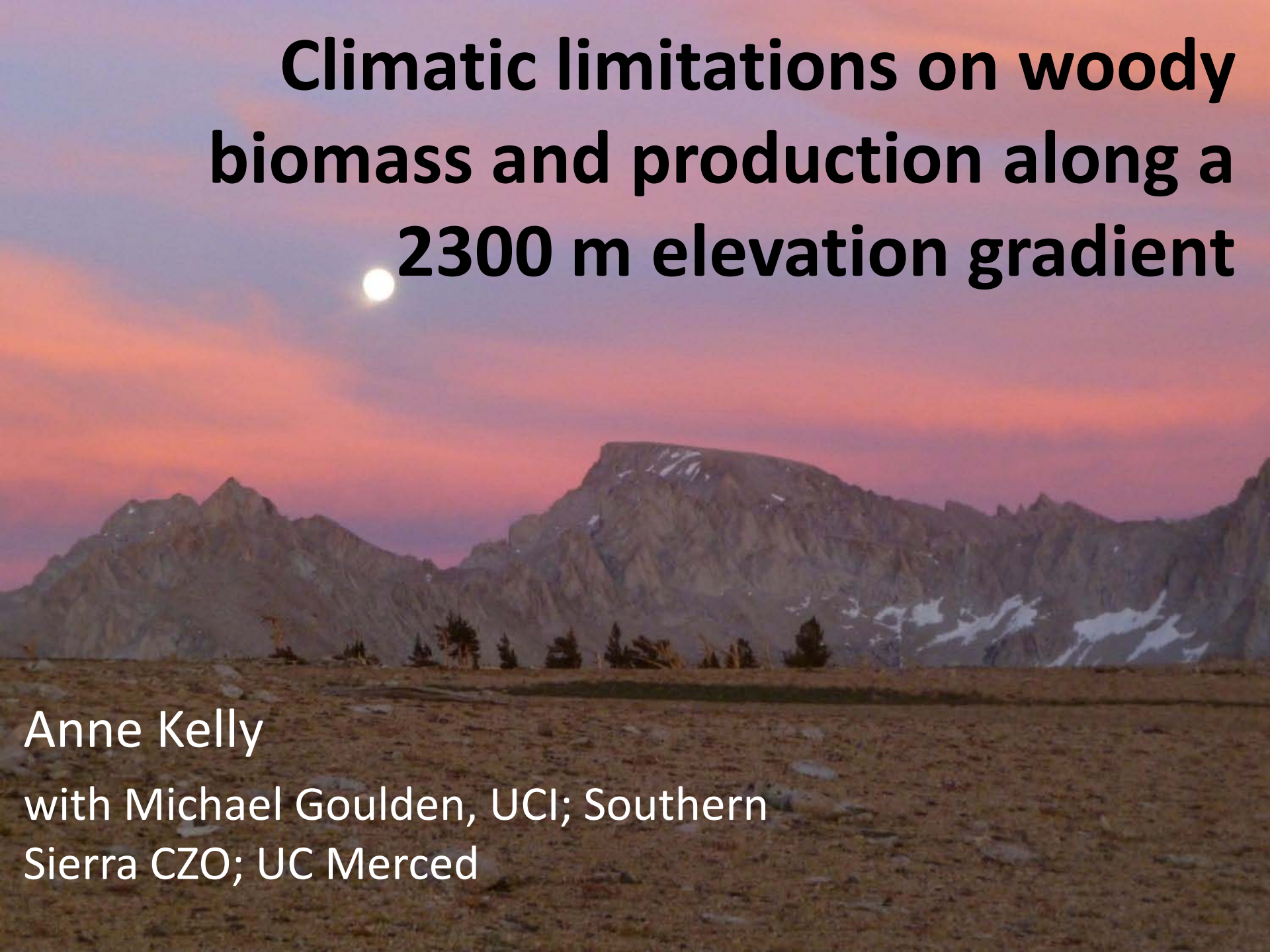
Climatic limitations on woody biomass and production along a 2300 m elevation gradient



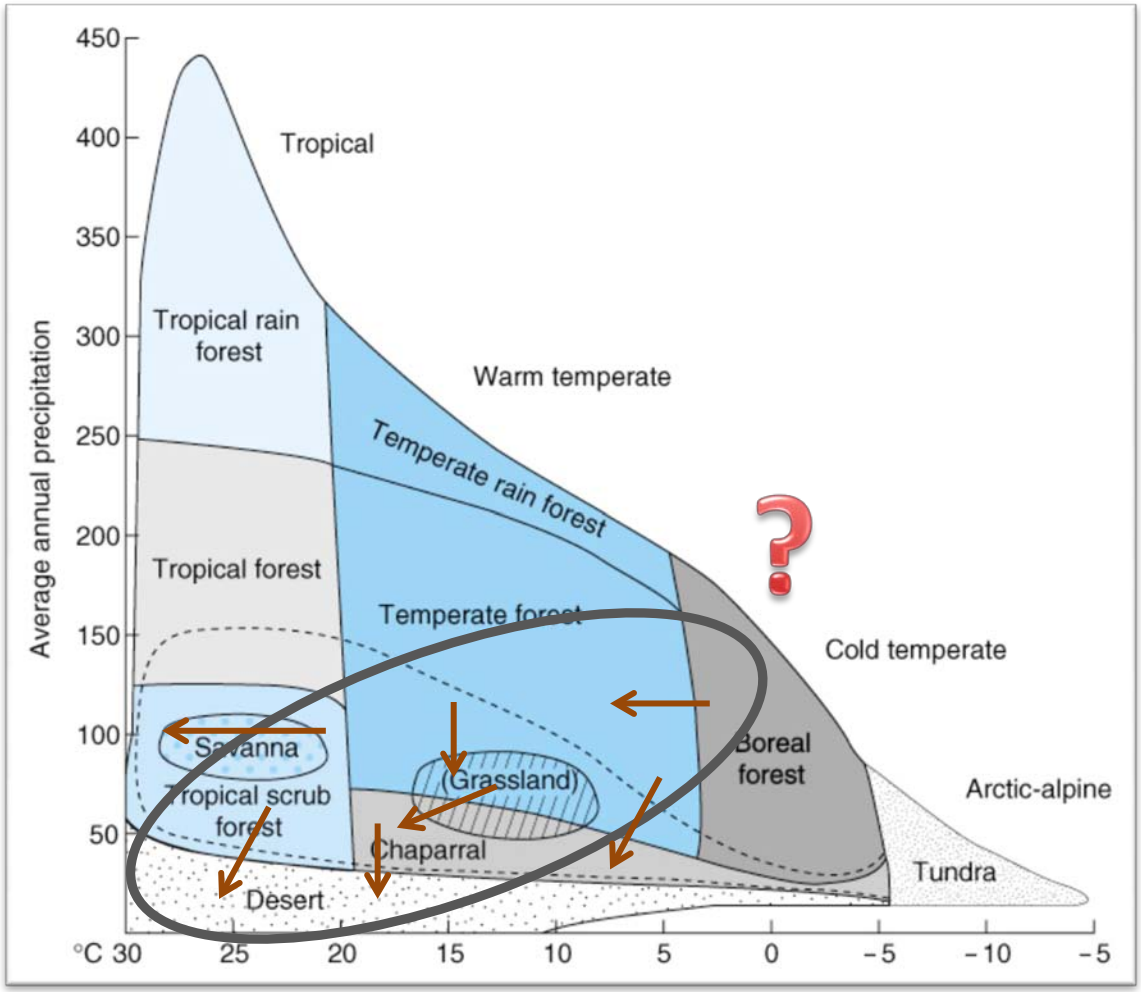
Anne Kelly

with Michael Goulden, UCI; Southern Sierra CZO; UC Merced

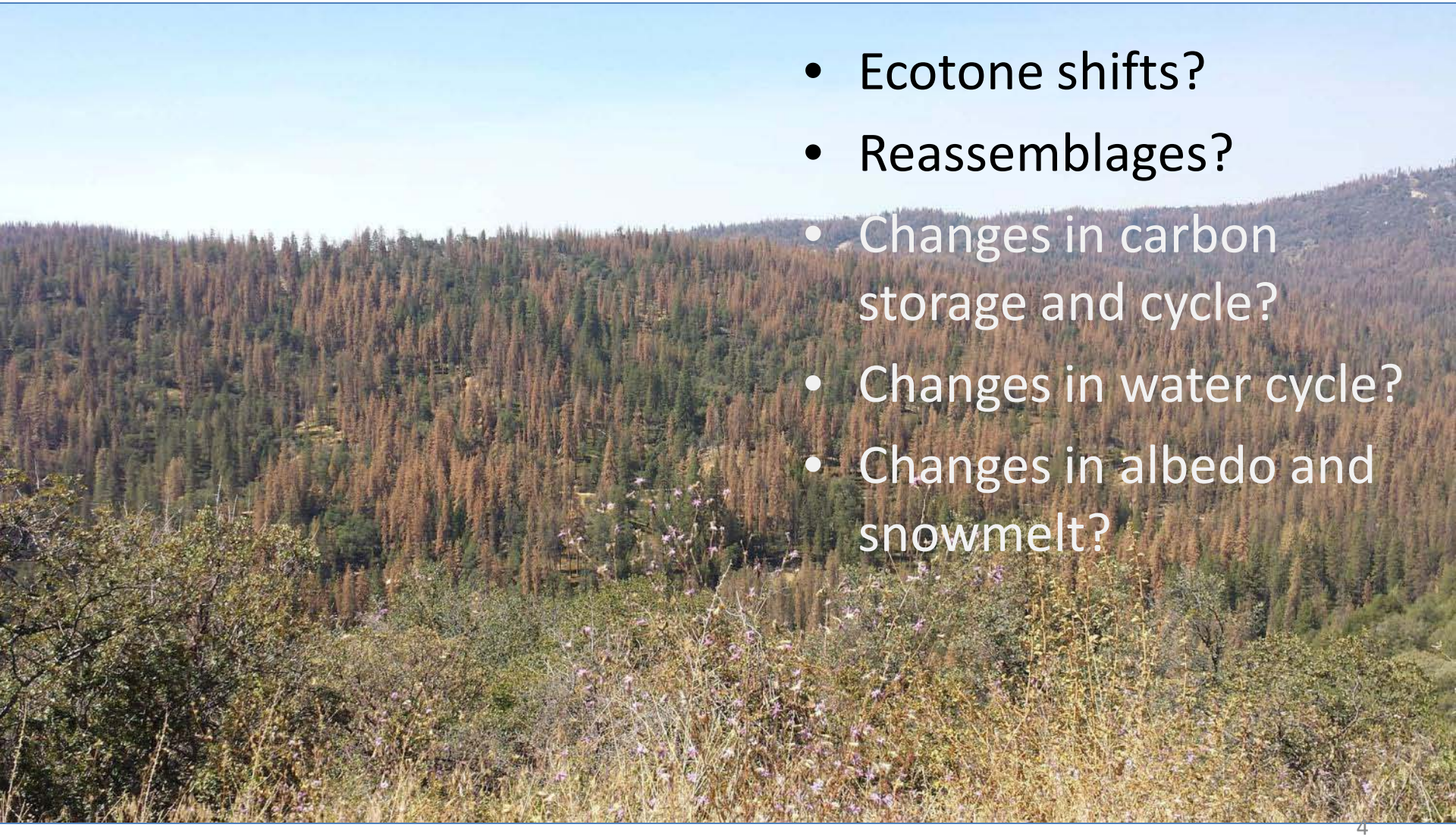
Overview

- Why do plants grow where they grow?
- How will climate change shuffle plants around?
- How will climate change alter ecosystem carbon cycling and water use?

