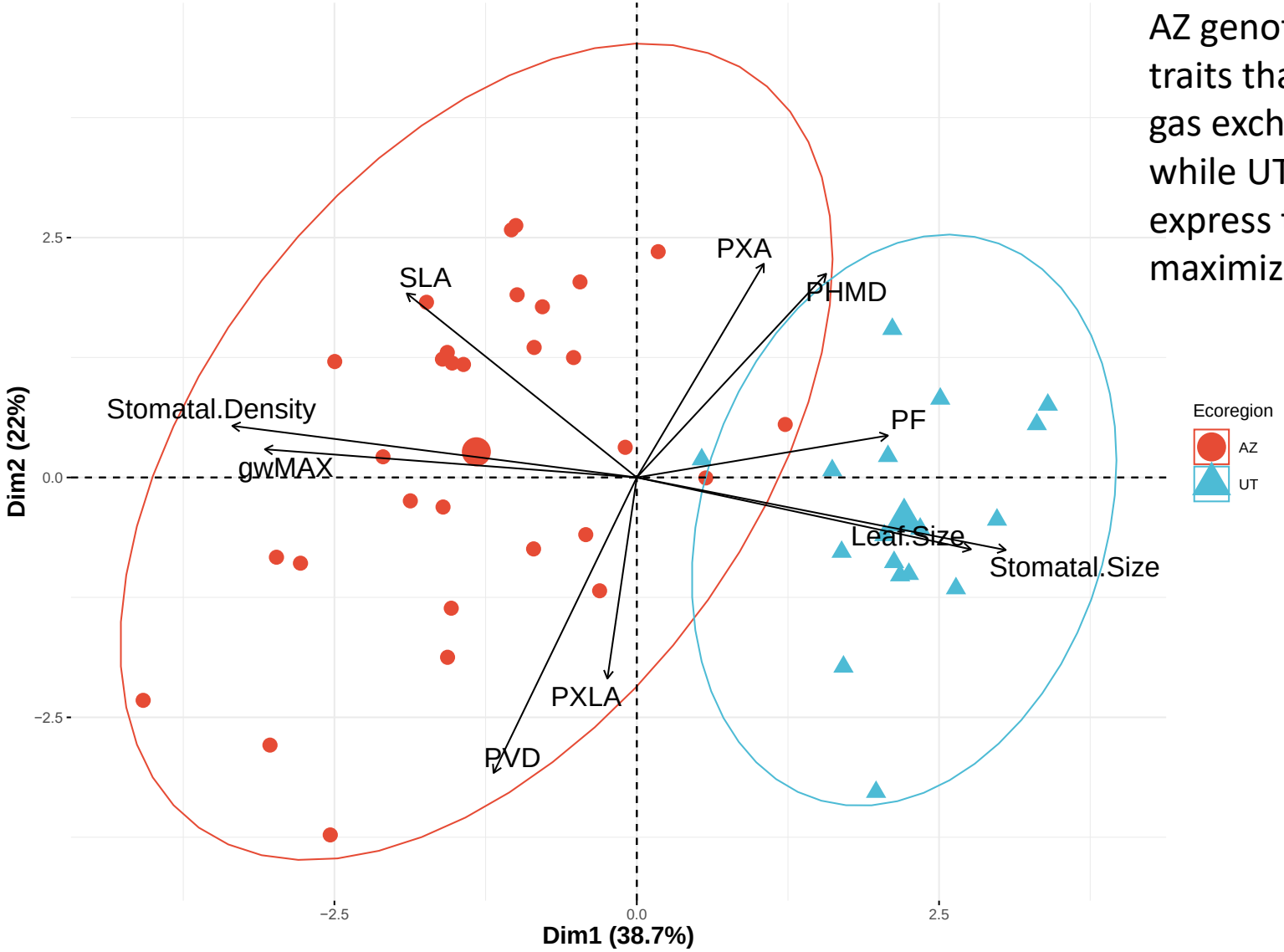
Local adaptation in foliage phenology



- Budburst varied by over two months
- Bud set varied by over three weeks
- Phenology was highly correlated to the # of frost freeze days

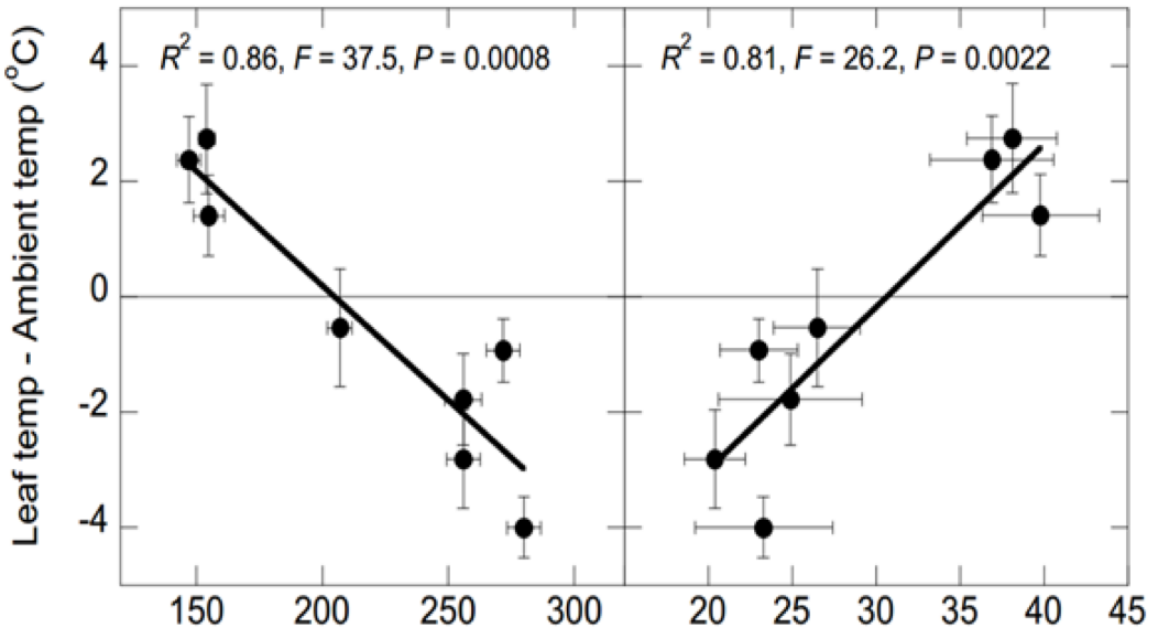
Blasini et al., in prep

Large leaf trait contrasts between ecoregions



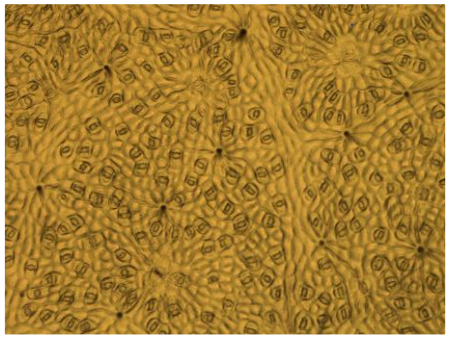
AZ genotypes express traits that maximize gas exchange efficiency while UT genotypes express traits that maximize leaf longevity

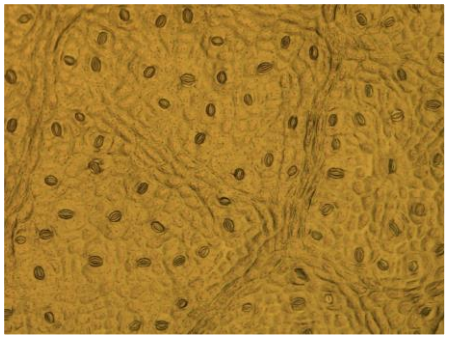
Leaf cooling features



Stomatal density (# mm^{-2})

