Berkeley Faculty Roundtable on Environmental Services in Rangeland Production Systems

Presentation and Discussion Notes from the Second Roundtable: March 20, 2009

DENNIS BALDOCCHI

CARBON AND WATER EXCHANGE OF AN OAK – GRASS SAVANNA AND PEATLAND PASTURE ECOSYSTEM

Berkeley Faculty Roundtable on Environmental Services in Rangeland Production Systems

Part I:
Powerpoint Presentation by Dennis Baldocchi

Carbon & Water Exchange of an Oak-Grass Savanna and Peatland Pasture Ecosystem

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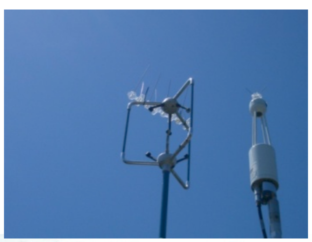
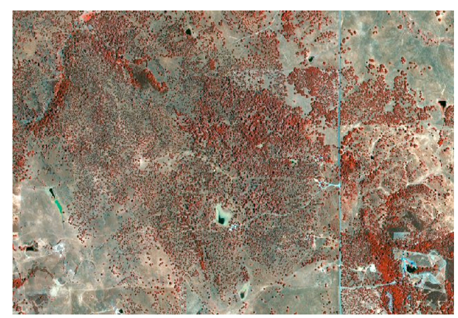




Conclusions

- Oak Woodlands are Carbon Sinks, Grasslands are Carbon Neutral
- Year to year variability in Carbon Uptake is due to length of wet season.
  - Oaks are risk adverse and experience less inter-annual variability in NEE than grasslands
- Photosynthesis and Respiration are tightly linked
  - Oaks need high N levels to attain sufficient rates of carbon assimilation for the short growing season
- Savanna woodlands need about 80 mm more water to function than nearby grasslands
  - Trees tap ground-water to sustain themselves during the summer
- Oaks are darker and warmer than annual grasslands

Oak-Grass Savanna: A Two Layer System

Winter:
Trees deciduous; grass green

Spring:
Trees green;grass green

Summer:
Trees green; grass dead

Oak-Savanna Model System for Studying Ecosystem Ecology

- Structure/Function
  - Oak and grasses provide contrasting life forms, woody/herbaceous, perennial/annual
  - The Canopy is open and heterogeneous, giving us a opportunity to test the applicability of ecosystem and biogeophysical models, mostly developed for ideal and closed canopies
- Environmental Biology
  - The Mediterranean climate provides distinct wet/ cool and dry/hot seasons to examine the ecosystem response (photosynthesis, transpiration, respiration, stomatal conductance) to a spectrum of soil moisture and temperature conditions
- Global Change
  - The Mediterranean climate experiences great extremes in inter-annual variability in rainfall; we experience a wider range in precipitation over a few years than long-term predicted changes.

Peatland Pastures are a Model for studying Land Subsidence in the Delta

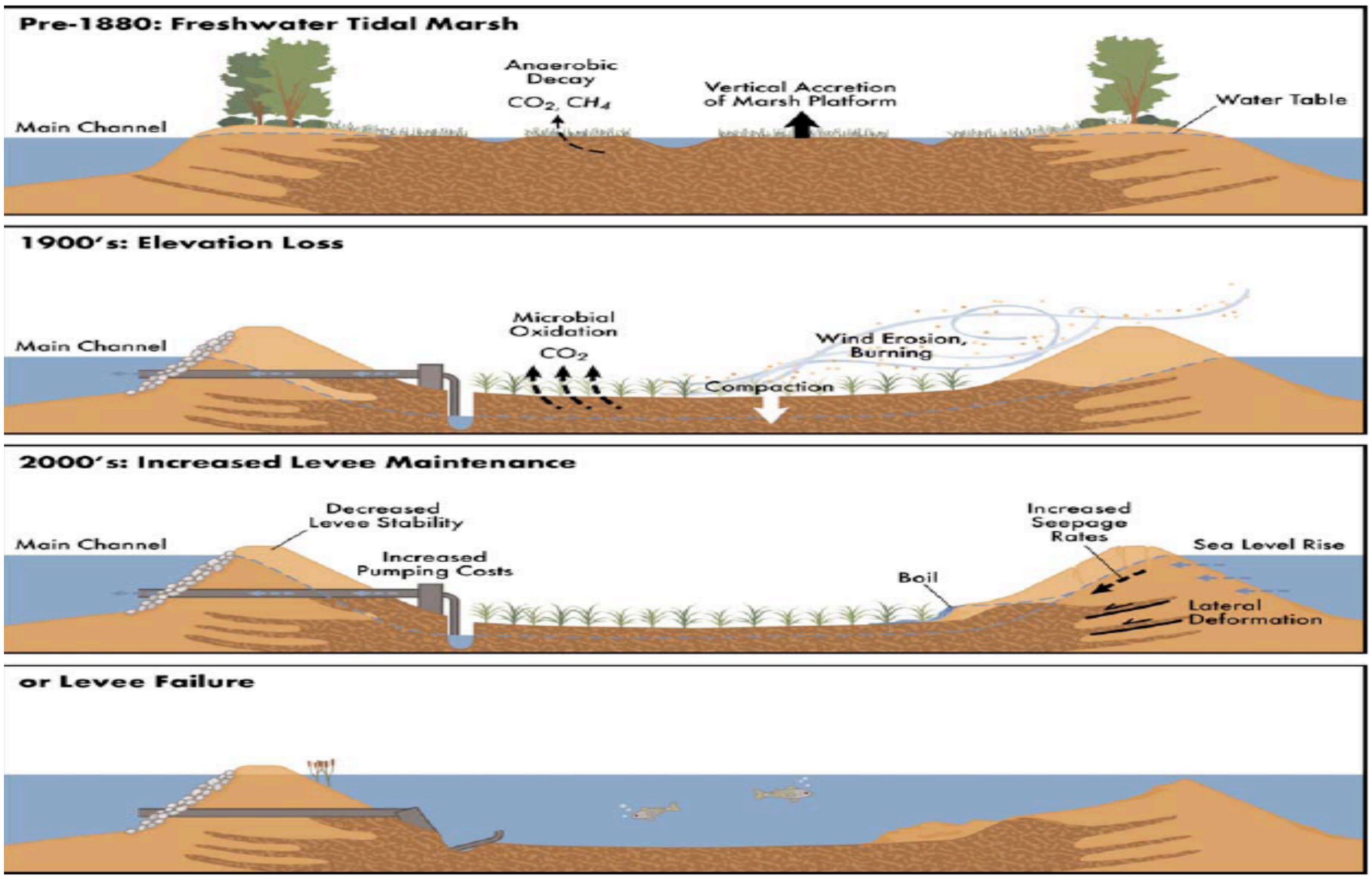
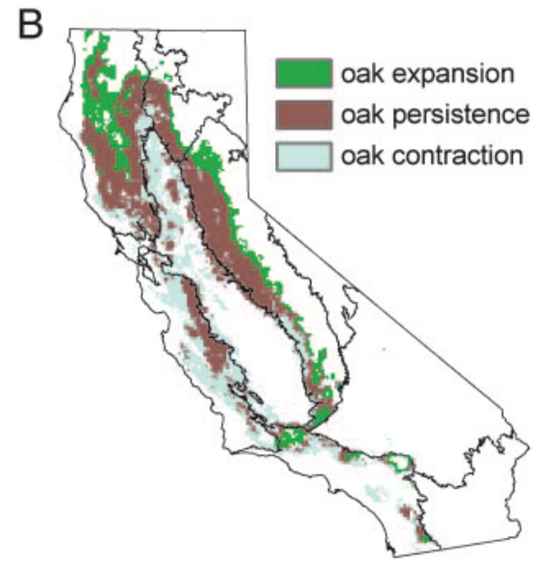


Figure 2. Conceptual diagram illustrating evolution of Delta islands due to levee construction and island subsidence. Modified from Ingebritsen et al. (2000).