How will California change?



Ecosystems are starting to respond



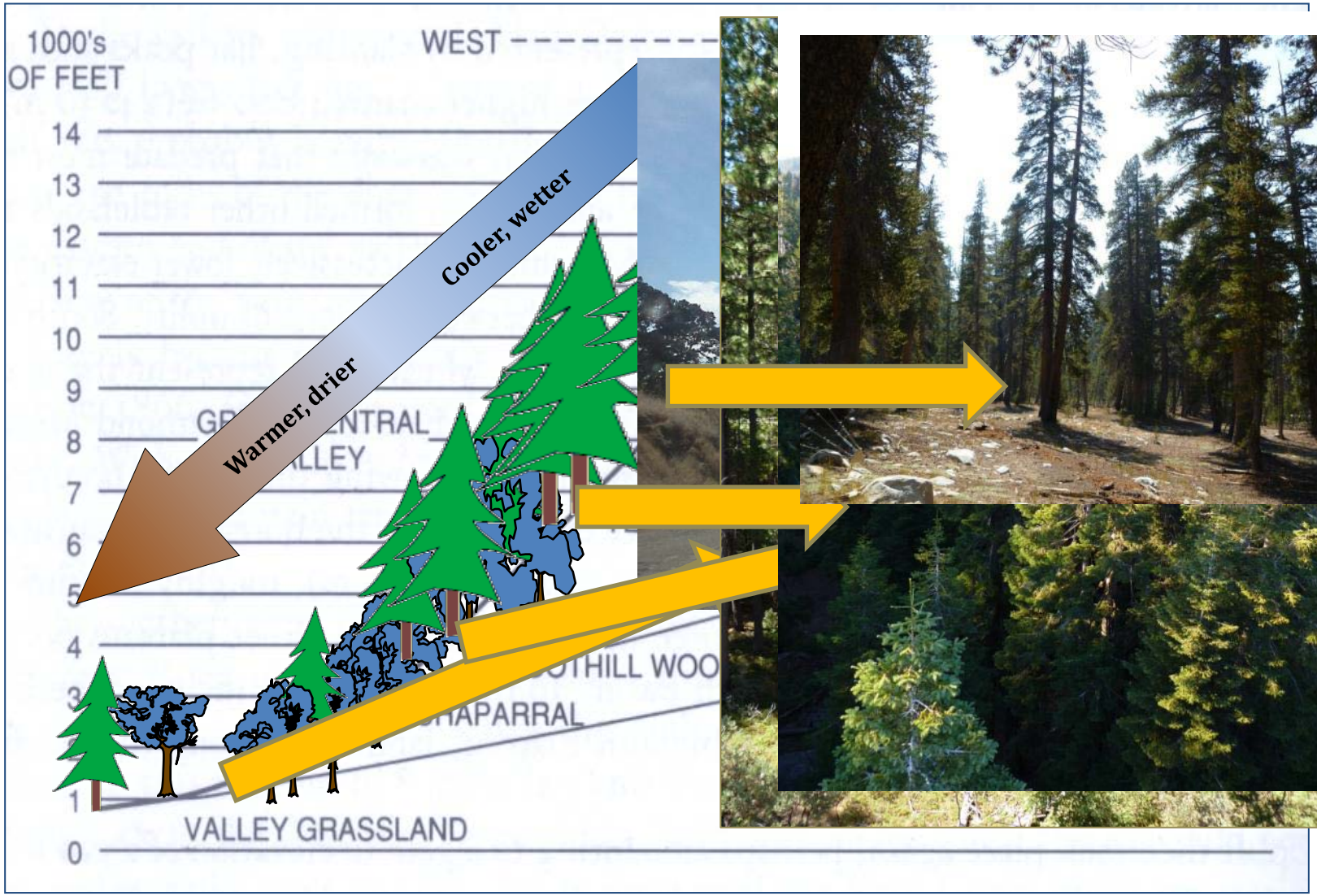
- Ecotone shifts?
- Reassemblages?
- Changes in carbon storage and cycle?
- Changes in water cycle?
- Changes in albedo and snowmelt?

Approach

Measure forest biomass, productivity, and water use in response to daily-to-annual weather

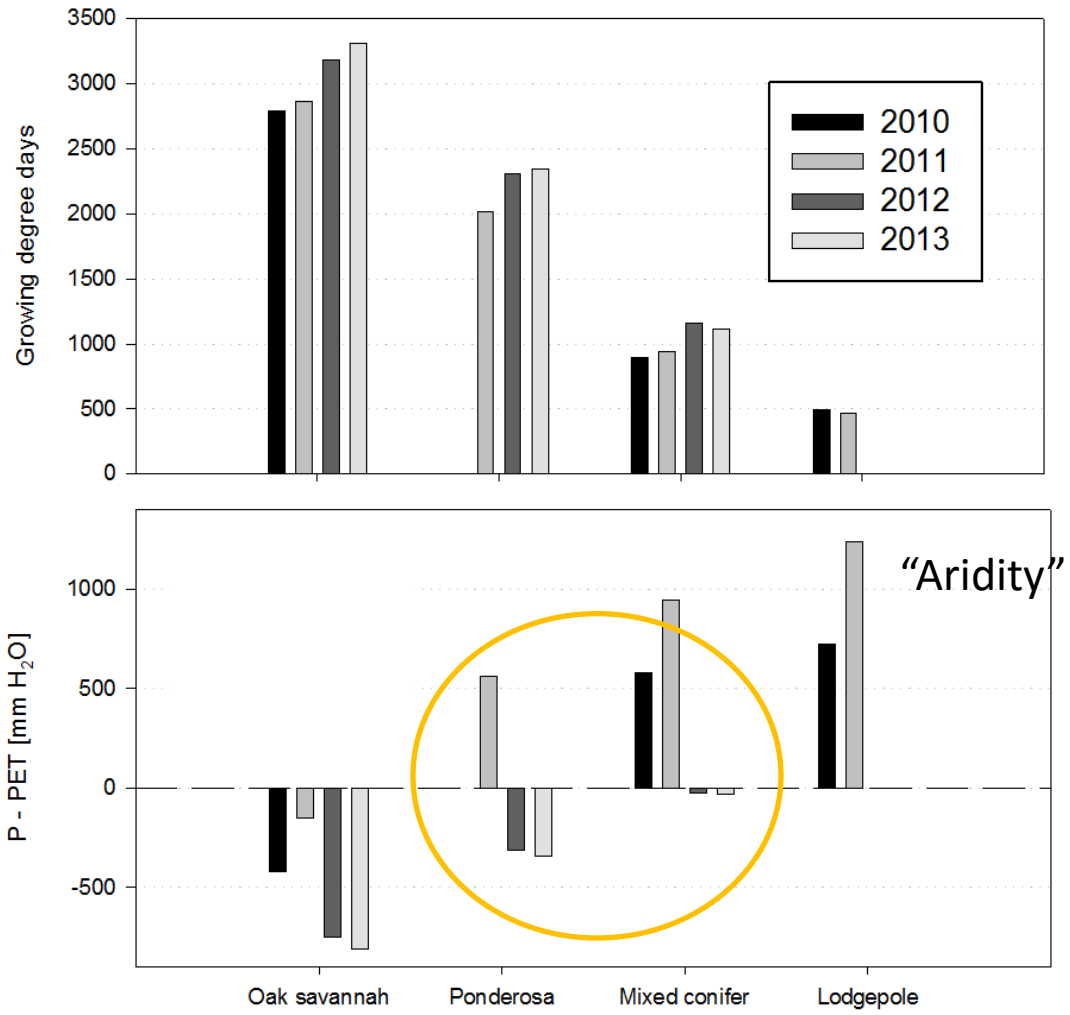
- 2300 m elevation gradient
- Weather
- Water and CO2 fluxes
- Tree growth and death
- Litterfall
- Soil moisture