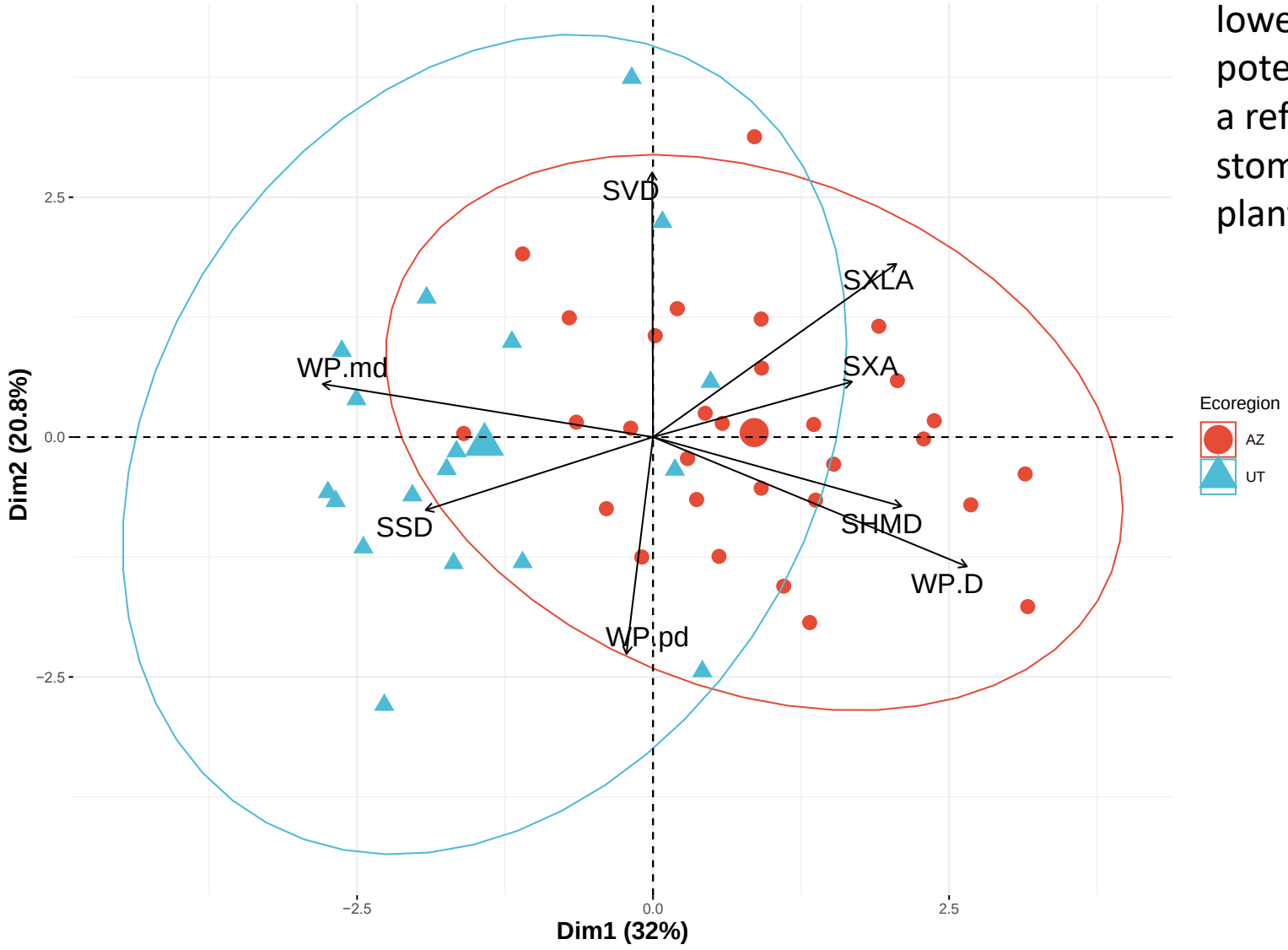
Leaf area (cm^2)





Blasini et al., in prep

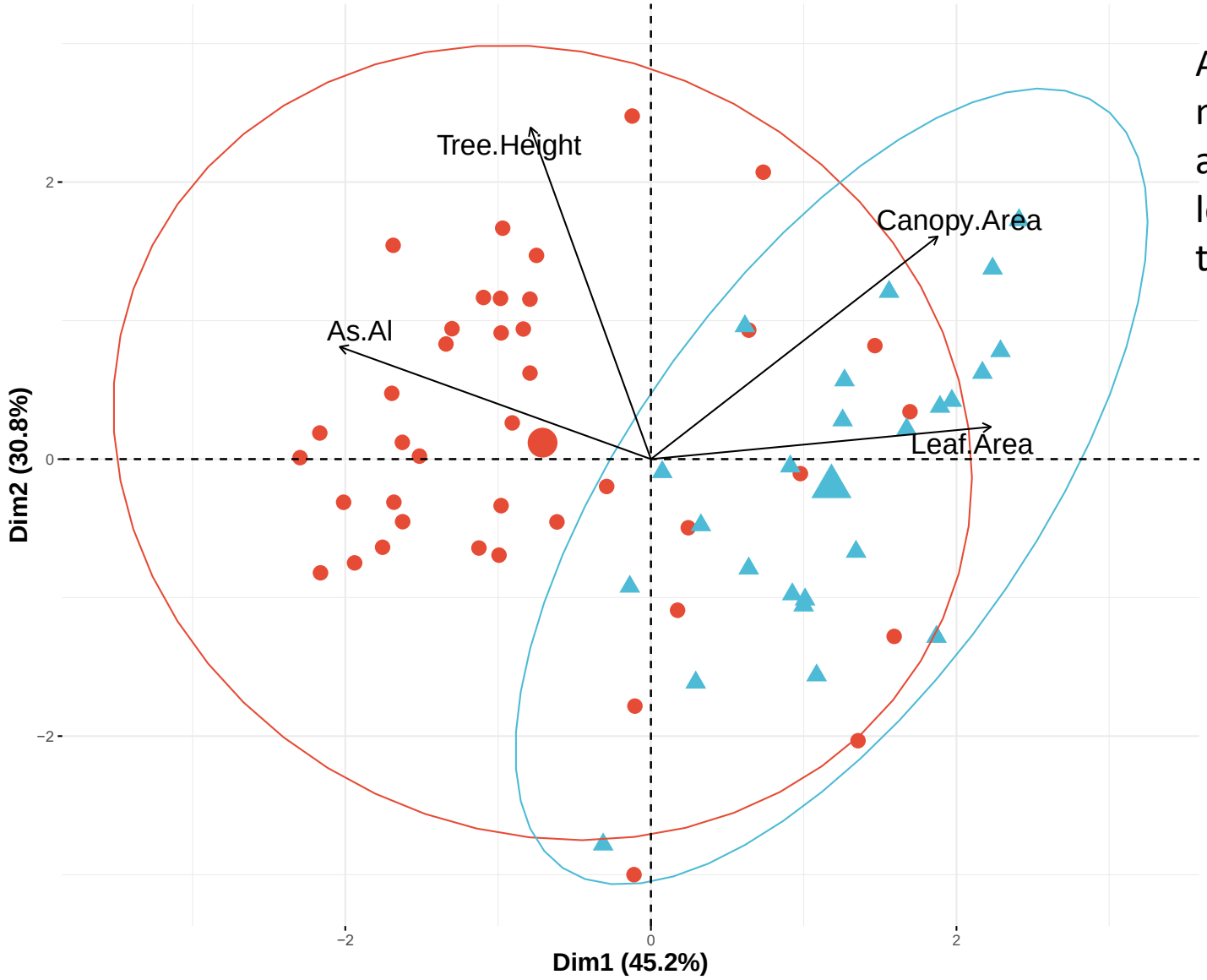
Small contrasts in wood / hydraulic traits between ecoregions