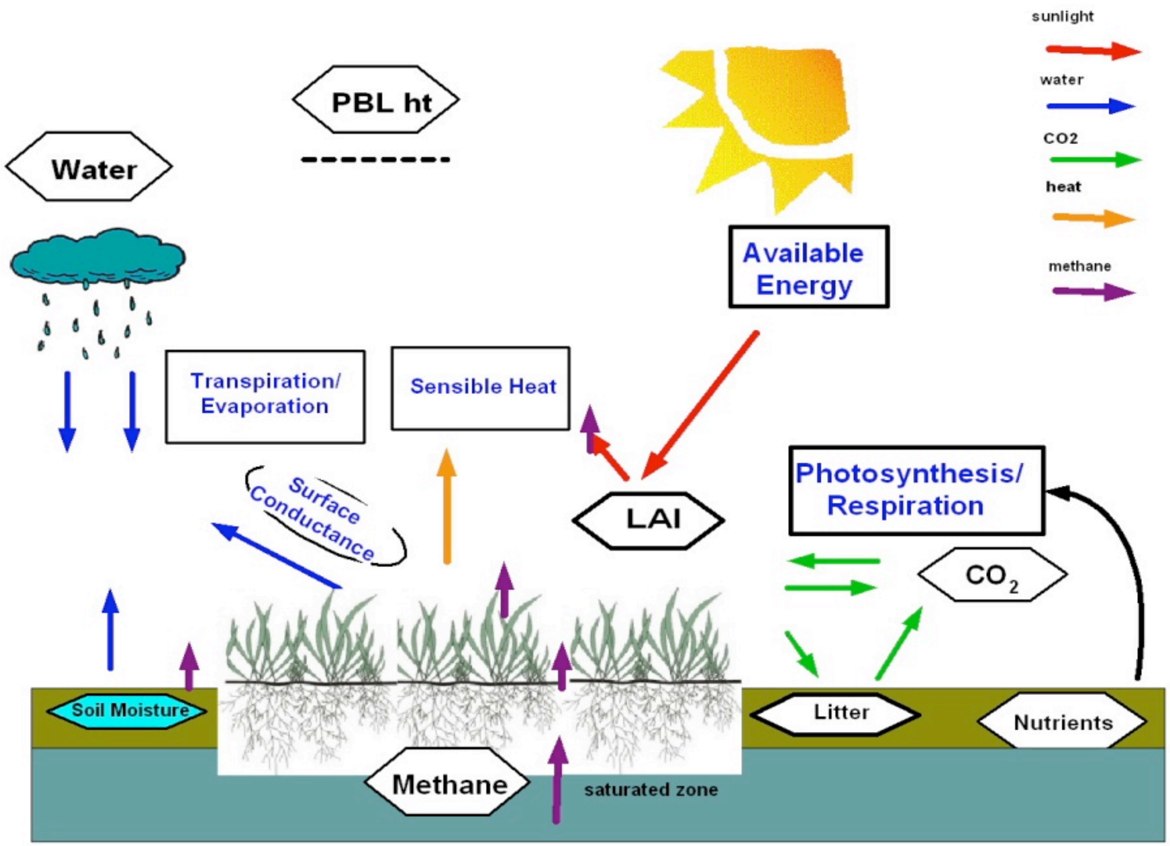
Goals of Research

- Quantify the Biophysical Controls on Ecosystem Metabolism (carbon gains and losses) and Water Balance of Oak Woodlands and Peatland Pastures
- Quantify and understand mechanisms controlling net annual budgets and inter-annual variability of carbon, water and energy exchange of oak woodland and annual grassland and Peatland Pastures
- Produce predictive and mechanistic ability to quantify future conditions, e.g. global warming, elevated CO_2 and ozone, perturbed water supply, and land use change, land subsidence, methane emissions and in order to manage rangelands
- Upscale fluxes to the region for management decisions