Approach: experimental design

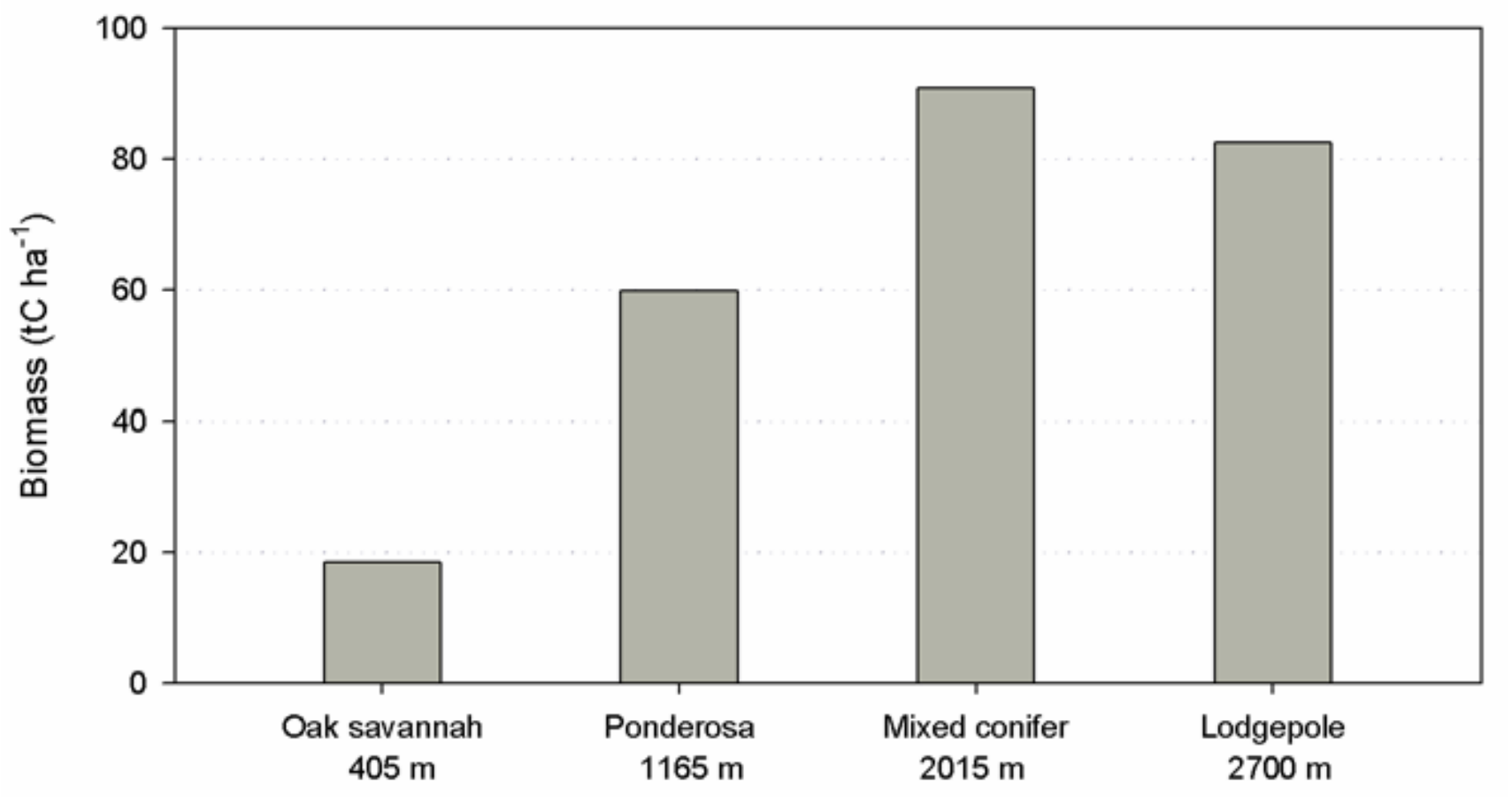


Weather at the Sierra sites

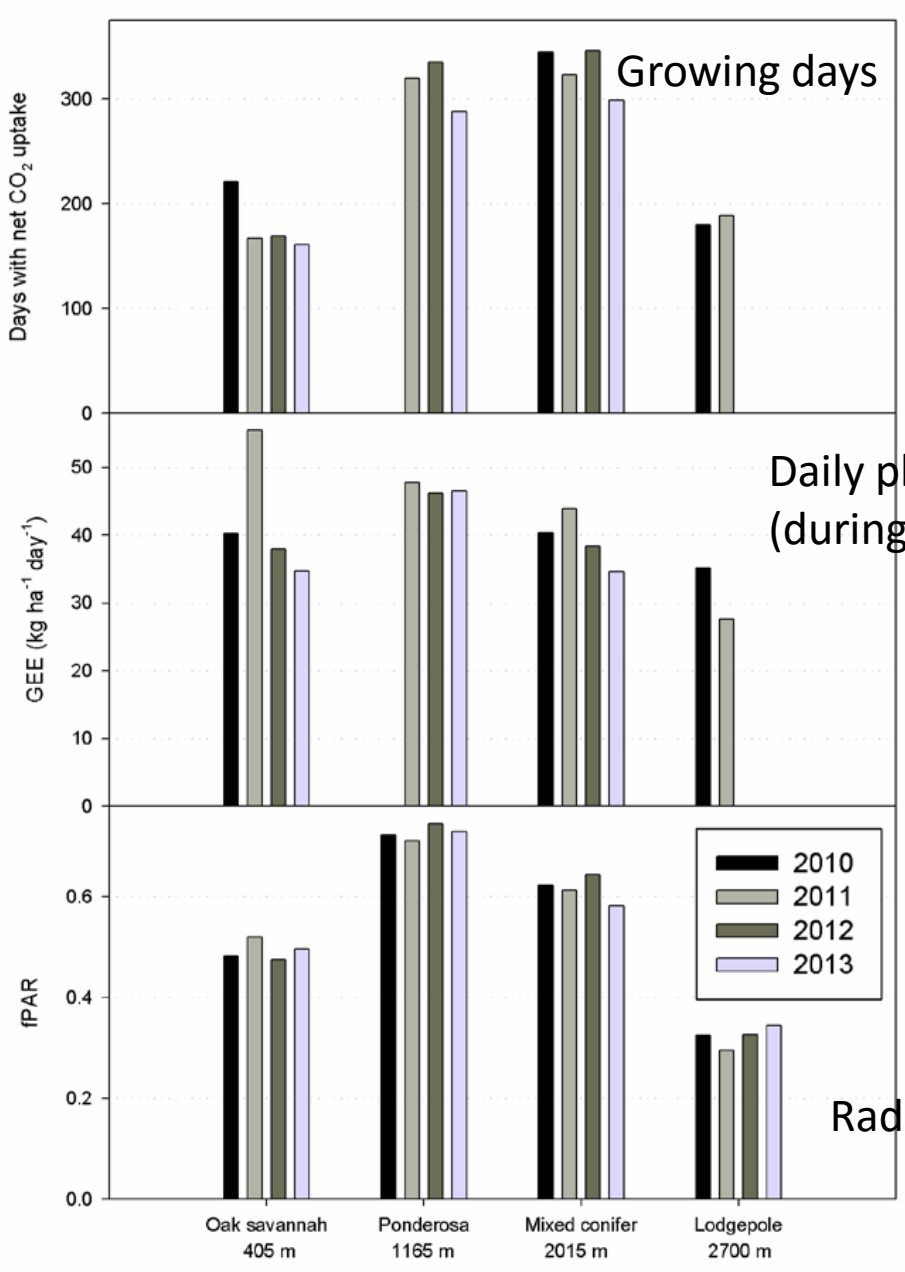
(pre-major-drought)



Biomass


Biomass (tC ha-1)
100
80
60
40
20
0
Oak savannah
405 m
Ponderosa
1165 m
Mixed conifer
2015 m
Lodgepole
2700 m

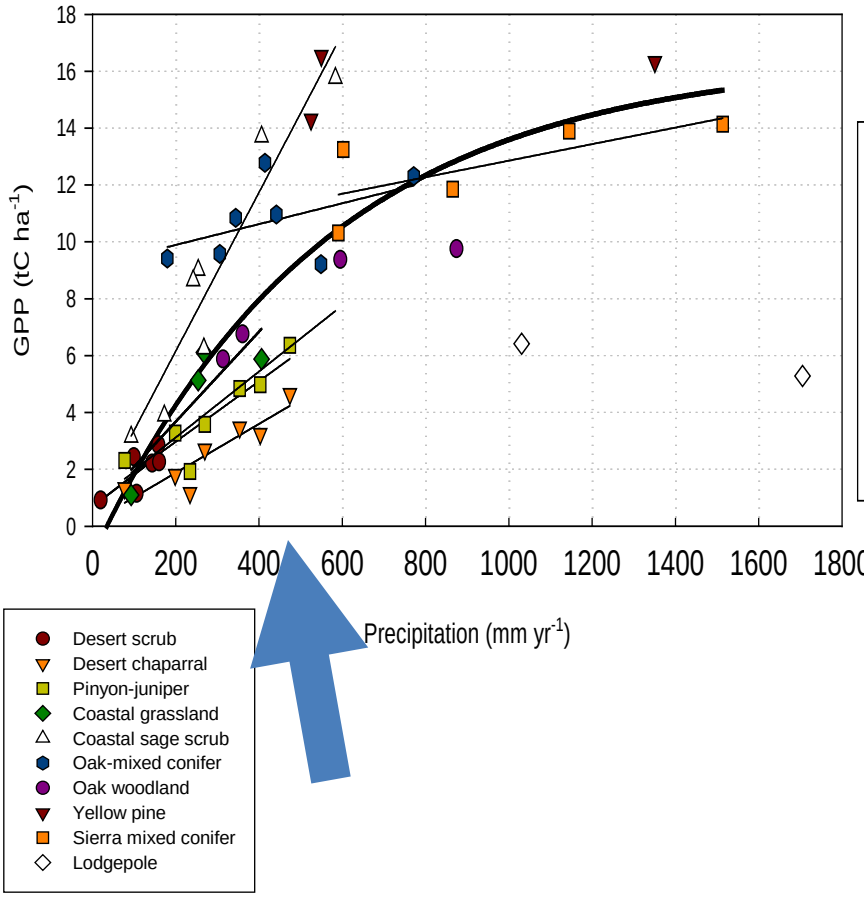
Growing season properties

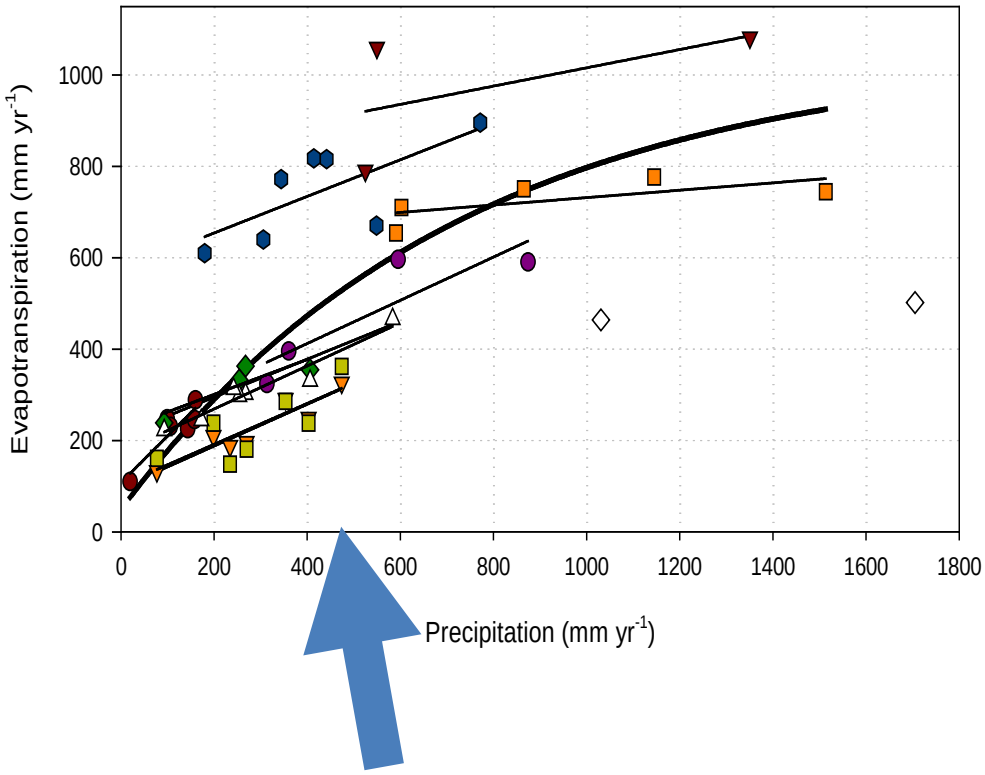


Daily photosynthesis
(during growing season)

Radiation absorbed by the forest

Growth and water use by annual precipitation

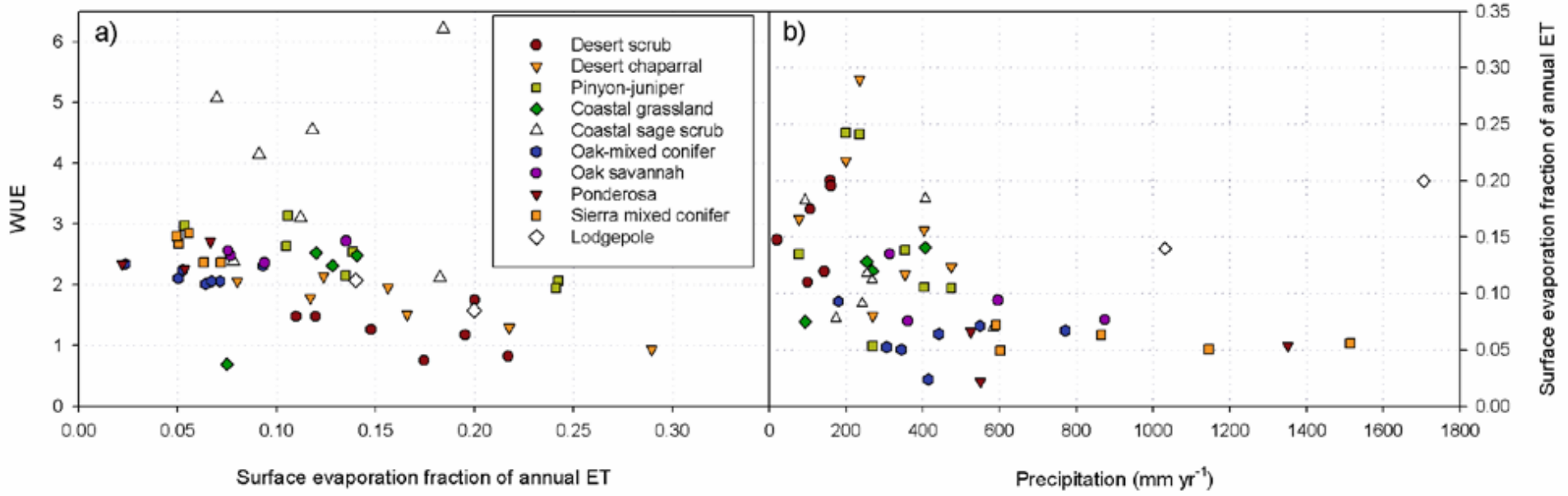




Thresholds at 500 mm yr^{-1}?