AZ genotypes have lower midday water potentials (WP.md), a reflection of reduced stomatal control over plant water potentials

Blasini et al., in prep

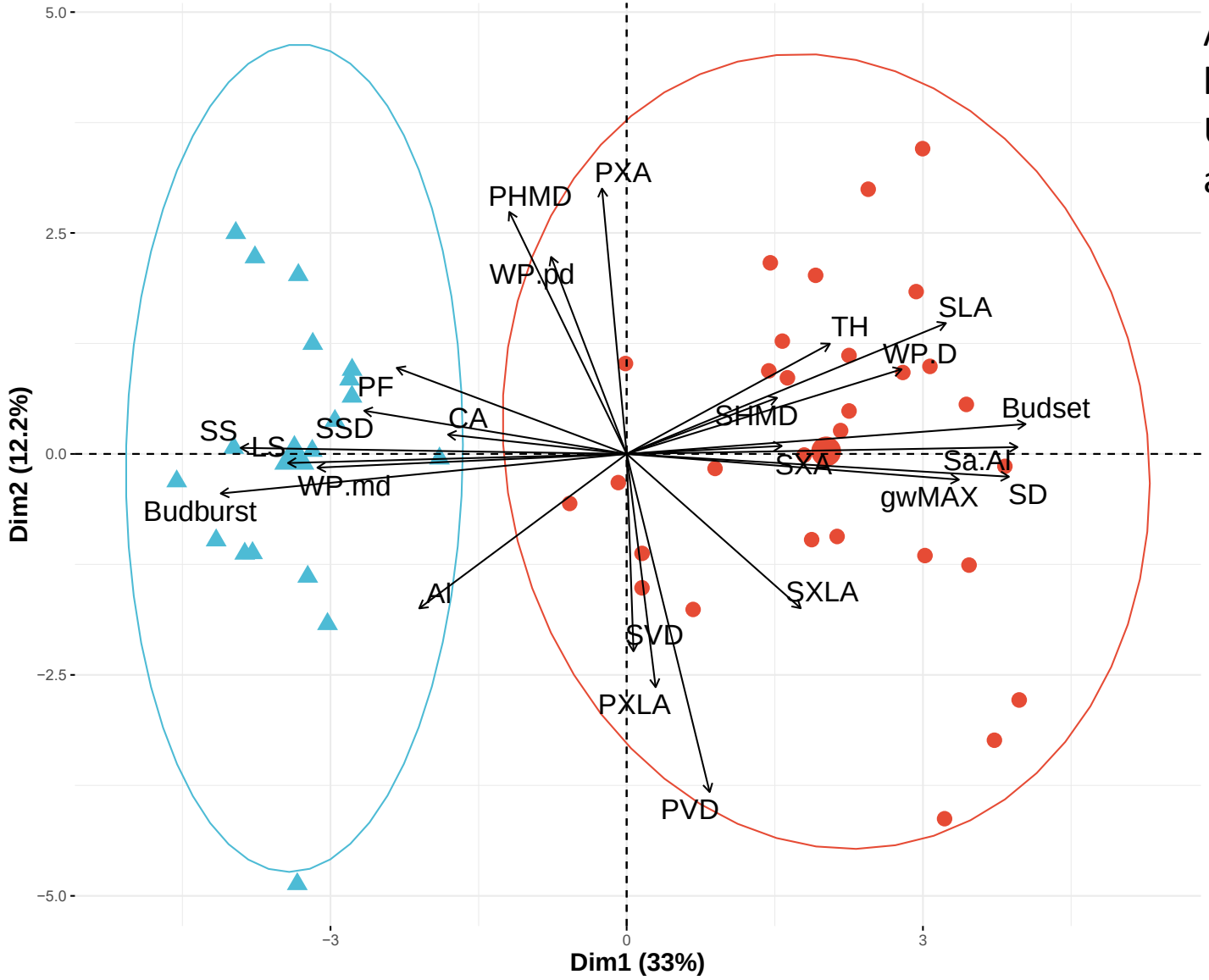
Moderate contrasts in above ground architecture between ecoregions



AZ genotypes have much higher sapwood area (supply) to leaf area ratios (demand) than UT genotypes

Blasini et al., 2014

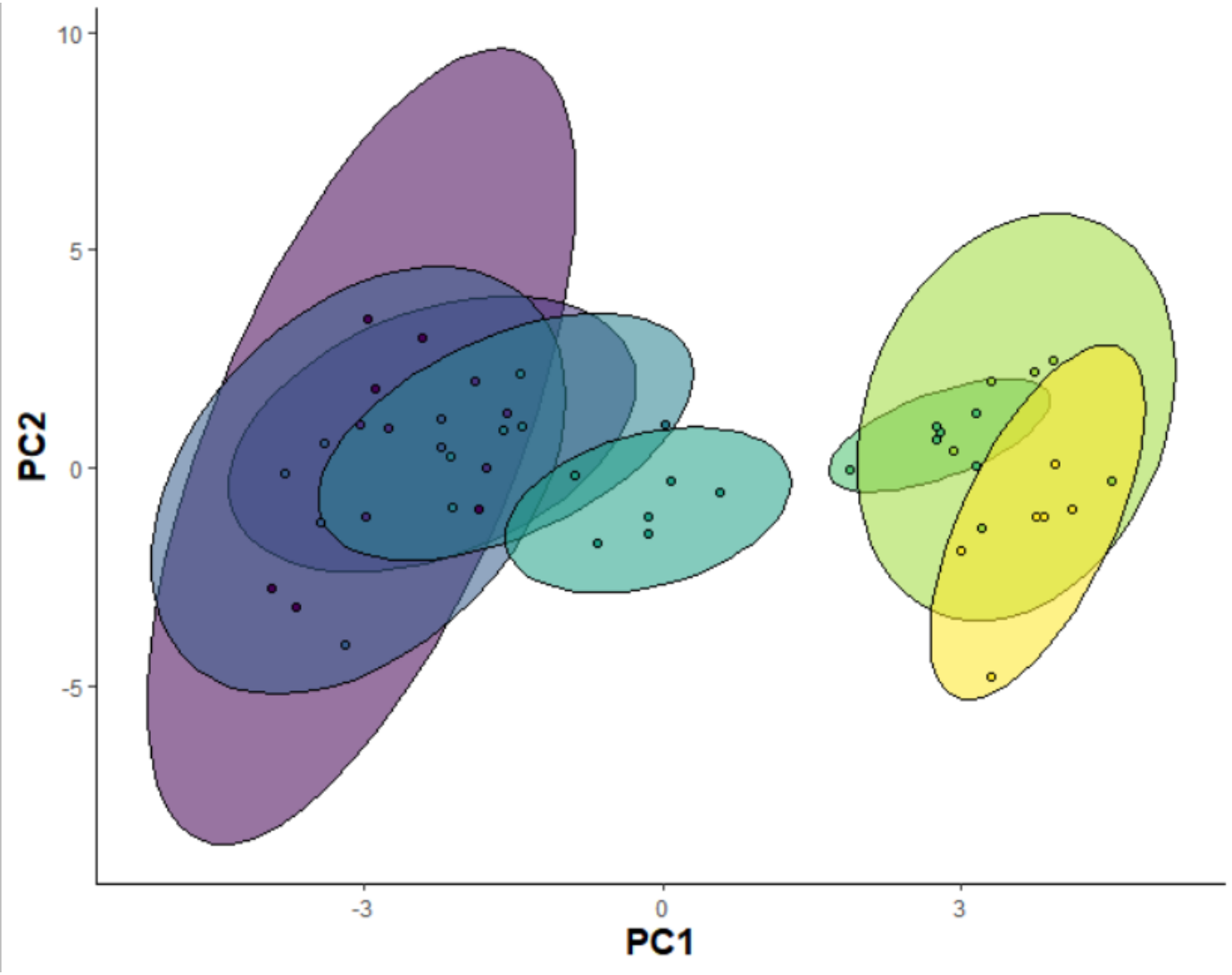
Large contrasts in trait expression between ecoregions