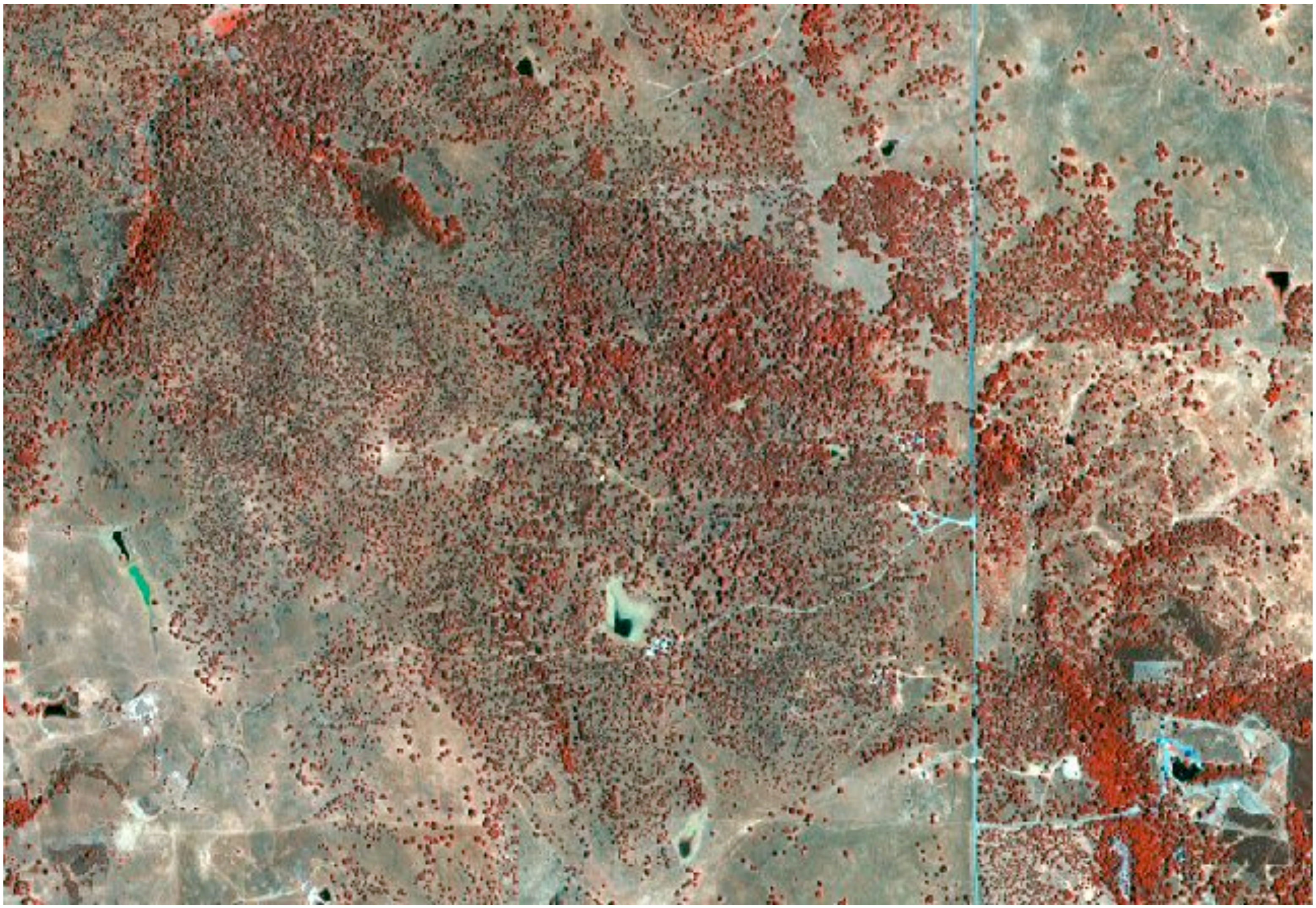
Kueppers et al 2005 PNAS

Coupled Carbon-Water-Methane Fluxes



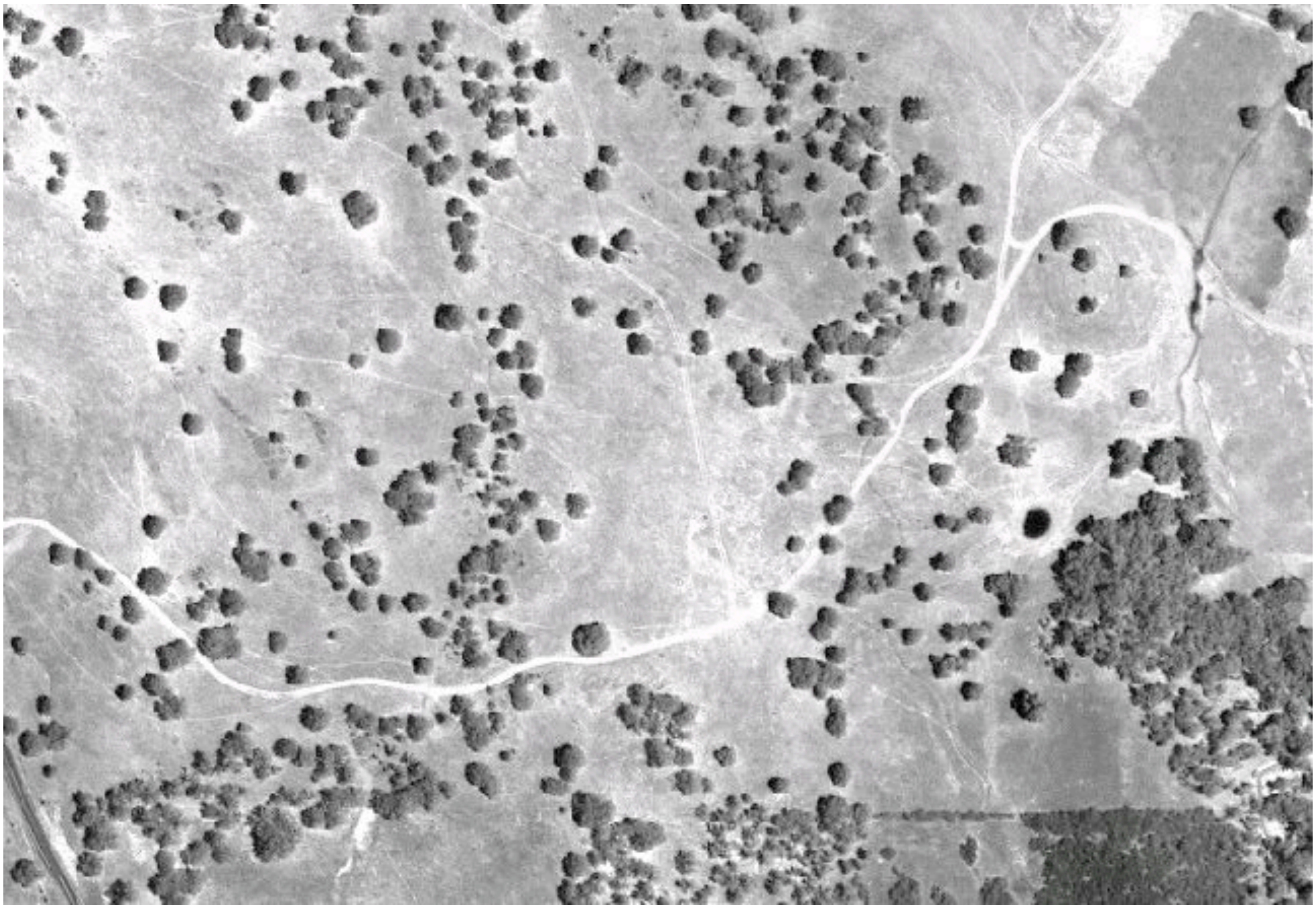
Tonzi Ranch Flux Tower

IKONOS: Savanna & Fetch



Vaira Ranch

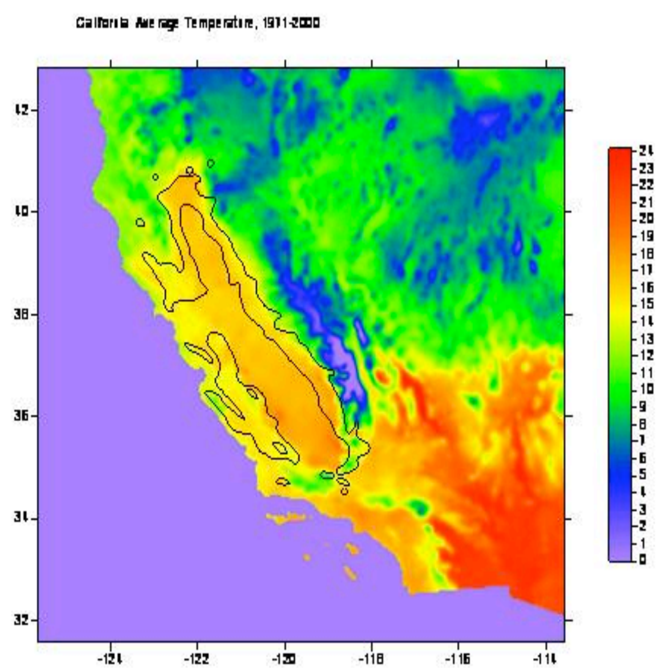
IKONOS:Grassland



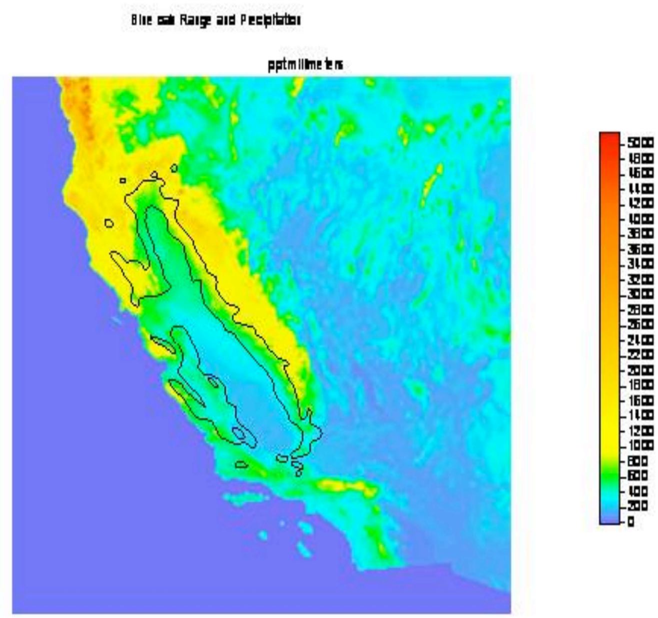
Sherman Island Peatland Pasture

Sherman Island Peatland Pasture

Annual Precipitation ~500 - 700 mm/y
Mean Annual Temperature ~ 14-16 C

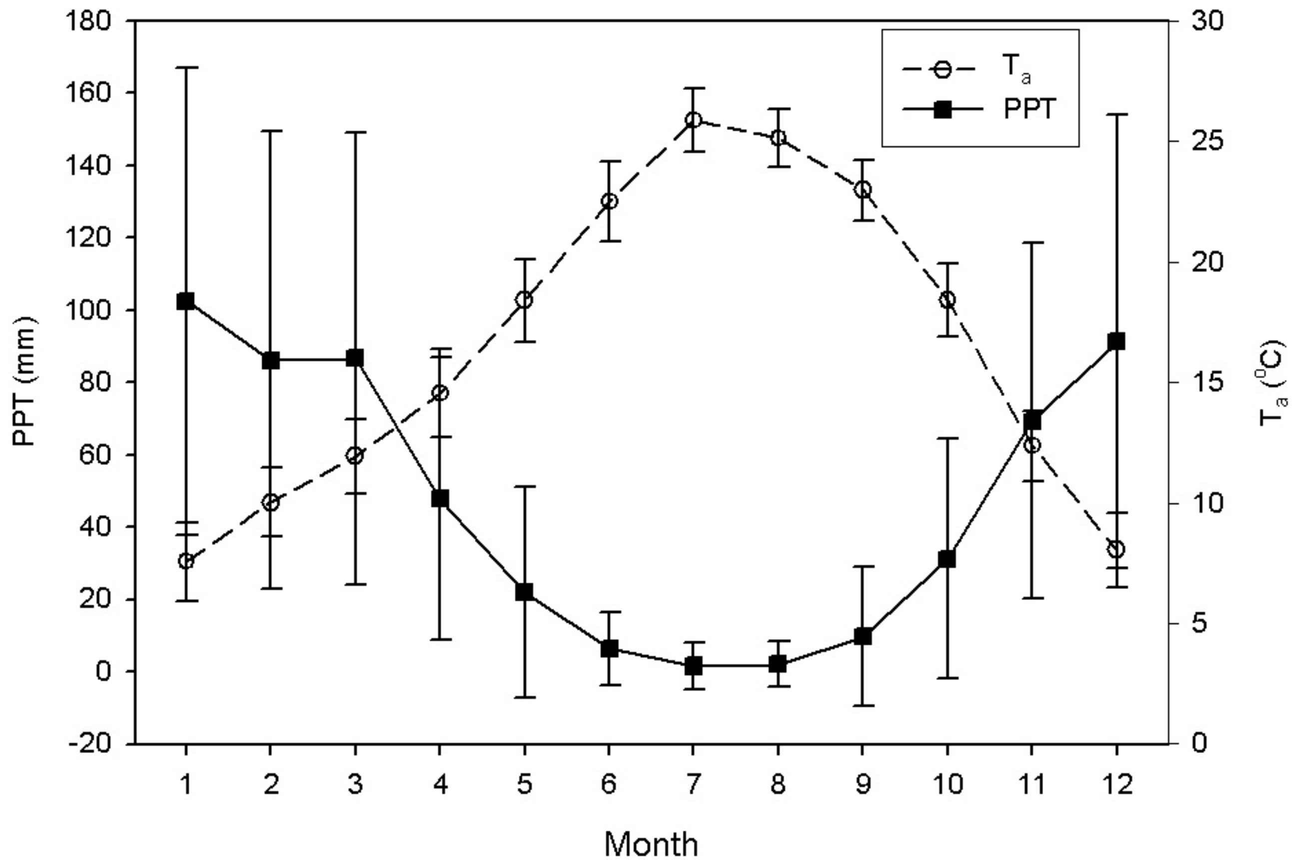


*Spatial Climate Analysis Service, Oregon State University, http://www.ocs.oregonstate.edu/prism/,