- What happens at 500 mm yr^{-1}?
- Why is the curve steep at the dry end?
- What parts of the weather and the water cycle are responsible for WUE?
  - Surface evaporation
  - Vapor pressure deficit
  - Internal CO2 concentration

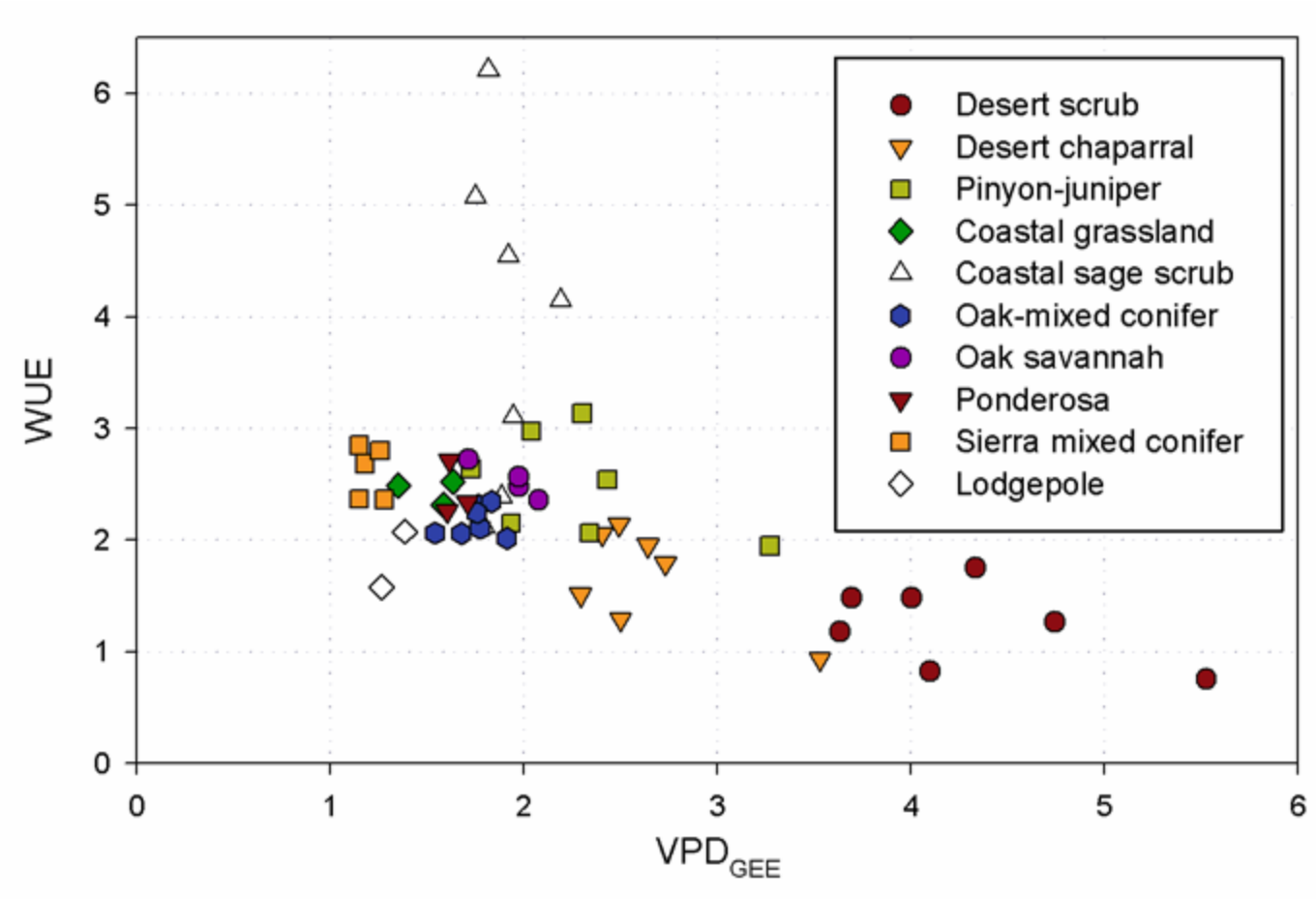
Ecosystem water fate by annual precip



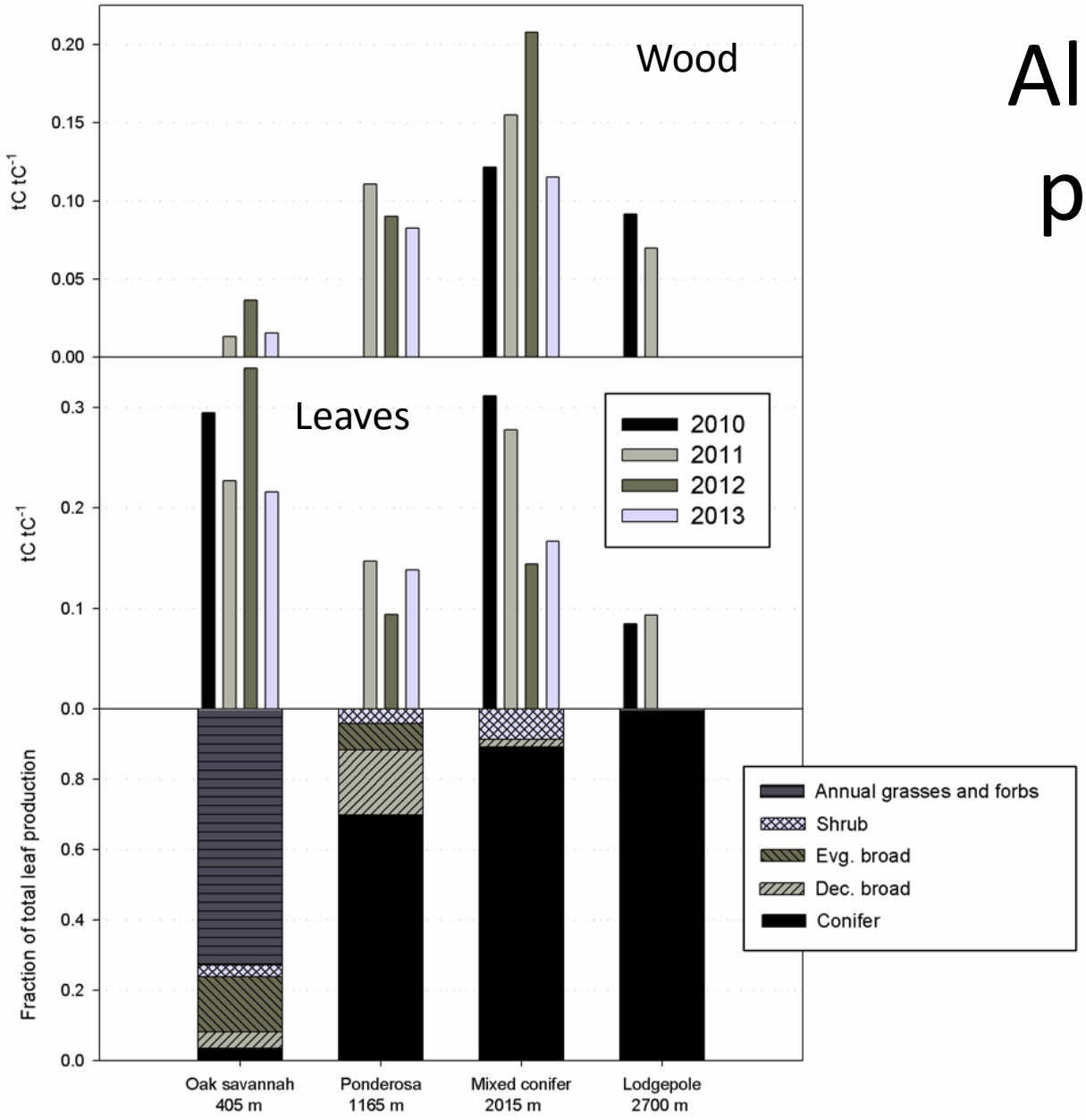
Ecosystem water use efficiency vs. surface evaporation lost

Fraction of annual ET as surface evap, vs annual precipitation

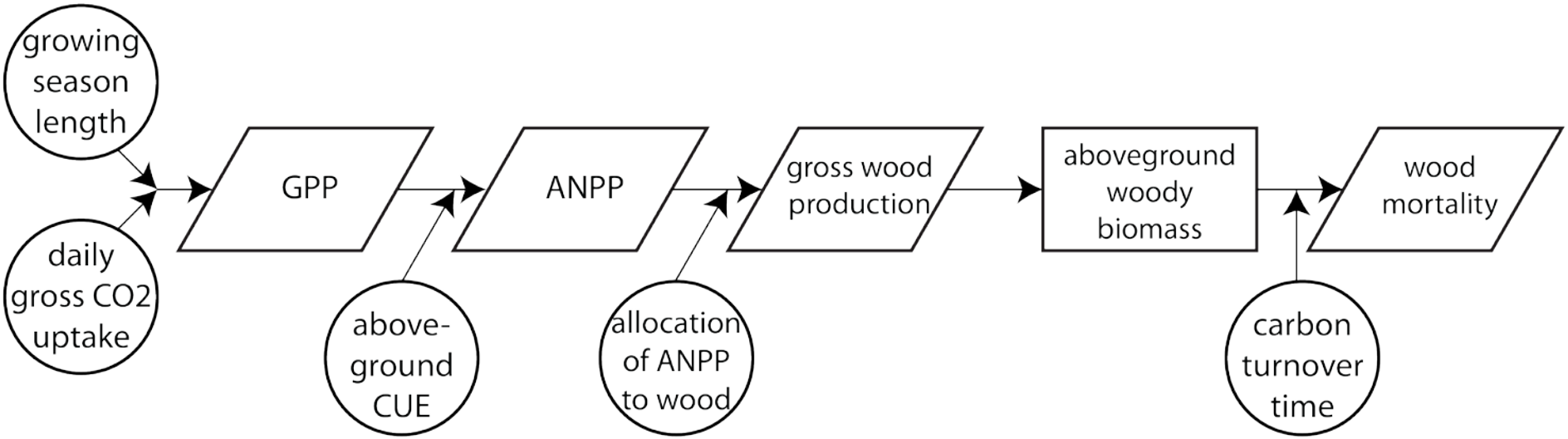
Vapor pressure deficit



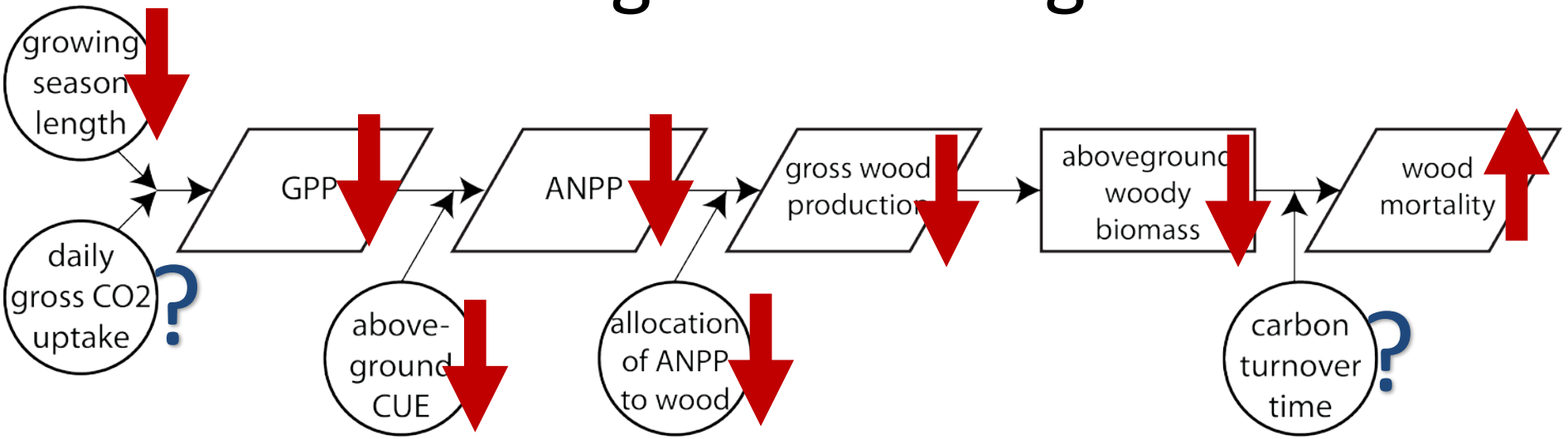
Allocation of production



Conceptual model of forest production and biomass



What will we see with prolonged drought+warming?