AZ genotypes maximize heat avoidance, while UT genotypes largely avoid Frost exposure

Blasini et al., 2014

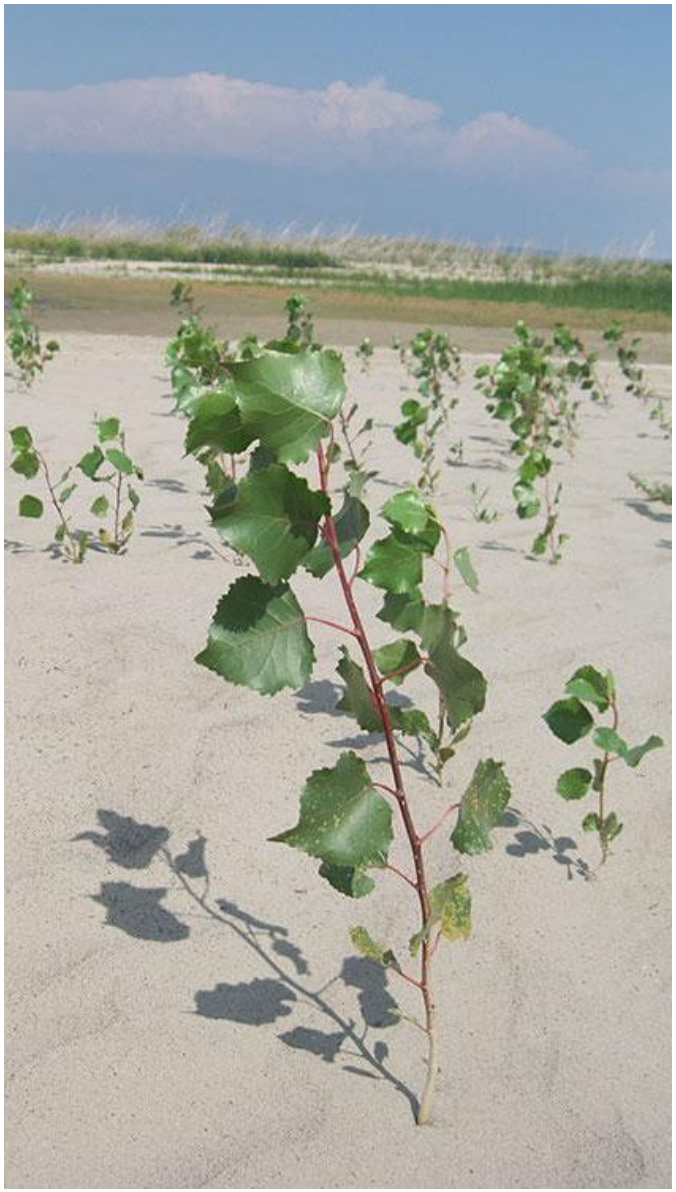
Large contrasts in trait expression between ecoregions



AZ genotypes maximize heat avoidance, while UT genotypes largely avoid Frost exposure

Blasini et al., in prep

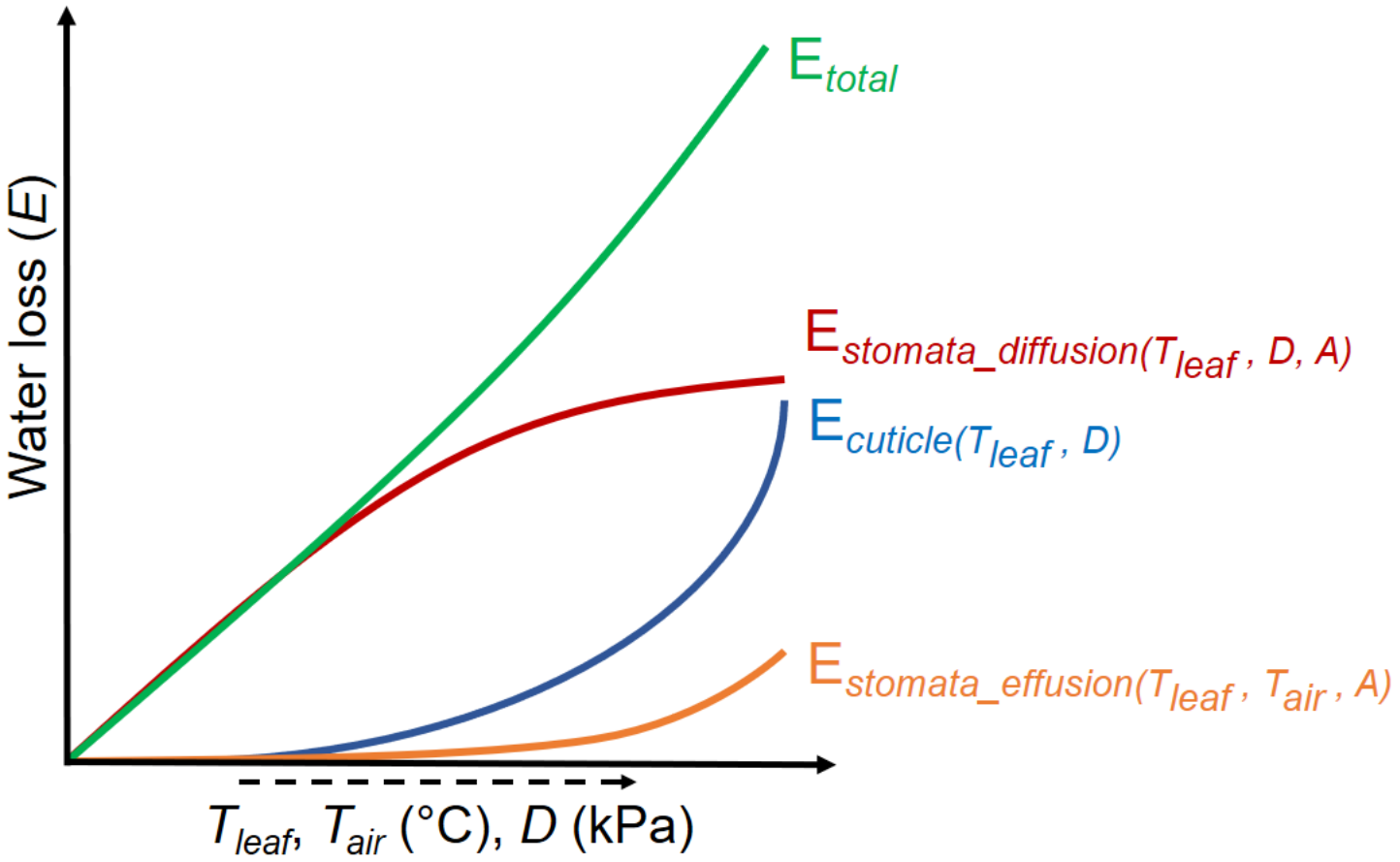
Is there a super genotype



- Probably not – Evidence for strong local adaptation
- However many locations may never be exposed to both late freezes and extreme thermal stress
- Target genotypes with high plasticity
- Linking trait expression to molecular markers will close knowledge gaps