*Spatial Climate Analysis Service, Oregon State University, http://www.ocs.oregonstate.edu/prism/,

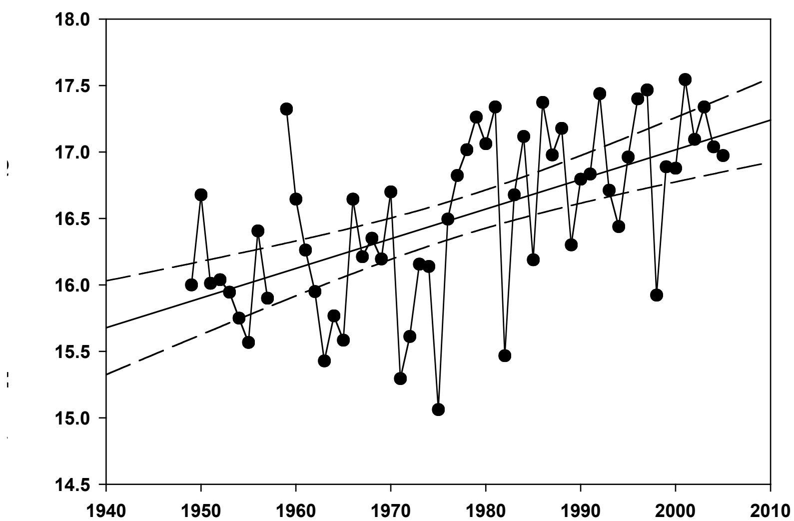
Mean Temperature and Precipitation

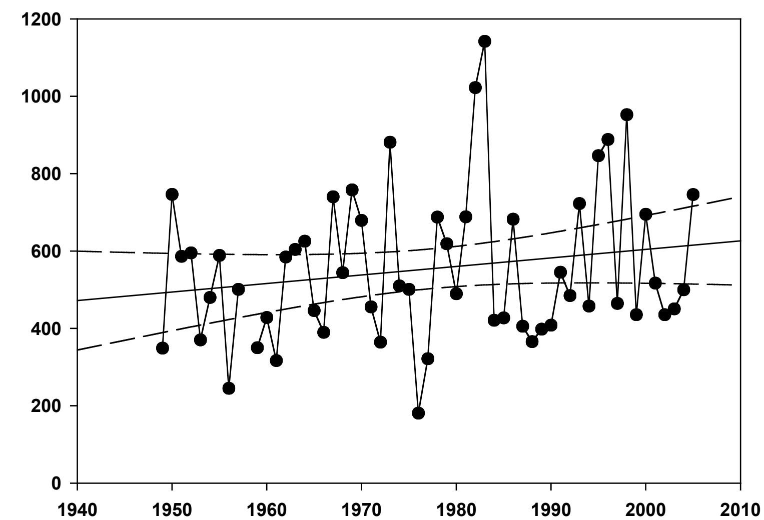


Camp Pardee, CA

Climate Trends: Pardee, CA

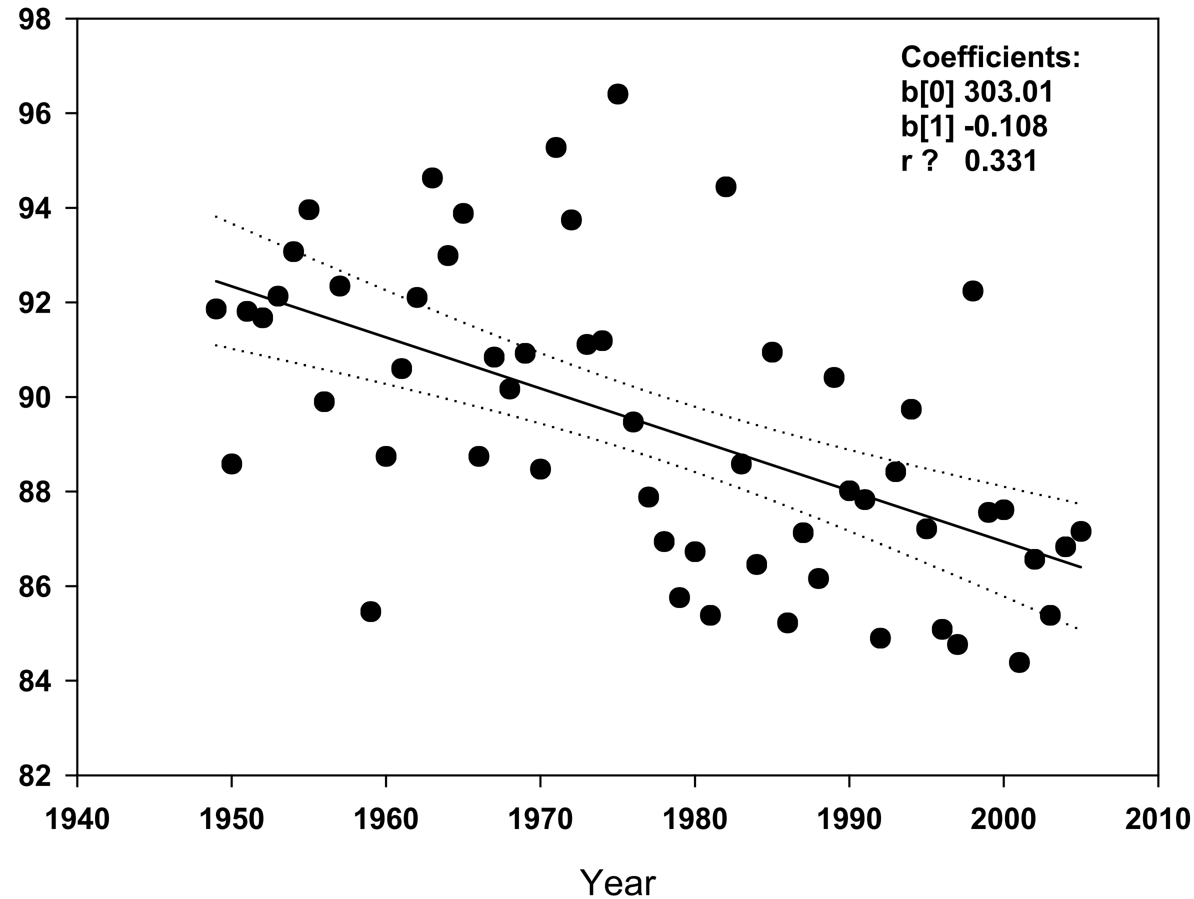
Temperature Increased by about 1.25 C over 50 Years;
Precipitation Trend is Flat, but with High Inter-annual Variation





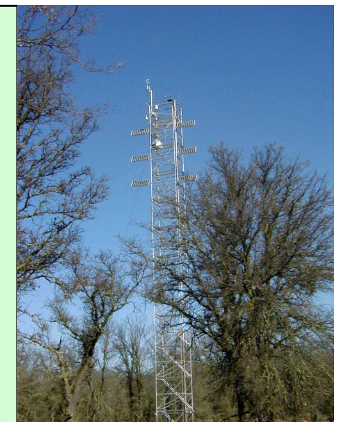
Inferred Trends in Phenology; leaf-out about 10 days earlier over 50 years