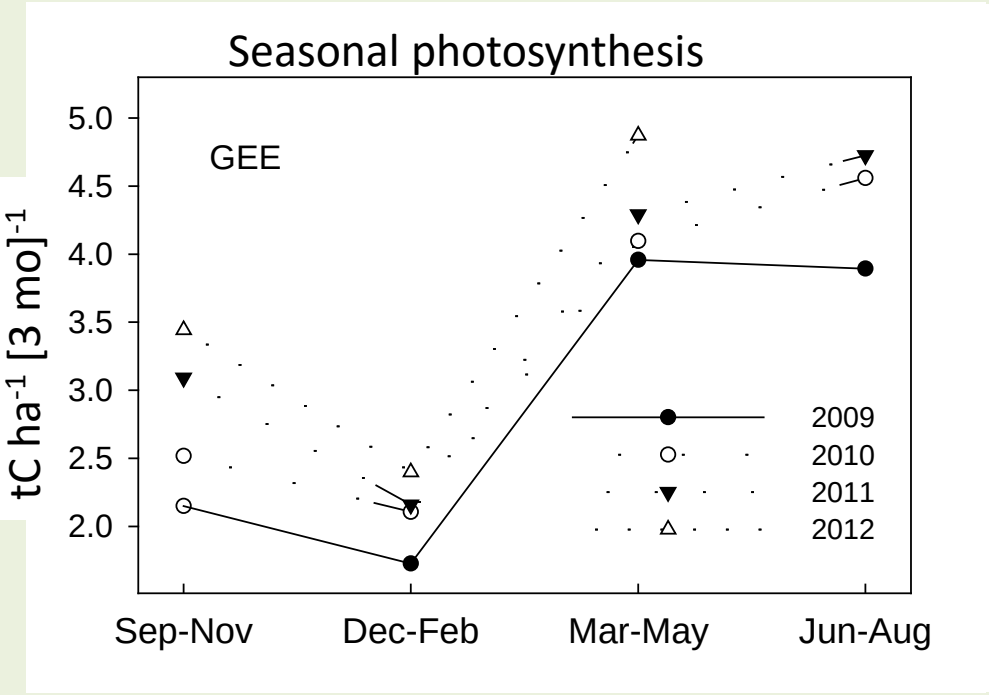


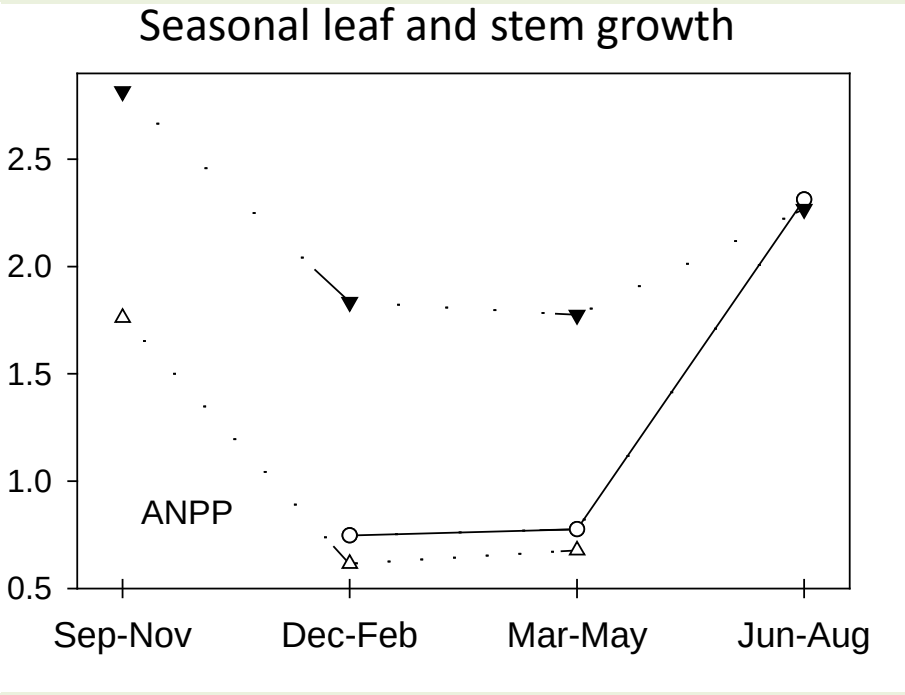
Ecohydrological consequences of precip < 500-600 mm (or mean annual PET > P)

- Shift to earlier, shorter, more vigorous growing season
  - More snowmelt use by all ecosystems, less runoff
- Shift to deciduous plants and annuals
- Loss of biomass

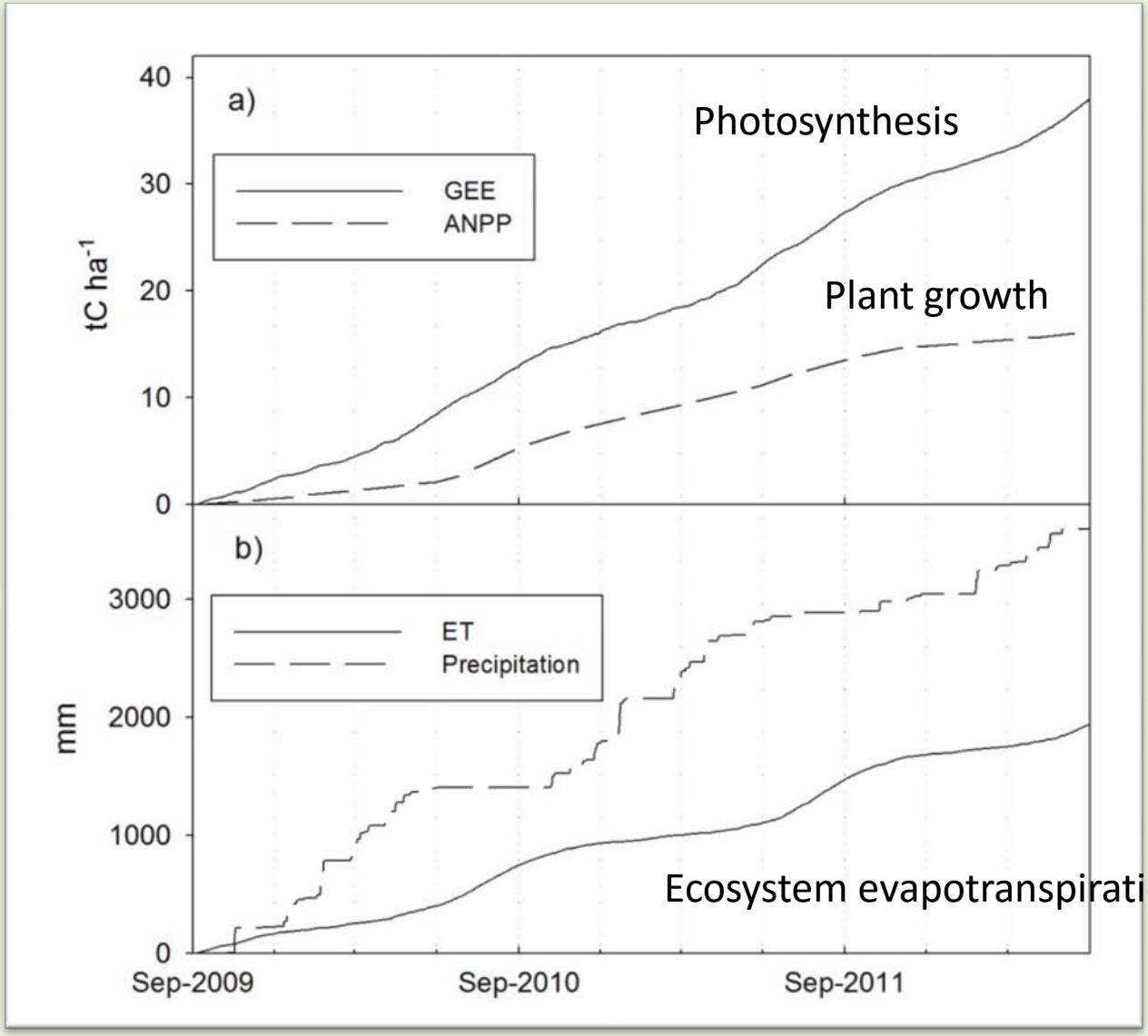

Thank you!