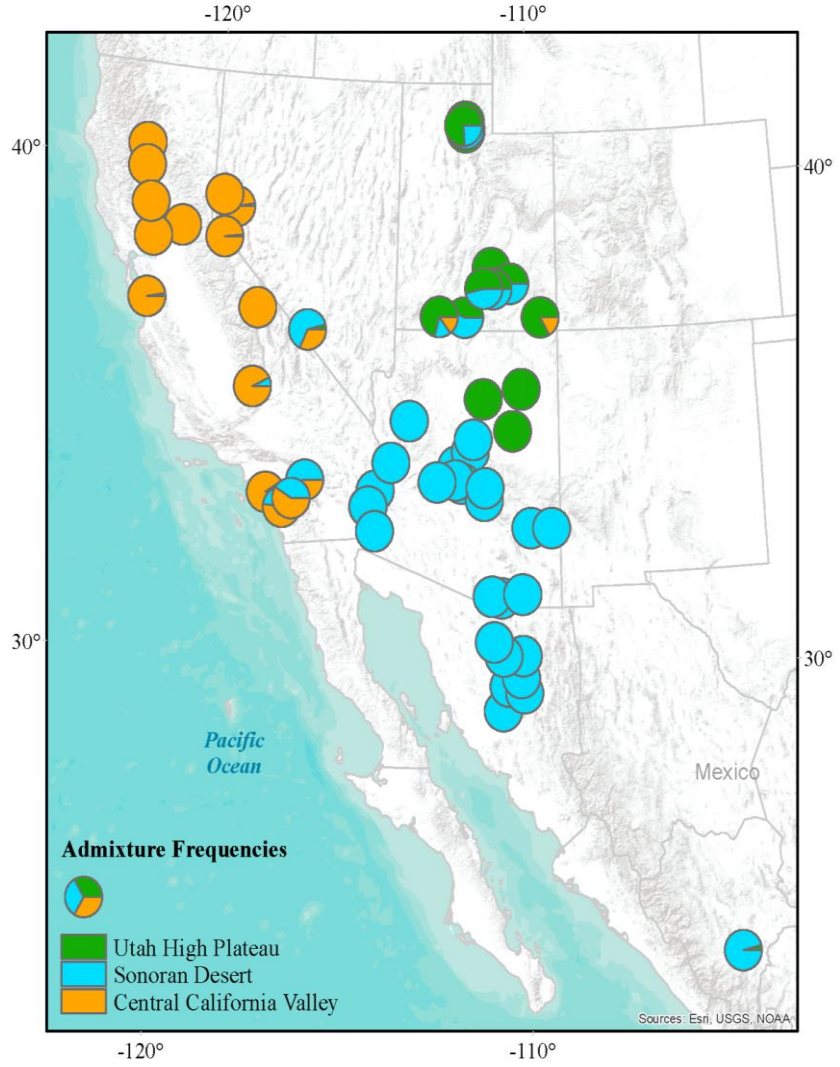
Heat exposure: adaptive (heat avoidance) or non-adaptive (heat failure)?

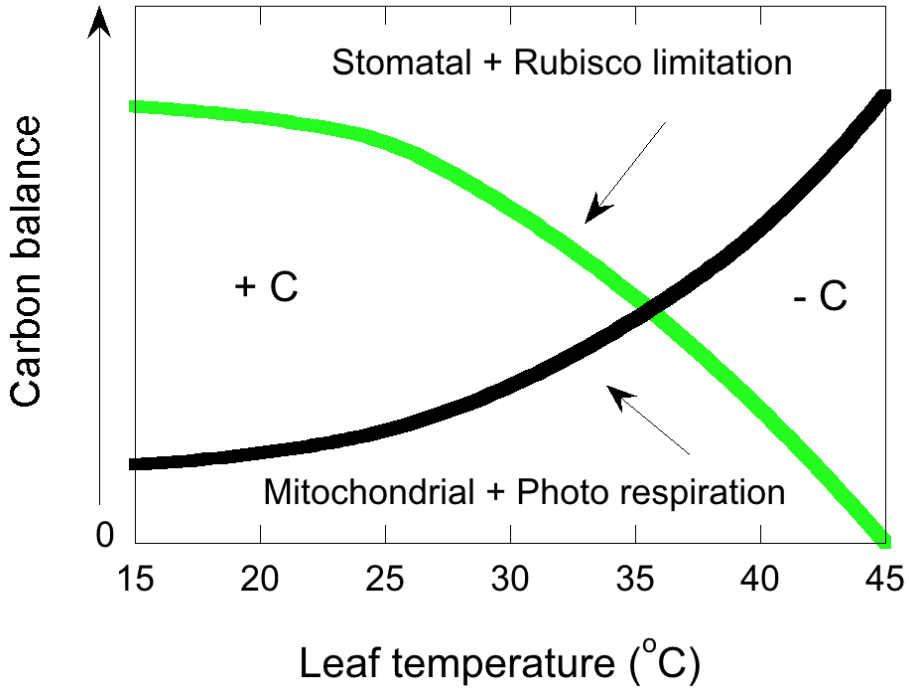
$$E_{total} = E_{stomata\_diffusion(T_{leaf}, D, A)} + E_{stomata\_effusion(T_{leaf}, T_{air}, A)} + E_{cuticle(T_{leaf}, D)}$$