Estimate of onset of photosynthesis for blue oak woodland



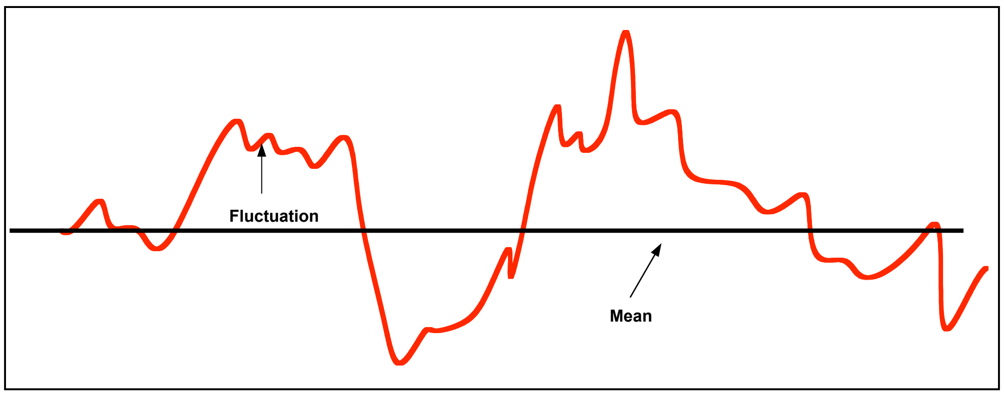
Experimental Methods

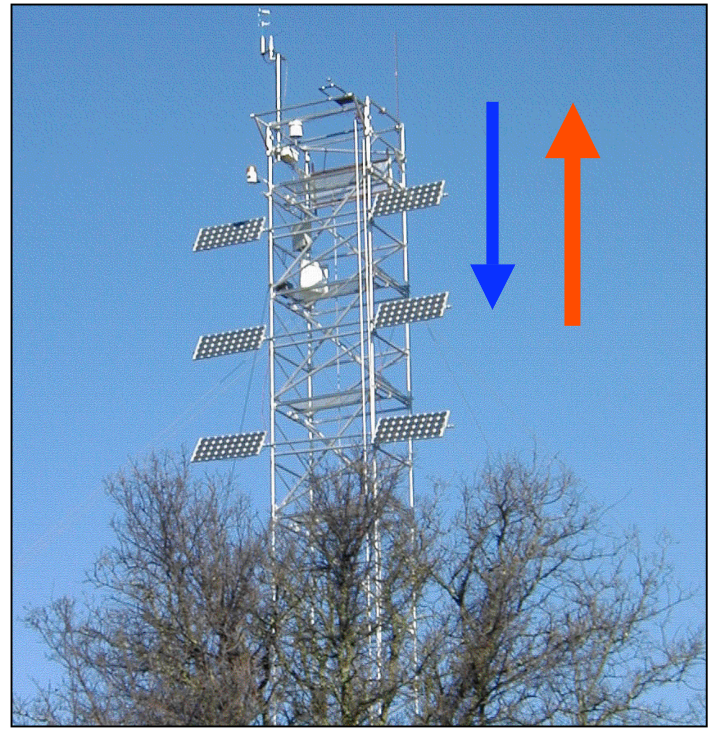
- Eddy Covariance
  - above the stand (20 m tower)
  - below the stand (2 m tower)
- Micrometeorology
- Sap flow (heat pulse)
- Soil respiration chambers
- Leaf Physiology (A-Ci curves)