Seasonal production

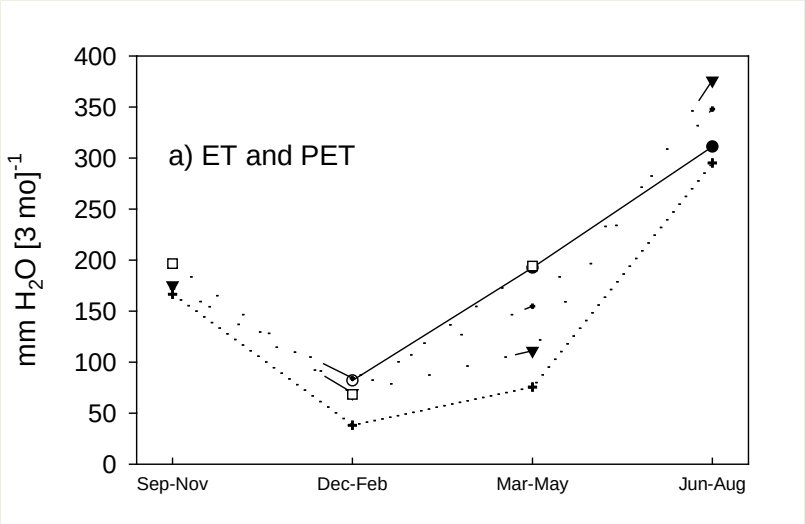


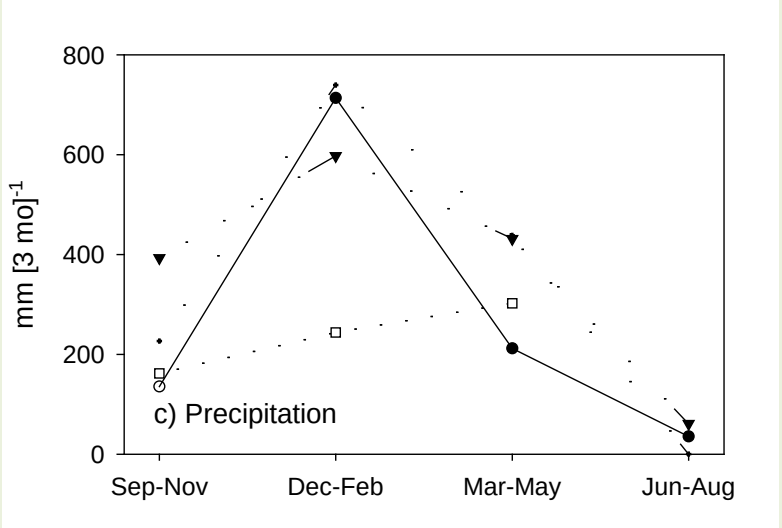


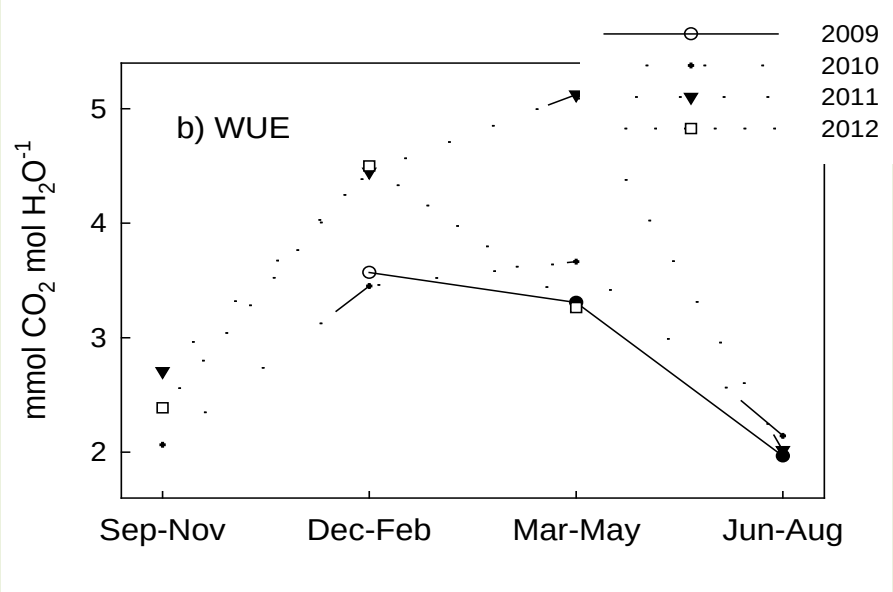
Carbon and water exchange



Ecosystem water use

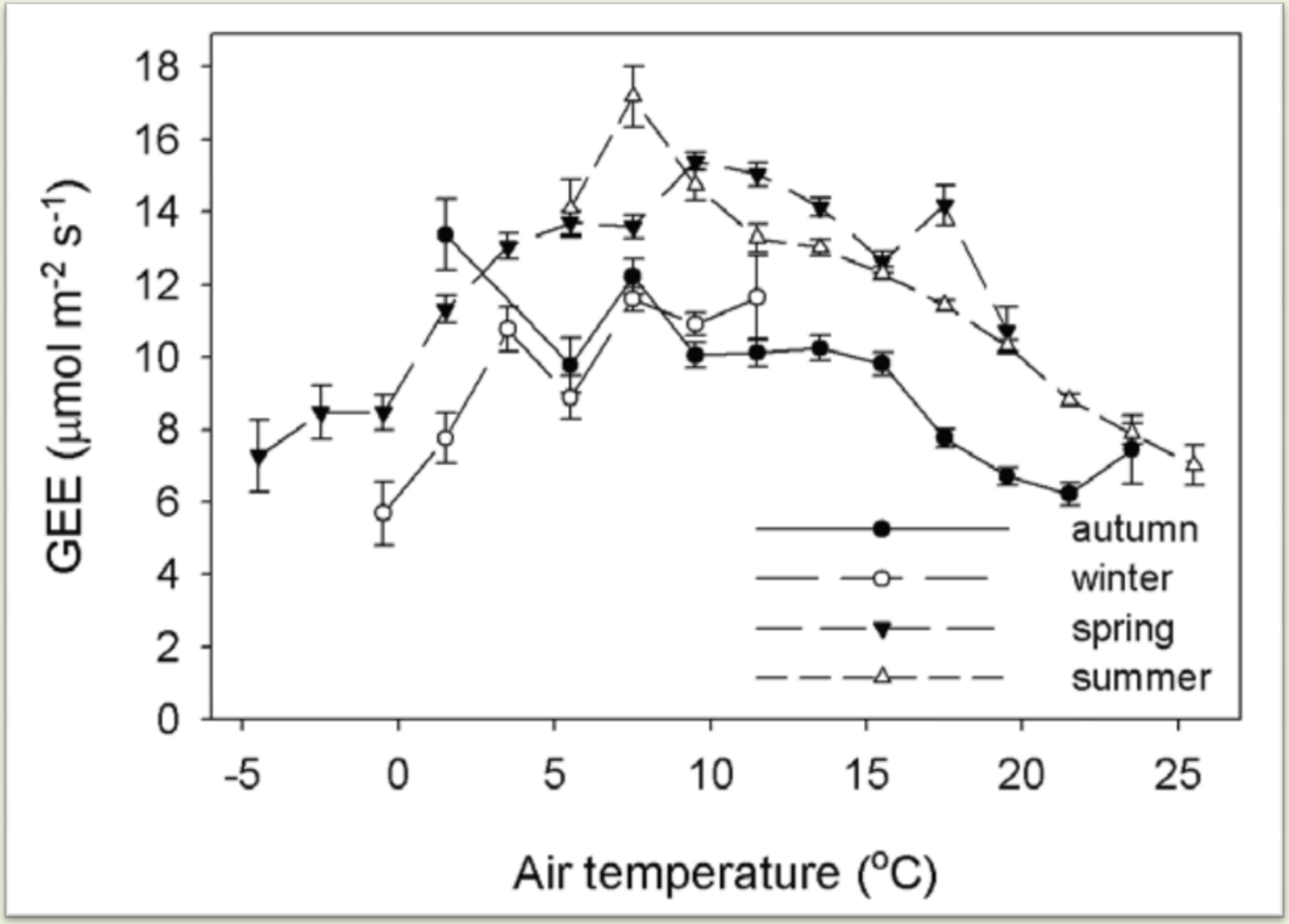




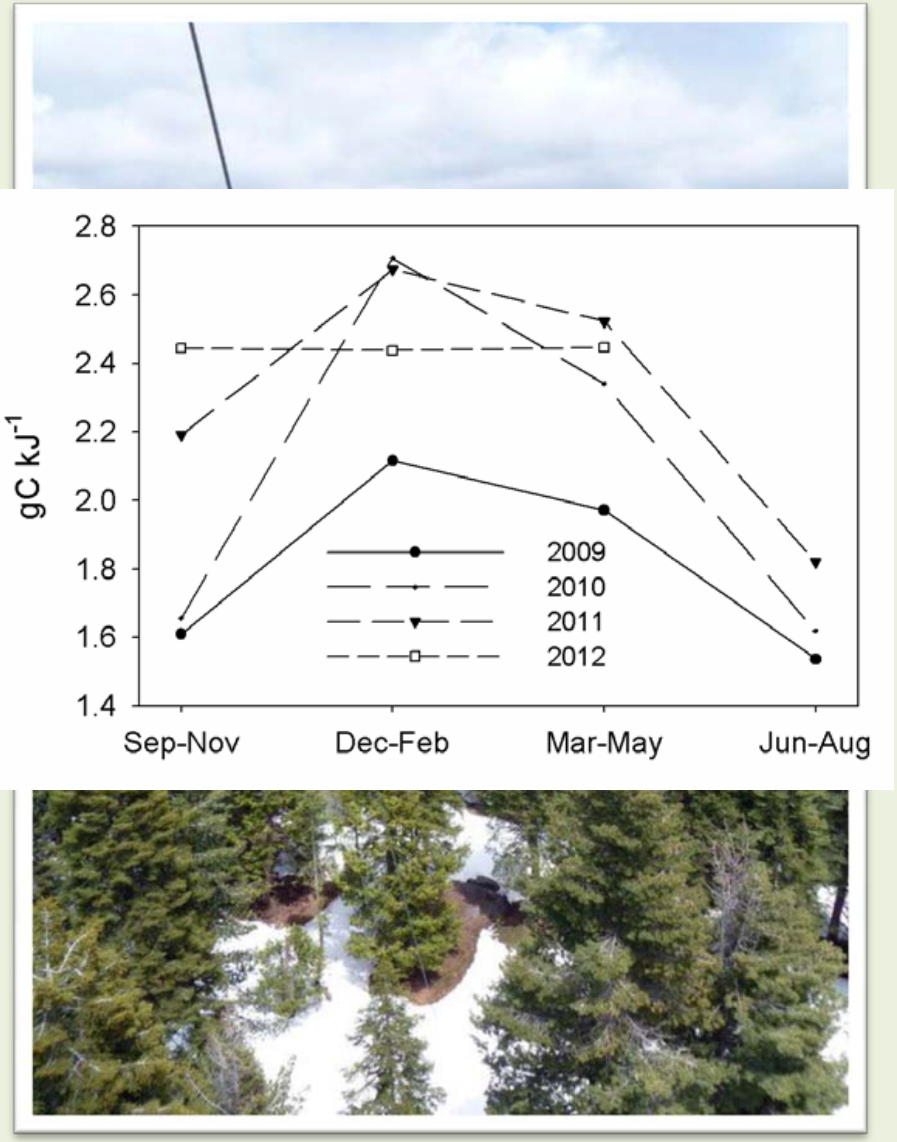


Temperature limits on growth?