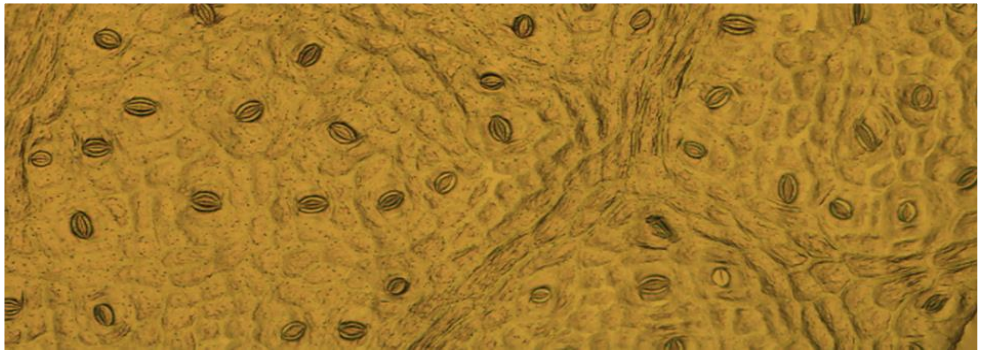


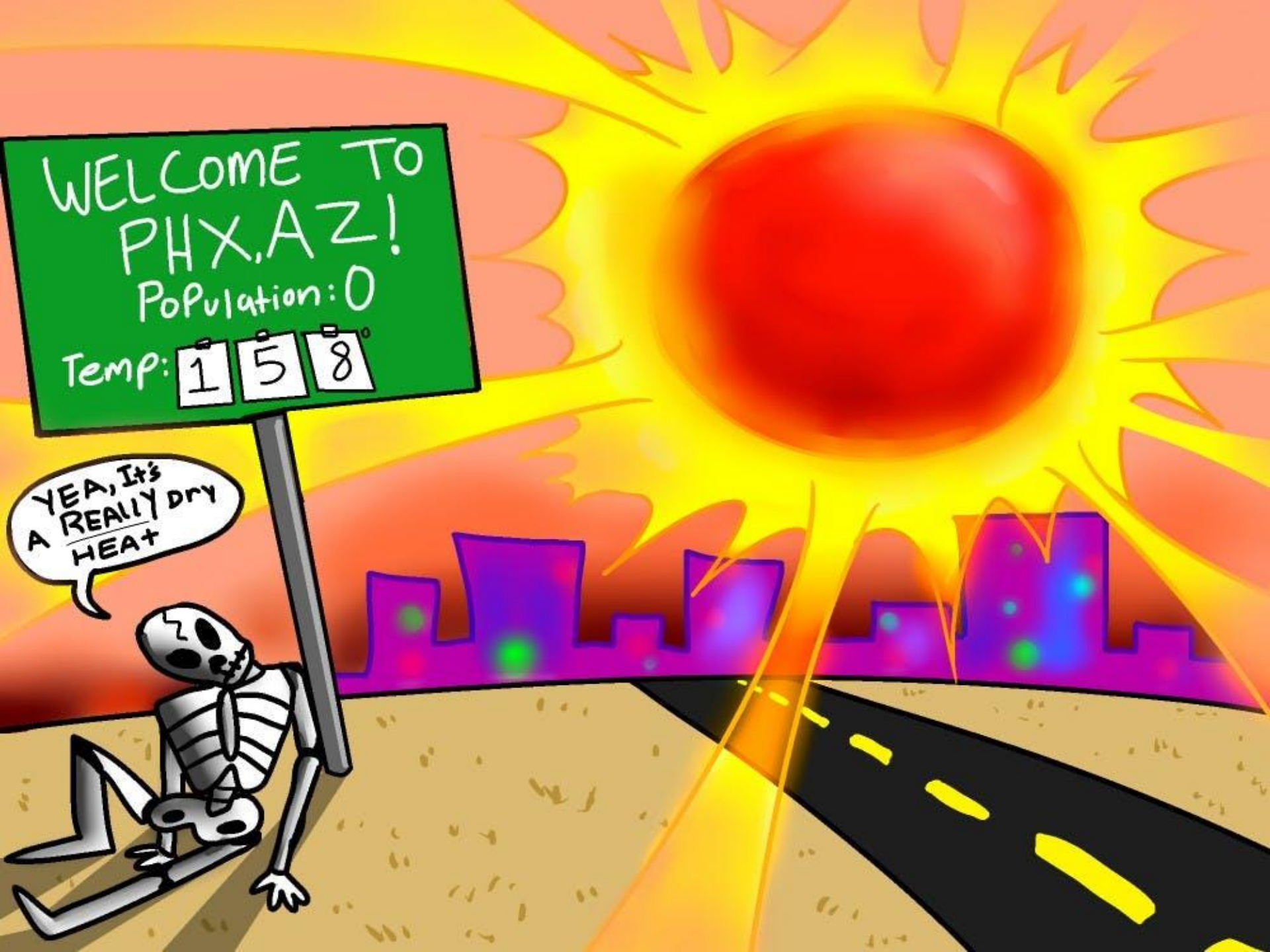
Aparecido, Hultine & Blonder, *Ecology Letters* (In press)