Eddy Covariance

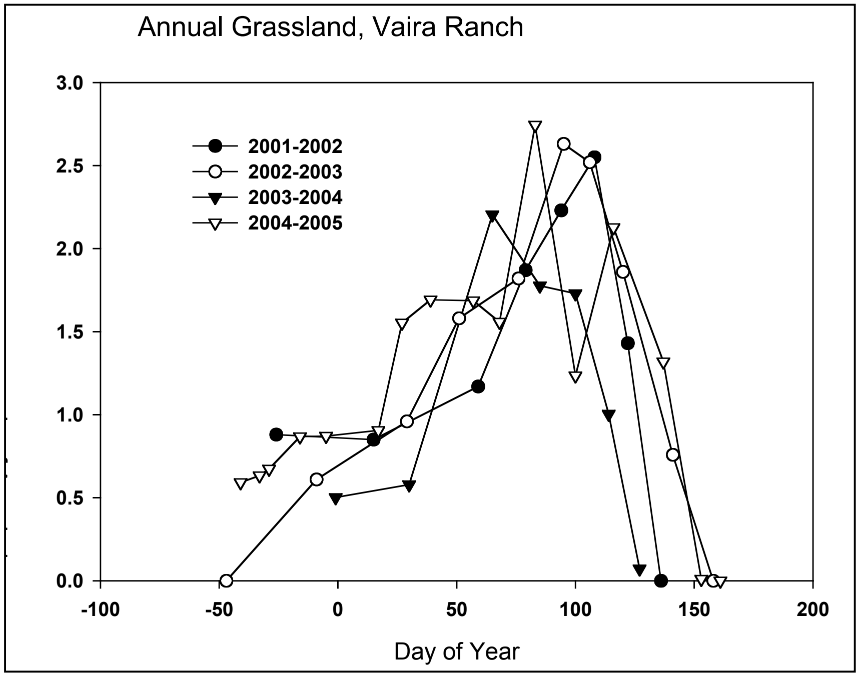
$$F = \overline{w'c'}$$

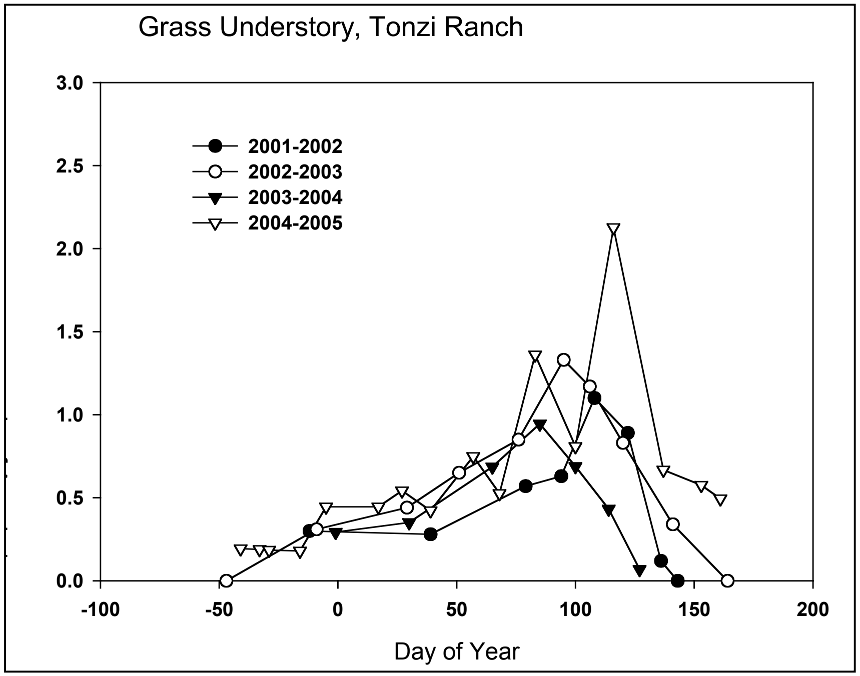




Results and Discussion

Dynamics of Canopy Structure

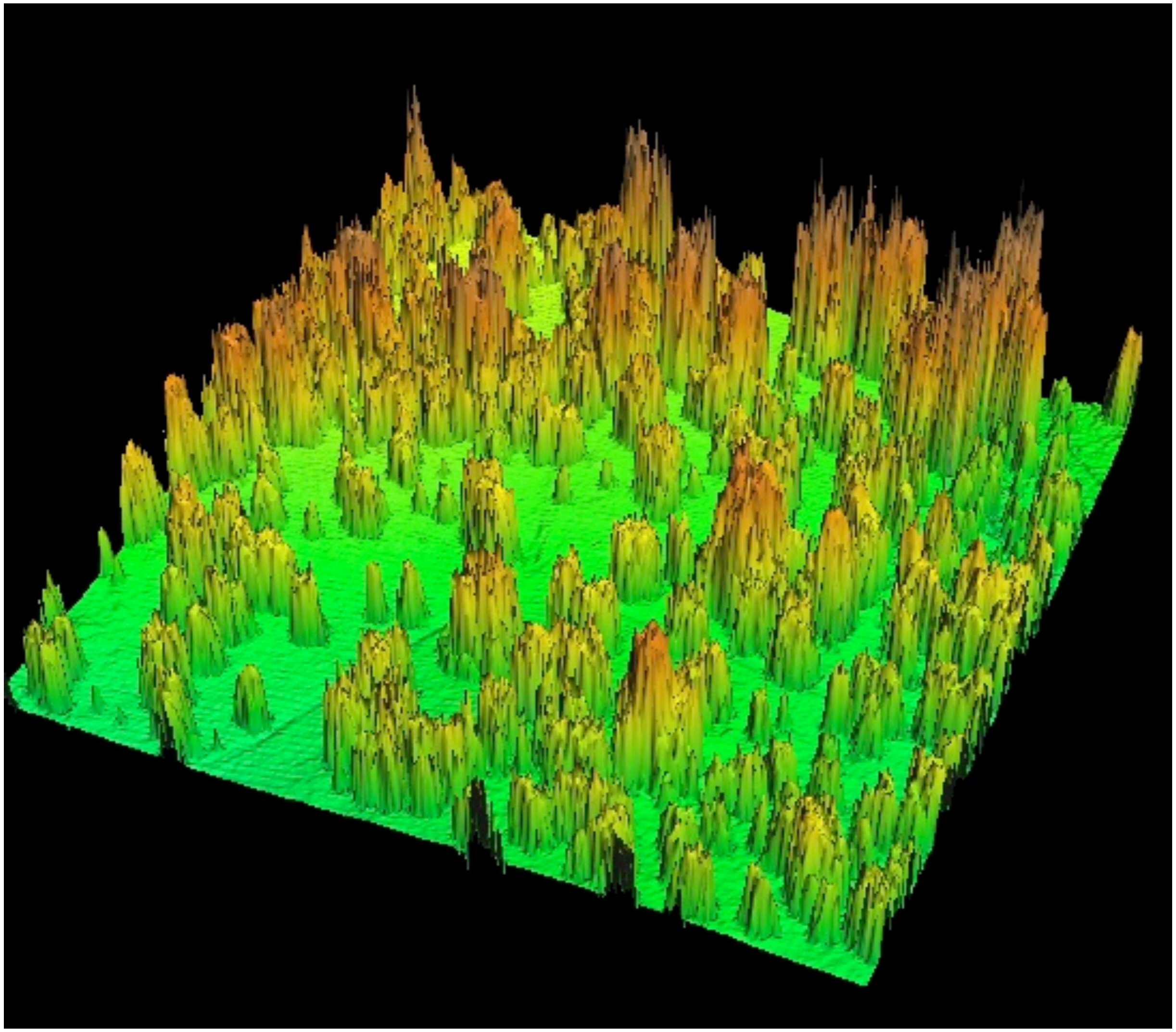




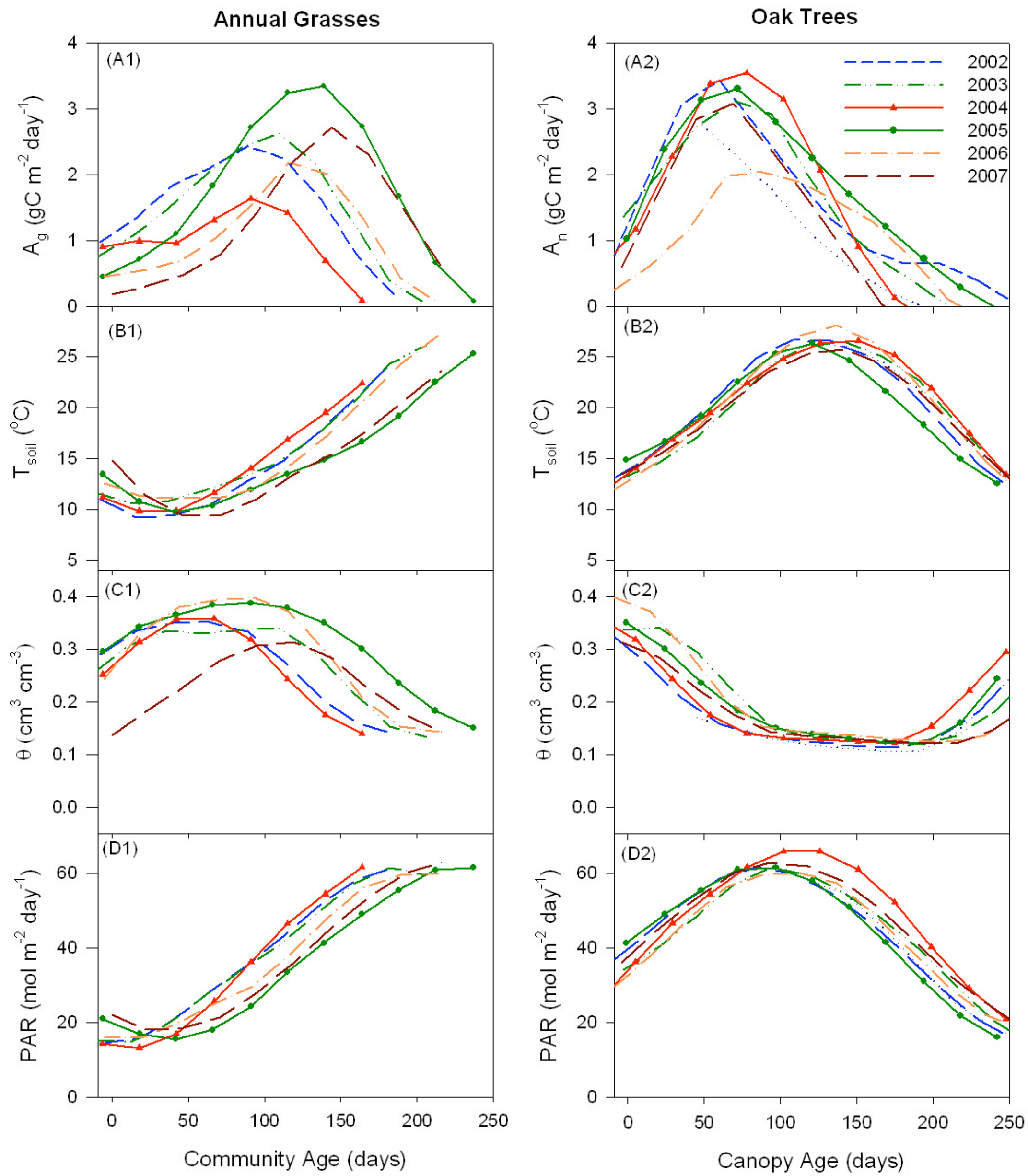
Canopy Structure: Tonzi Ranch

- Blue oak (*Quercus douglasii*)
- LAI=0.90
- Height 7.1 +/- 3.05 m
- Diameter at breast height 26.6 +/- 0.11 cm
- Understory: annual C_3 grasses
  - *Brachypodium distachyon, Hypochaeris glabra, Bromus madritensis*