Photosynthesis



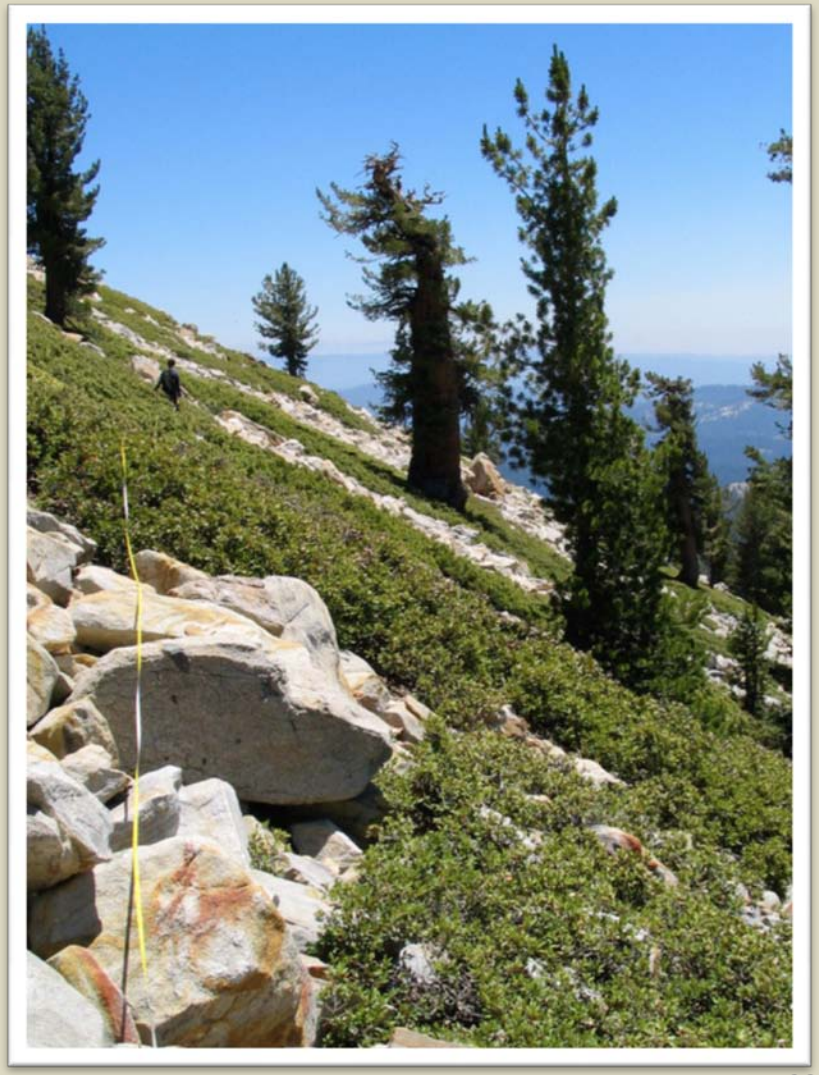
Conclusions



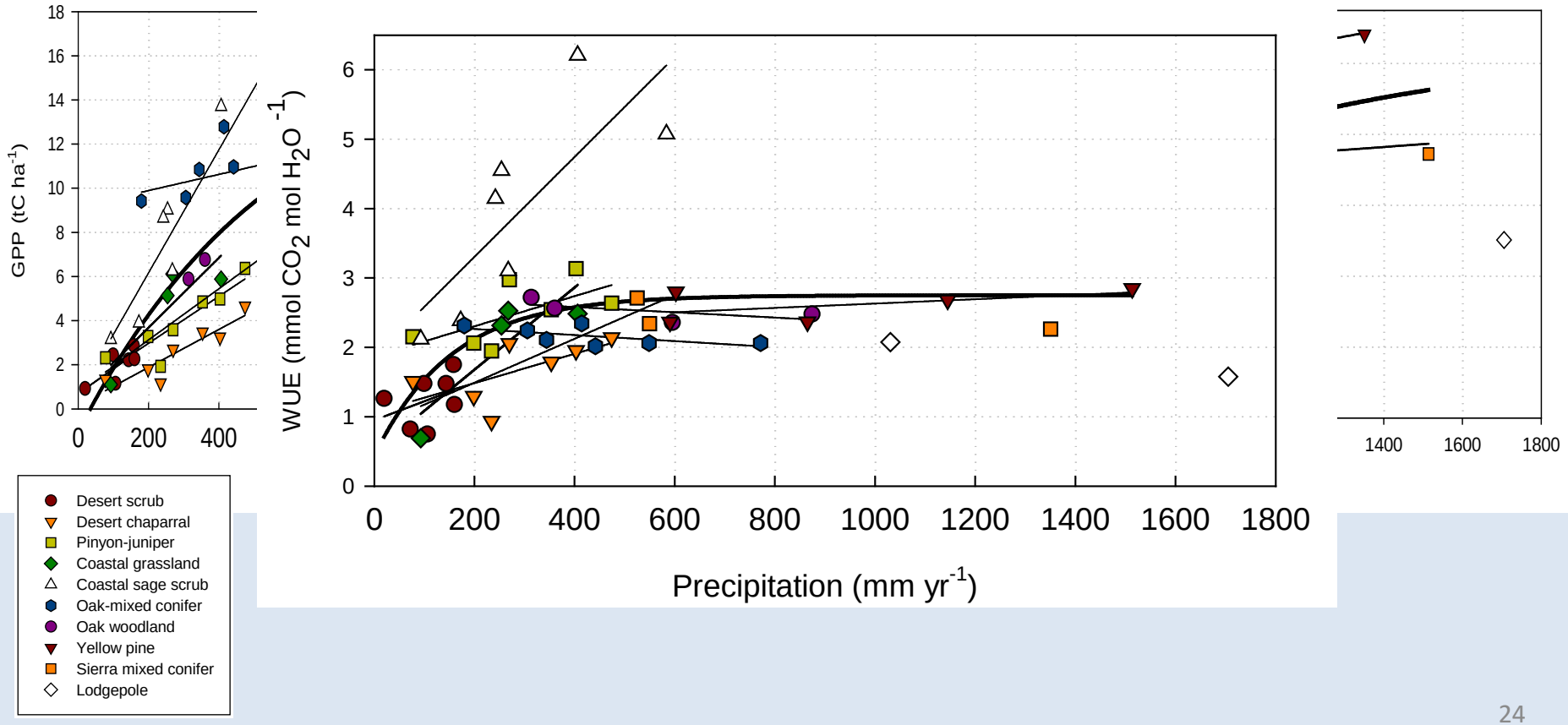
- Light is the main limitation in winter
- Super cold tolerant! (-6 ^{o}C, not 8.2 ^{o}C)
- Year-round access to water

Conclusions

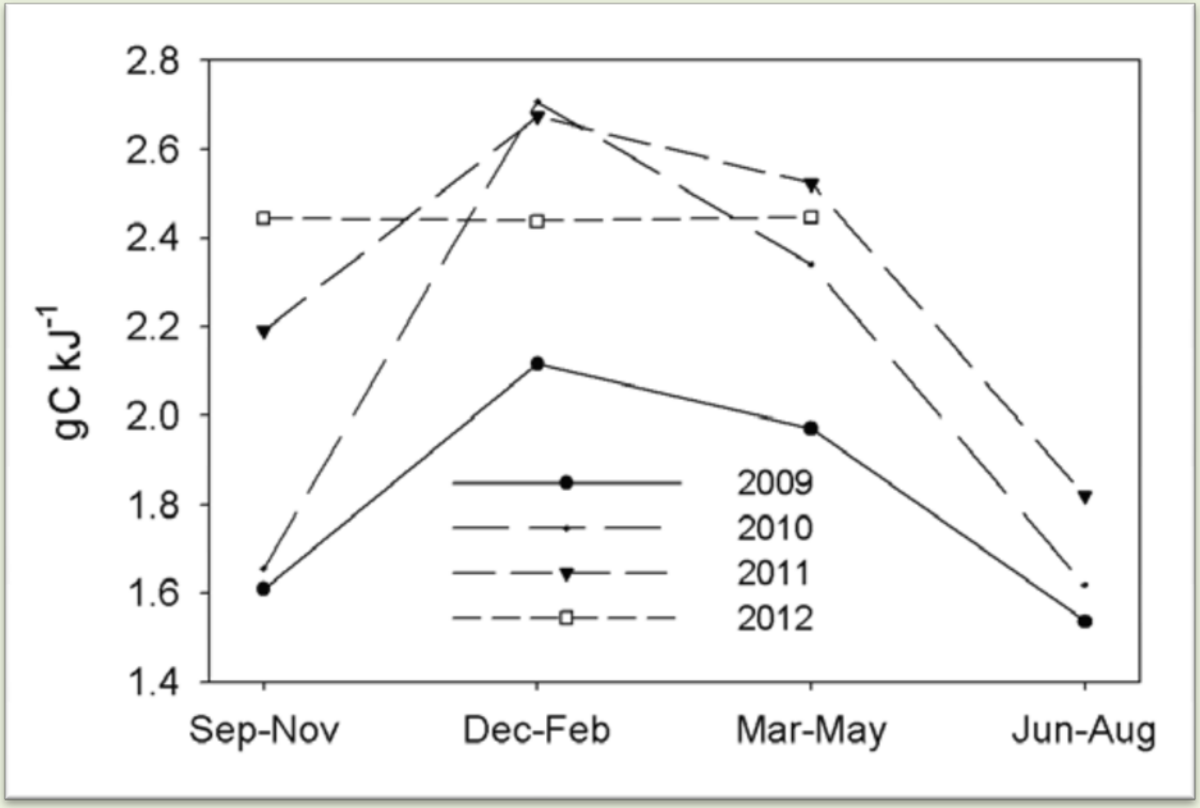
- Mid-elevation “sweet spot”
- Growing season length is more important than daily GEE
- EFT adapted to present climatic limitations
- Drought, warming will look different



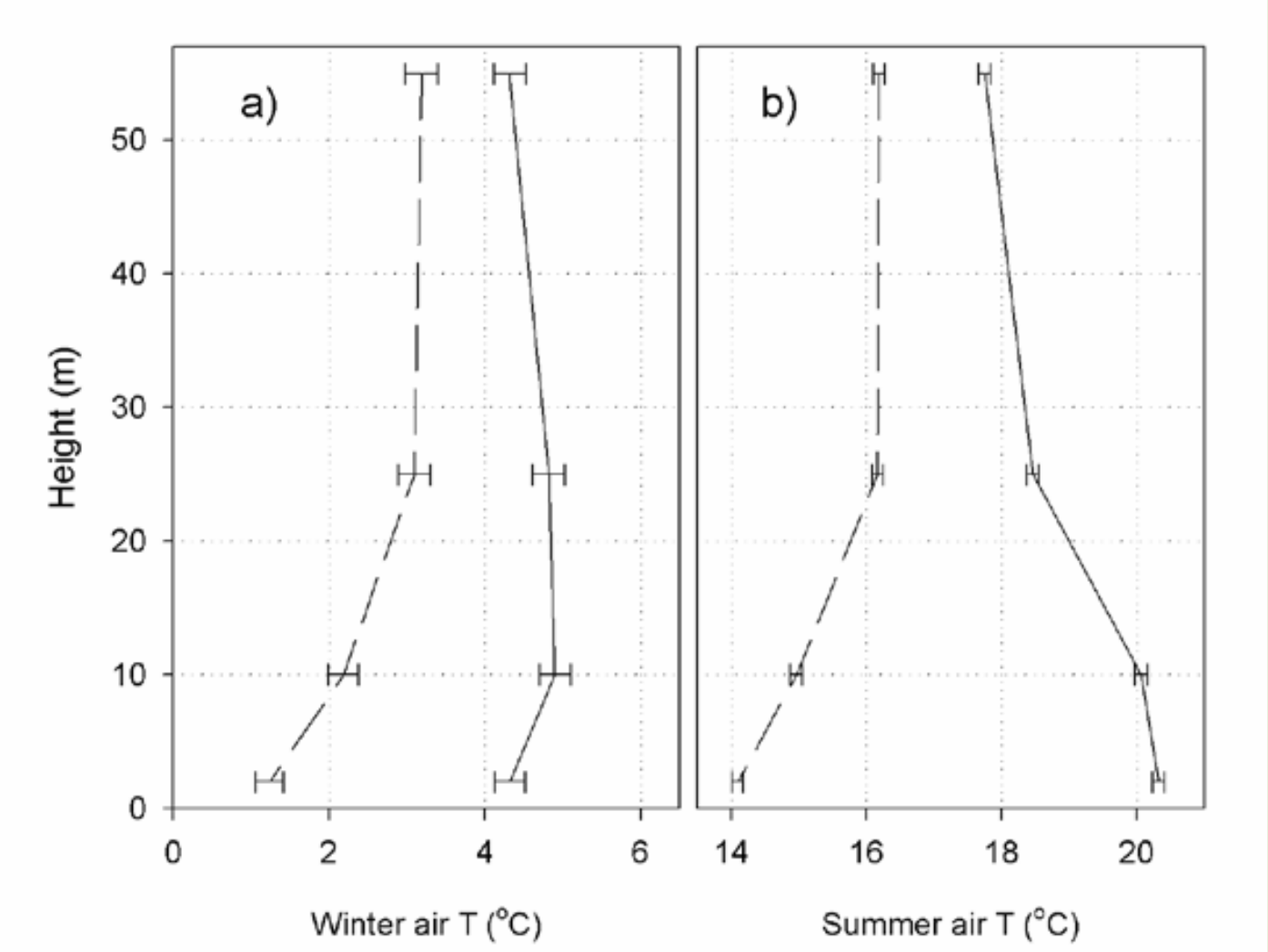
Carbon and water cycling along a precipitation gradient