Fremont cottonwood populations are distributed across discrete ecoregions

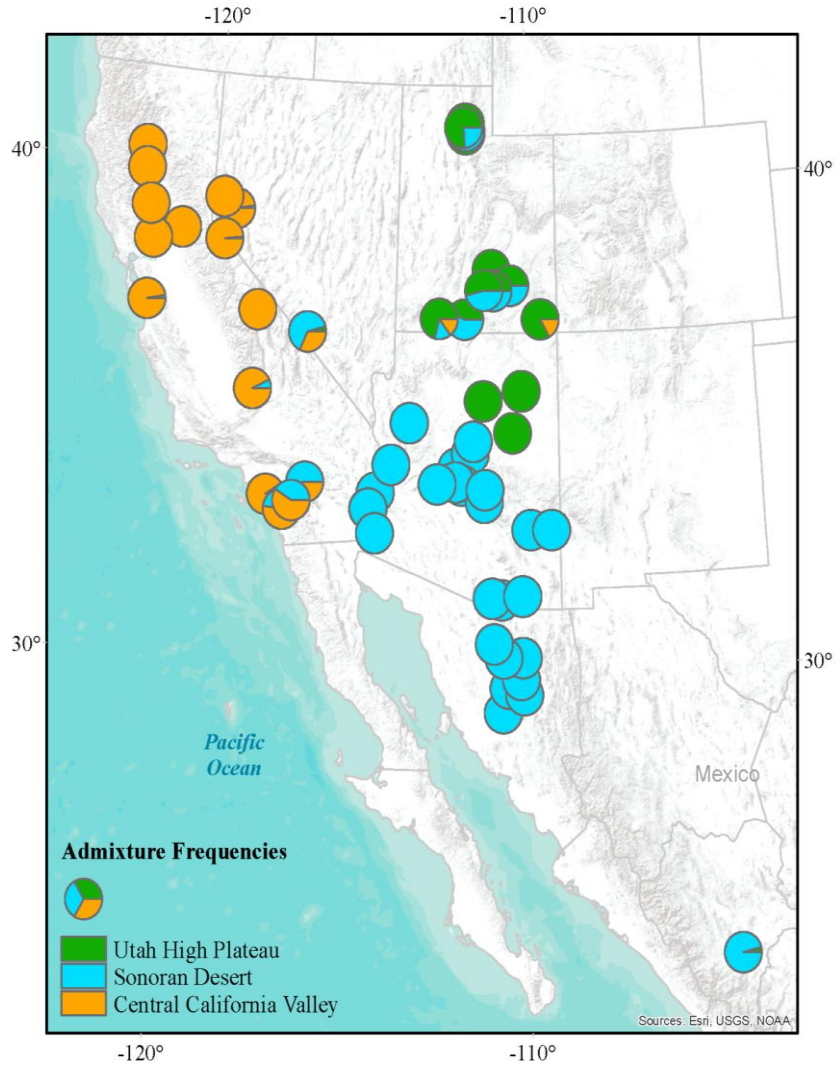




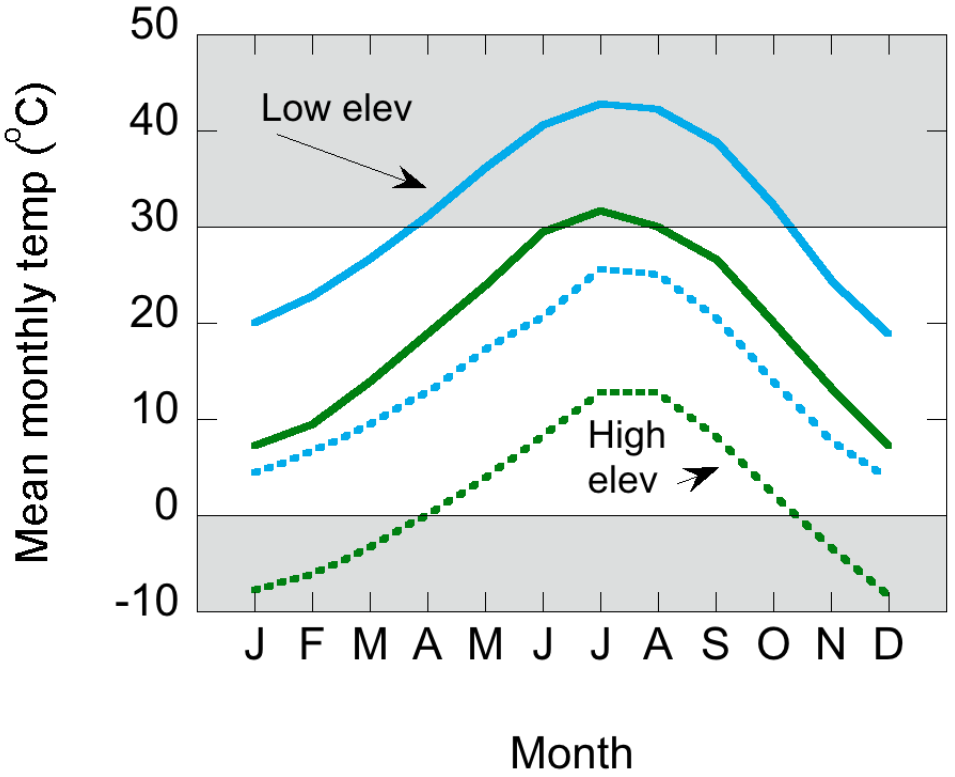



WELCOME TO PHX, AZ!
Population: 0
Temp: 158°
YEA, It's A REALLY DRY HEAT

Fremont cottonwood populations are distributed across discrete ecoregions



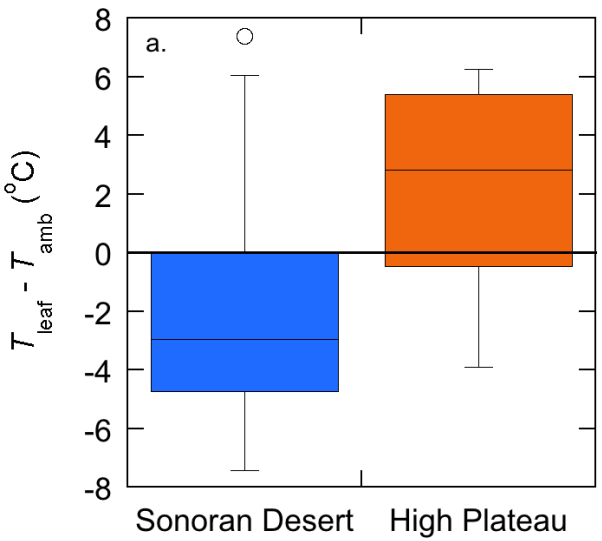
And display a high degree of local adaptation within each ecoregion