Canopy Structure:
Laser Altimeter Data



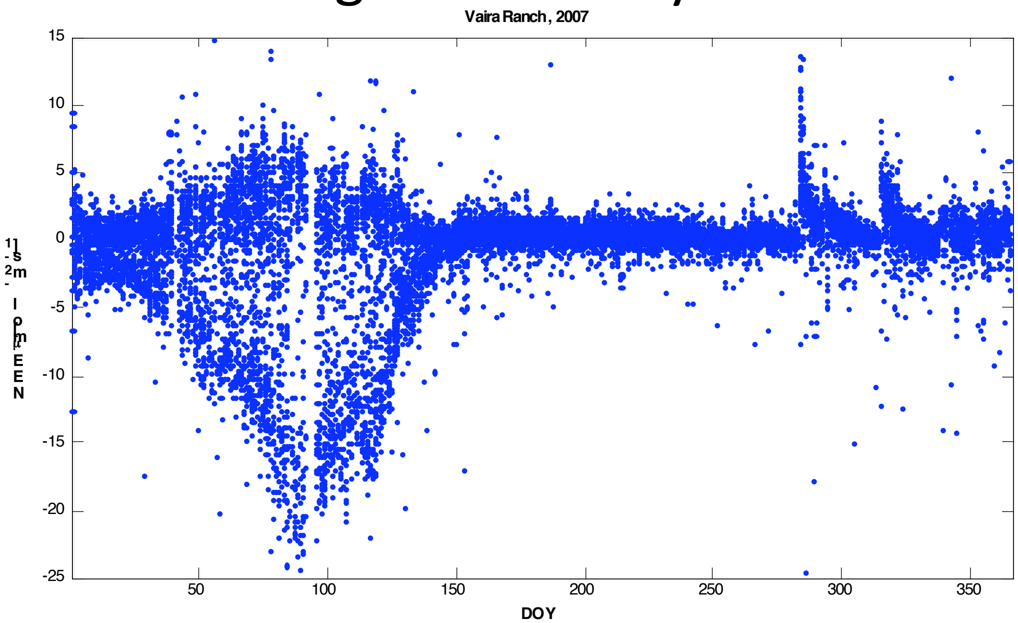
Environmental Conditions

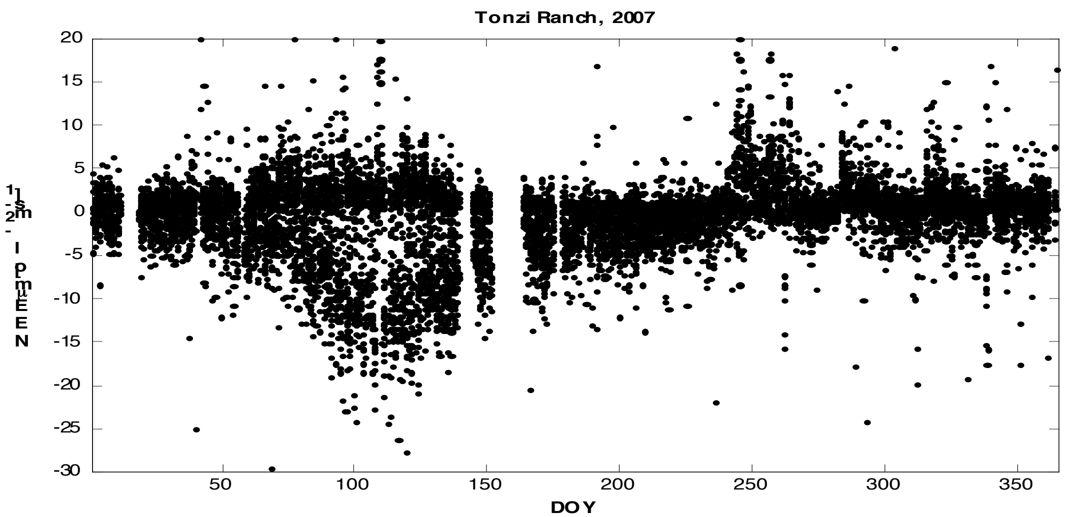


Ma et al, submitted, New Phytologist

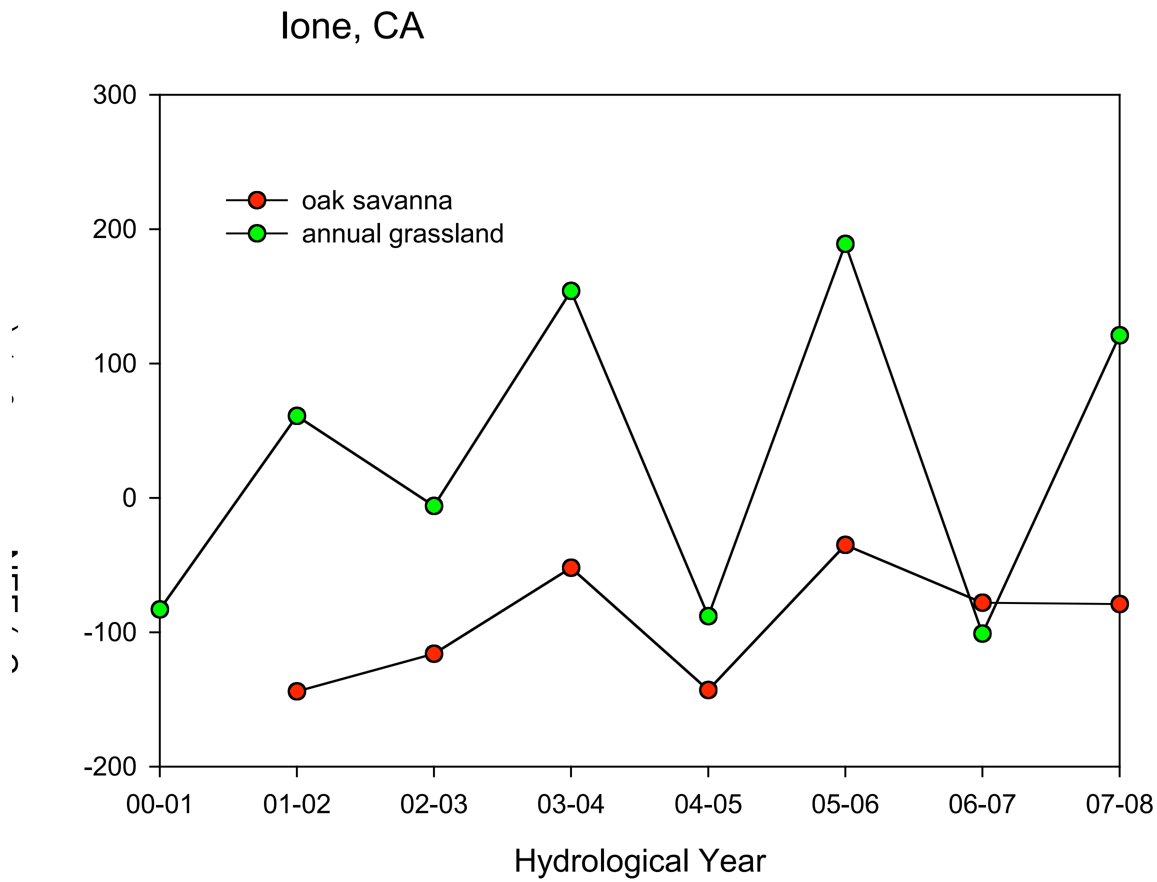
Ecosystem Ecology

‘Breathing of the Ecosystem’



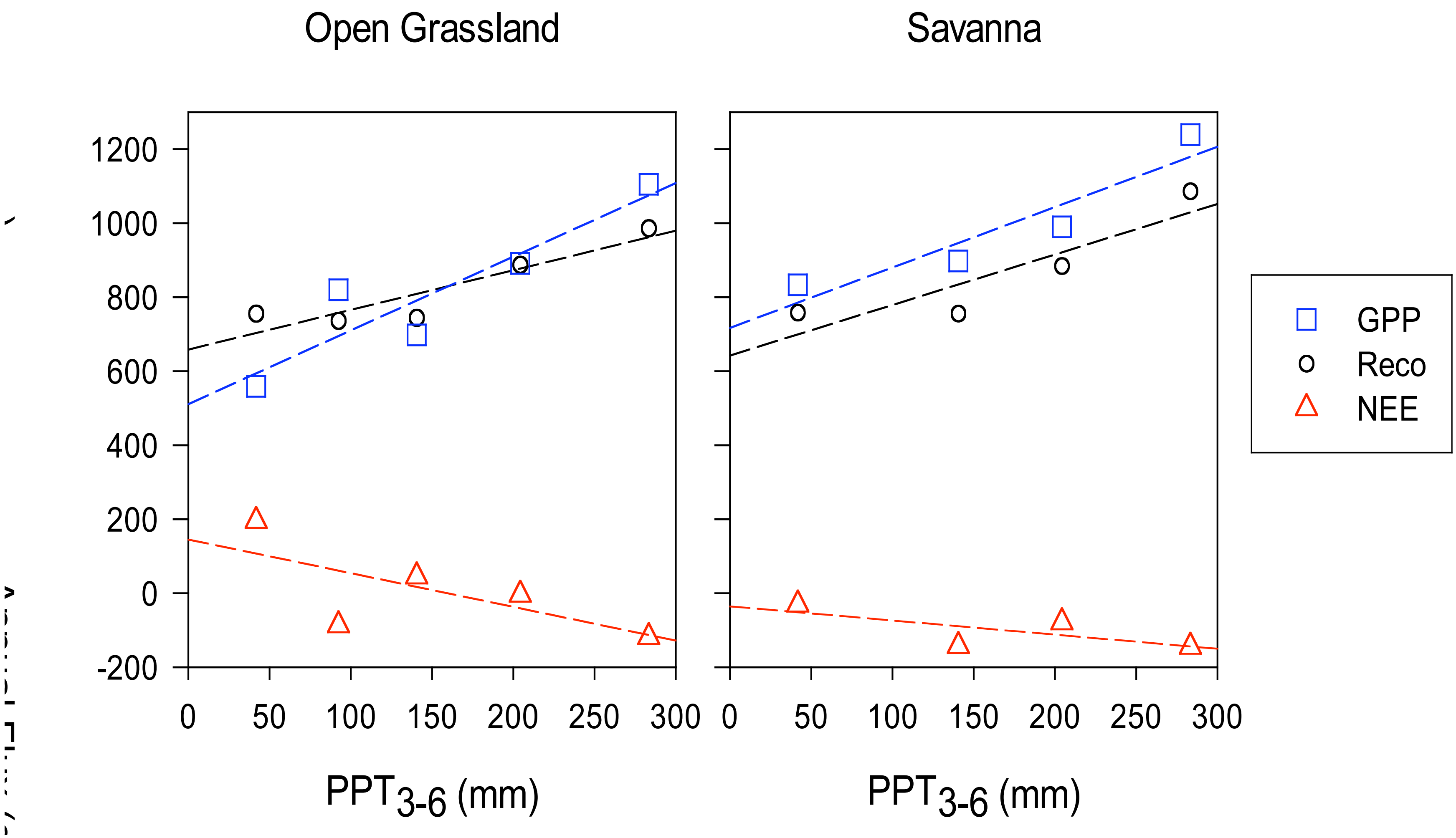


Oak Woodlands are Carbon Sinks, -92 +/- 43 $gC\ m^{-2}\ y^{-1}$
Annual Grasslands are Carbon Neutral, 30 +/- 116 $gC\ m^{-2}\ y^{-1}$



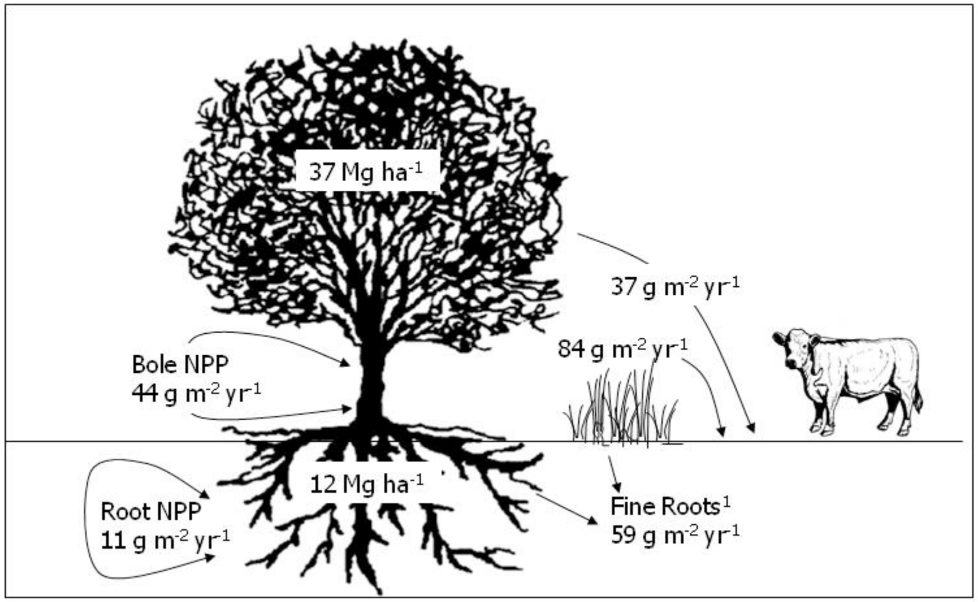
Oak Woodlands are Risk Adverse, they Experience less inter-annual variation in NEE than Grasslands