Mixed conifer LUE



Annual air T (°C)					
2 m		55 m		Mean annual	Mean annual contiguous period with
Max	Min	Max	Min	precipitation	precip < 1 mm/day
11.7	7.1	10.5	9.2	1102 mm	138 days

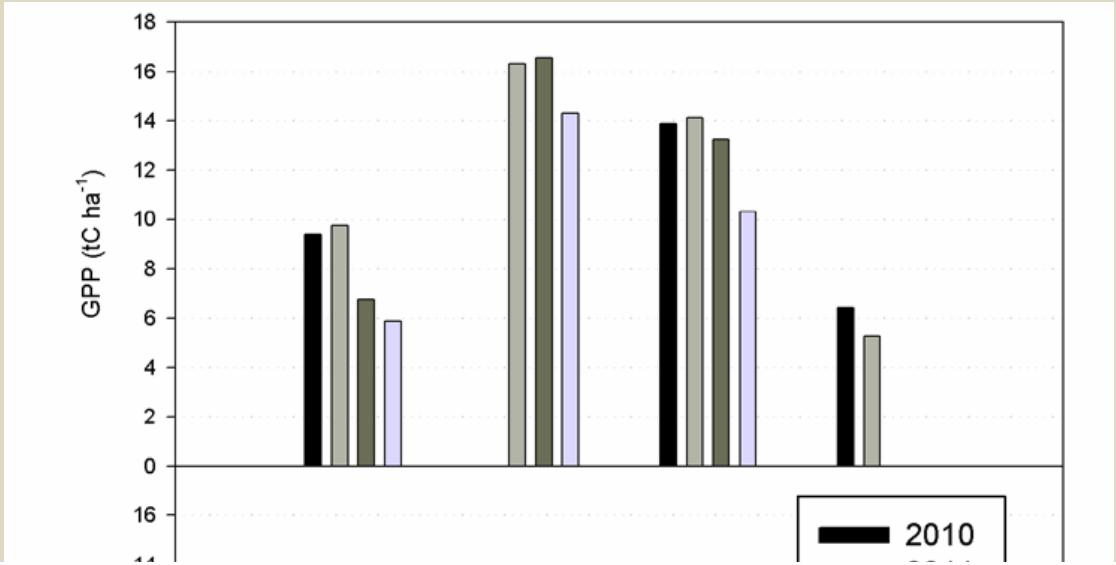


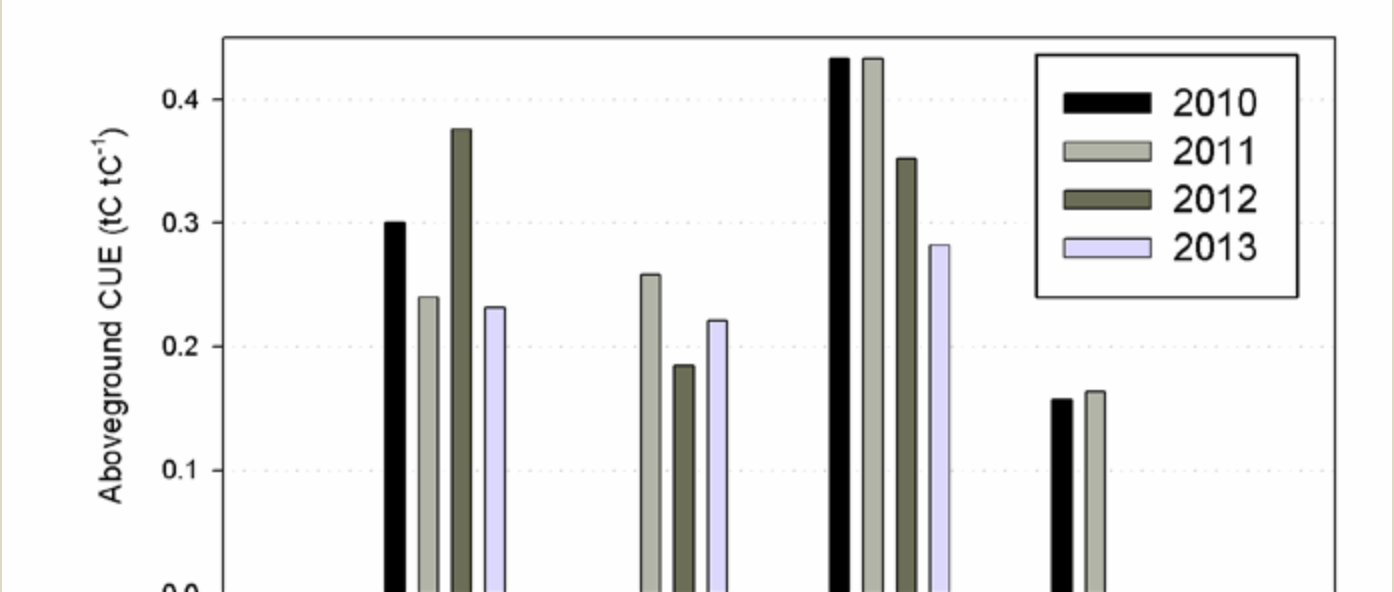
Weather

Table 2.2. Weather means for WY 2009-2012.

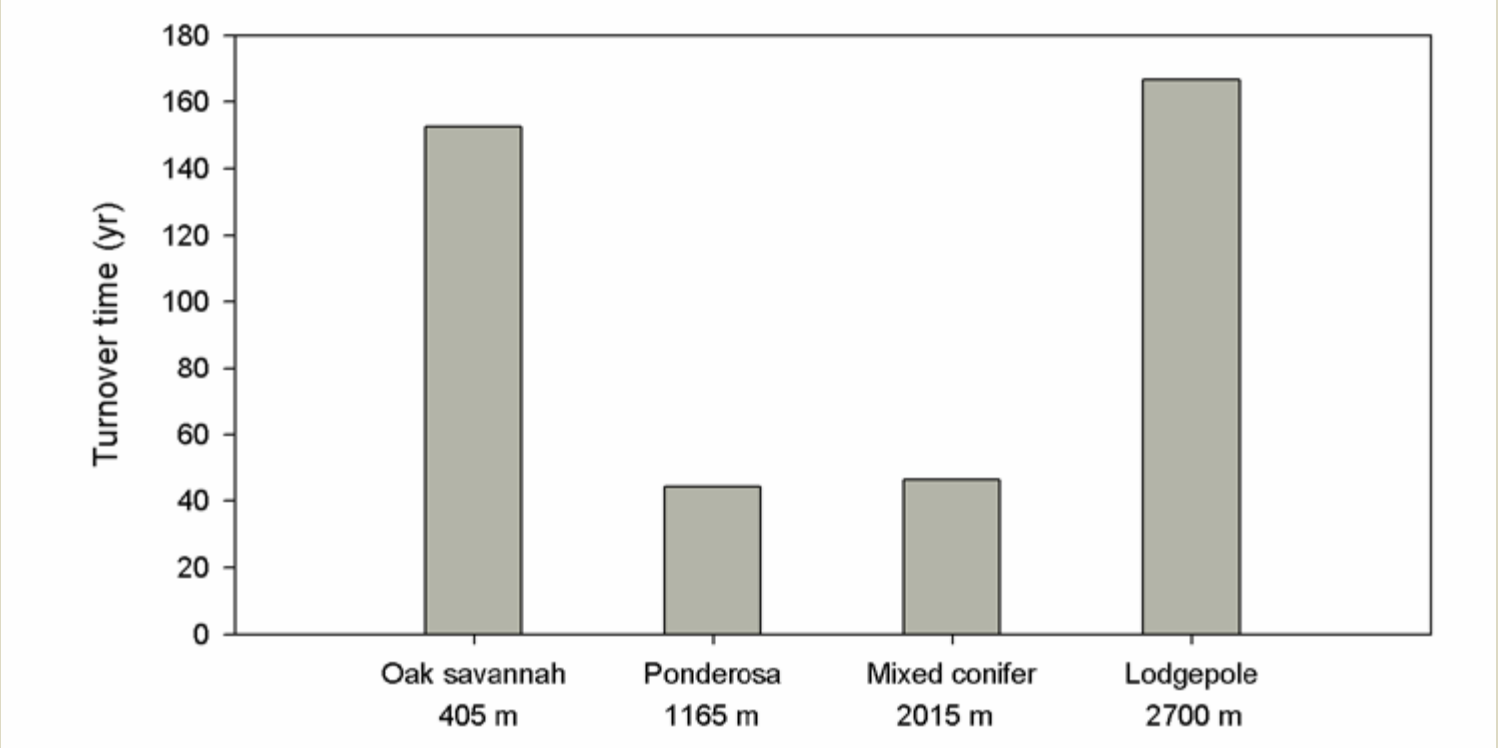
	Oak savannah	Ponderosa	Mixed conifer	Lodgepole
Annual temp. (^{o}C)	17.6	13.9	9.0	5.3
Feb mean	9.9	6.1	1.2	-1.6
July mean	28.3	23.4	18.3	14.5
Annual precip. (mm)	557	912	1031	1190
Midday VSD (kPa)	2.0	1.6	1.1	0.8

Carbon fluxes





Woody turnover time



Summary of results

Table 2.4. Summary of measured values of flows in the diagnostic framework [Figure 2.1].

	Growing season days yr^{-1}	GEE kg day^{-1}	Aboveground CUE % yr^{-1}	Allocation of ANPP to wood % yr^{-1}	Death rate by mass % yr^{-1}
Oak savannah	180	31.6	28.7%	5.9%	0.0%
Ponderosa pine	314	44.5	22.1%	43.1%	0.0%
Mixed conifer	328	38.4	37.5%	40.9%	1.1%
Lodgepole	185	31.6	16.0%	42.8%	1.0%

Weather at all sites

	Elevation (m)	Latitude (^{0}N)	Longitude (^{0}W)	MAT (^{0}C)	MAP (mm)
Desert scrub	275	33.652	-116.372	23.2	114.4
Desert chaparral	1300	33.610	-116.450	16.4	287.2
Pinyon-juniper	1280	33.605	-116.455	16.5	287.2
Coastal grassland	470	33.737	-117.695	16.5	288.4
Coastal sage scrub	475	33.734	-117.696	16.4	288.4
Oak-mixed conifer	1710	33.808	-116.772	13.2	429.4
Oak savannah	405	37.109	-119.731	17.6	535.6
Ponderosa	1160	37.031	-119.256	14.0	808.4
Sierra mixed conifer	2015	37.067	-119.195	9.0	943.4
Lodgepole	2700	37.067	-118.987	4.9	1368.0