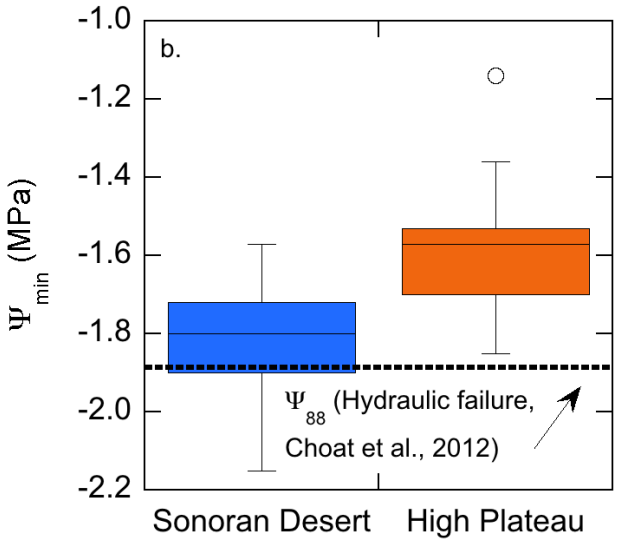


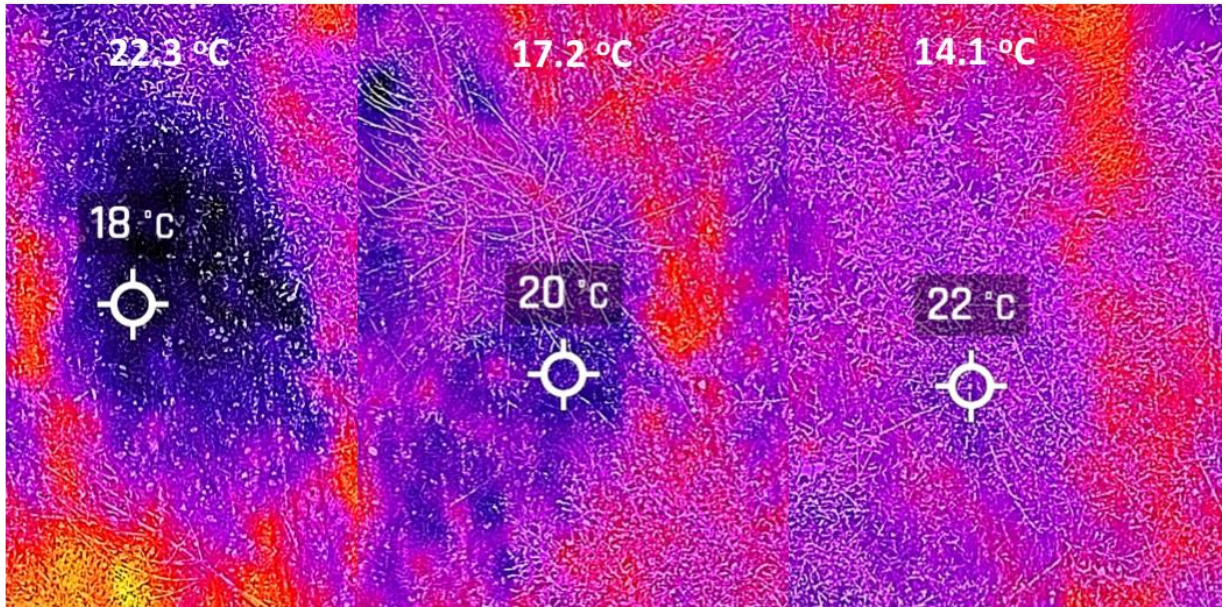
Bothwell et al., in prep

High plasticity in foliage phenology

Thermal regulation comes with inherent risk

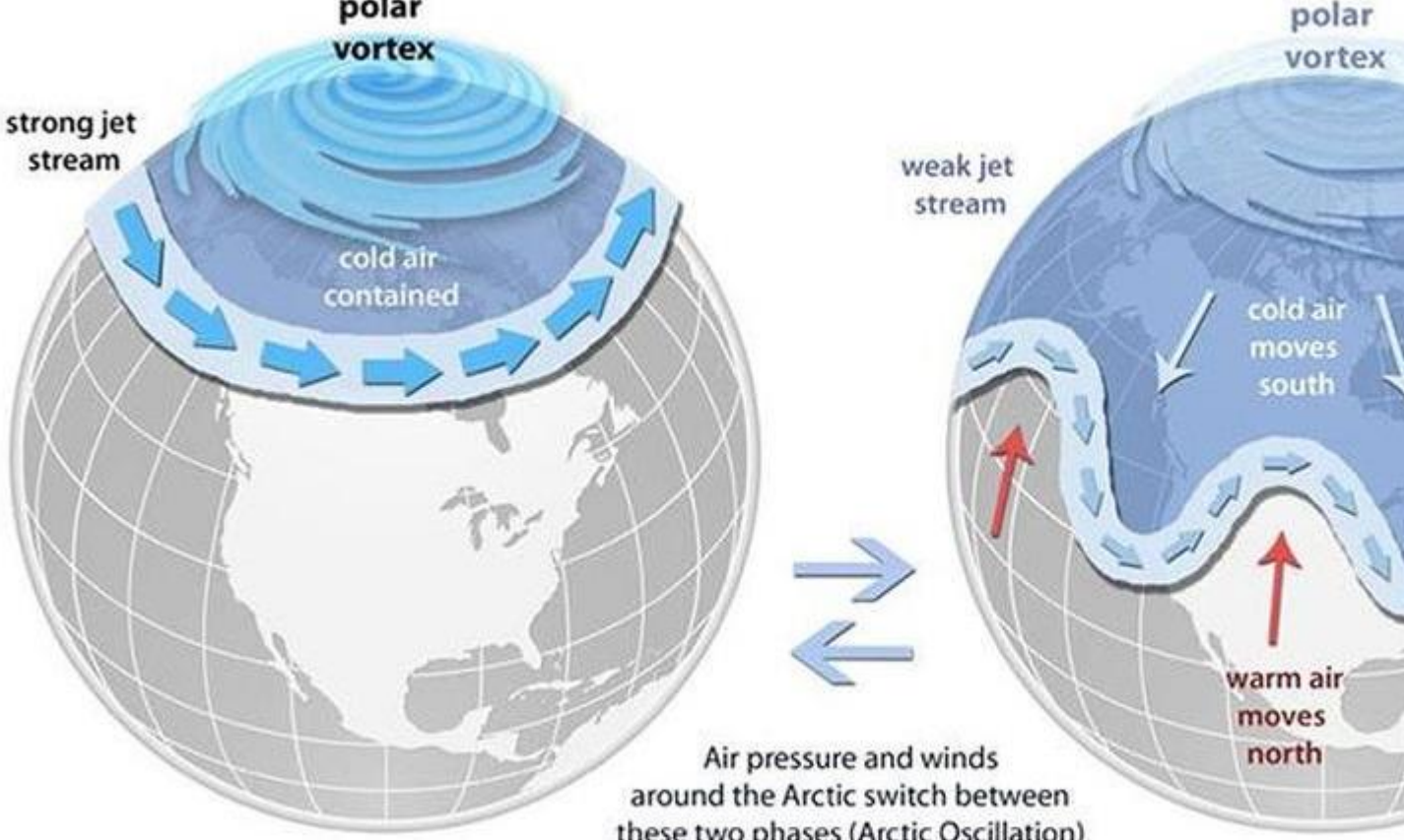






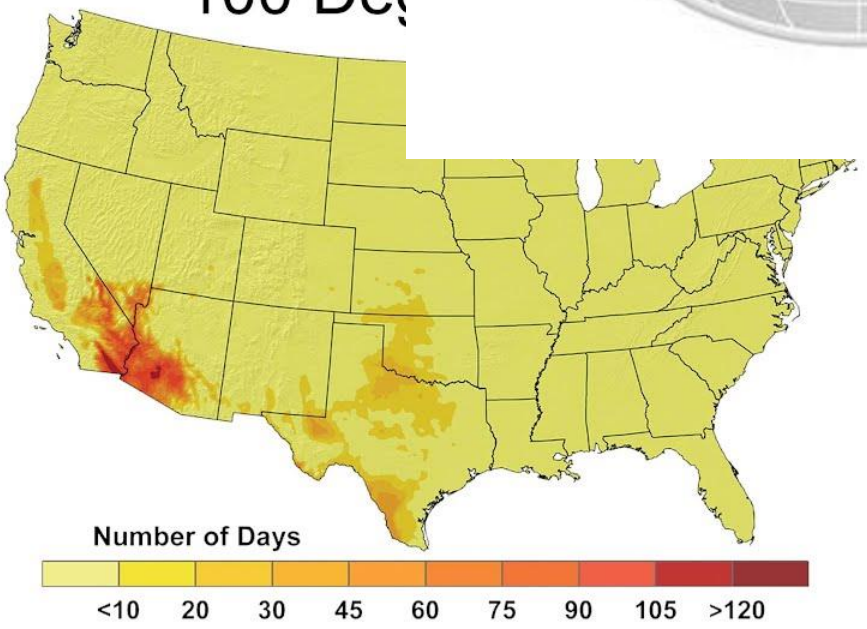
Hultine et al., 2020, *Hydrological Processes*

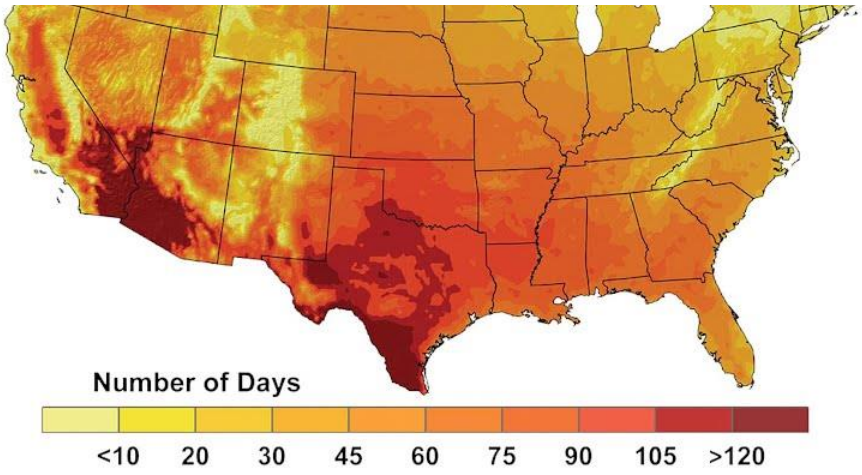
Fu



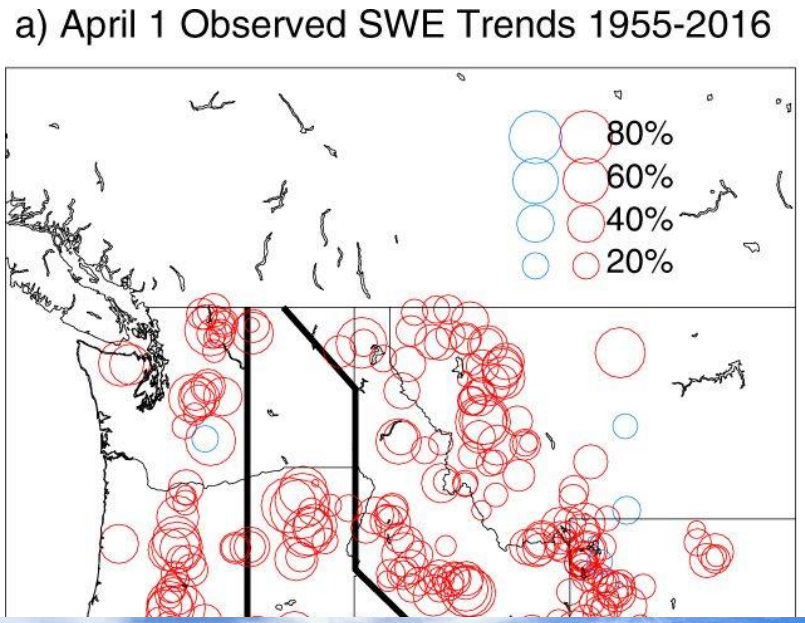
Air pressure and winds around the Arctic switch between these two phases (Arctic Oscillation) and contribute to winter weather patterns.

100 Deg





Regional snowpack is declining



- Declining snowpack = reduced stream flow and groundwater recharge

Mote et al., 2018