Carbon Fluxes Scale with Spring Rainfall



Ma et al, 2007 AgForMet

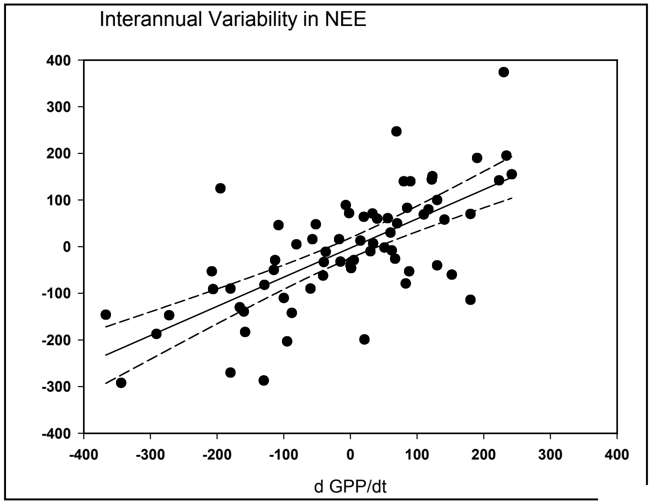
Net Primary Productivity



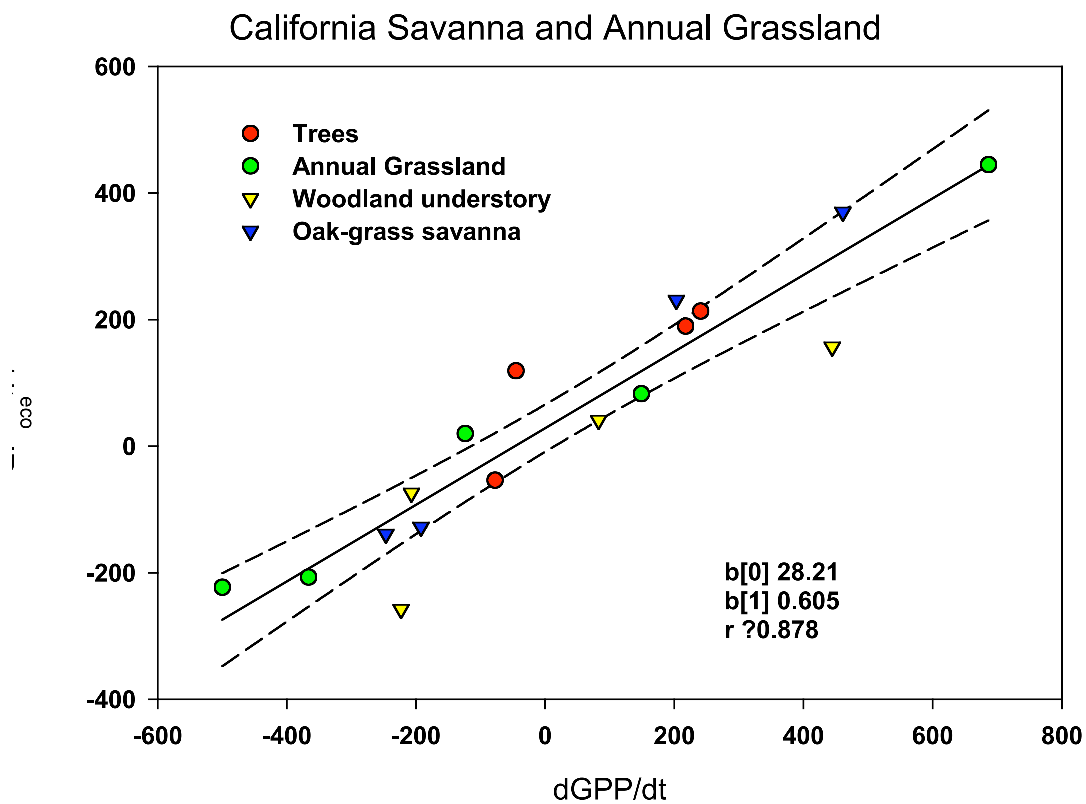
John Battle's biometric NPP = 235 gC m^{-2} y^{-1}.

NPP = GPPtree - Ra_tree - Rh = 299 gC m^{-2} y^{-1}

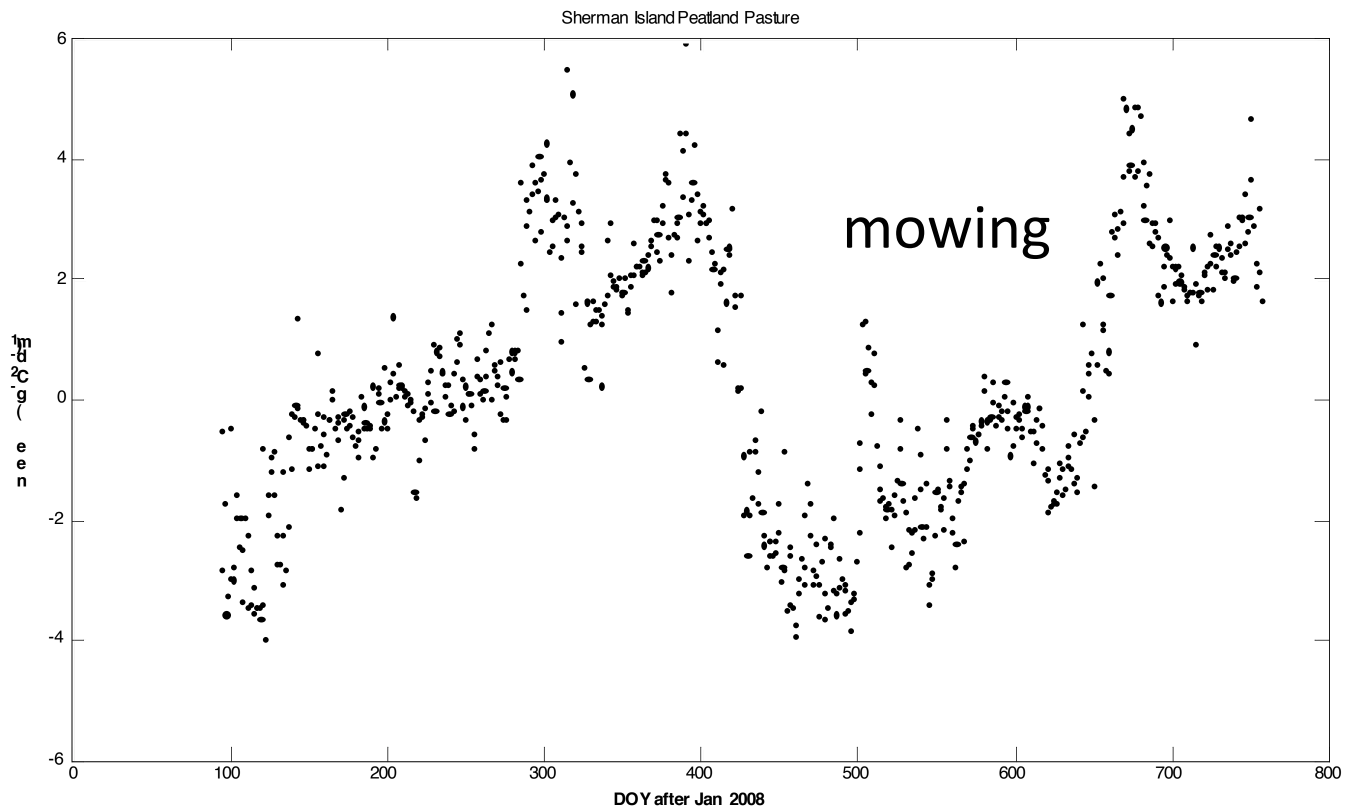
NPP=NEP+Rh=97+186=283 gC m^{-2} y^{-1}.



Interannual Variability in GPP and Reco scale with one another



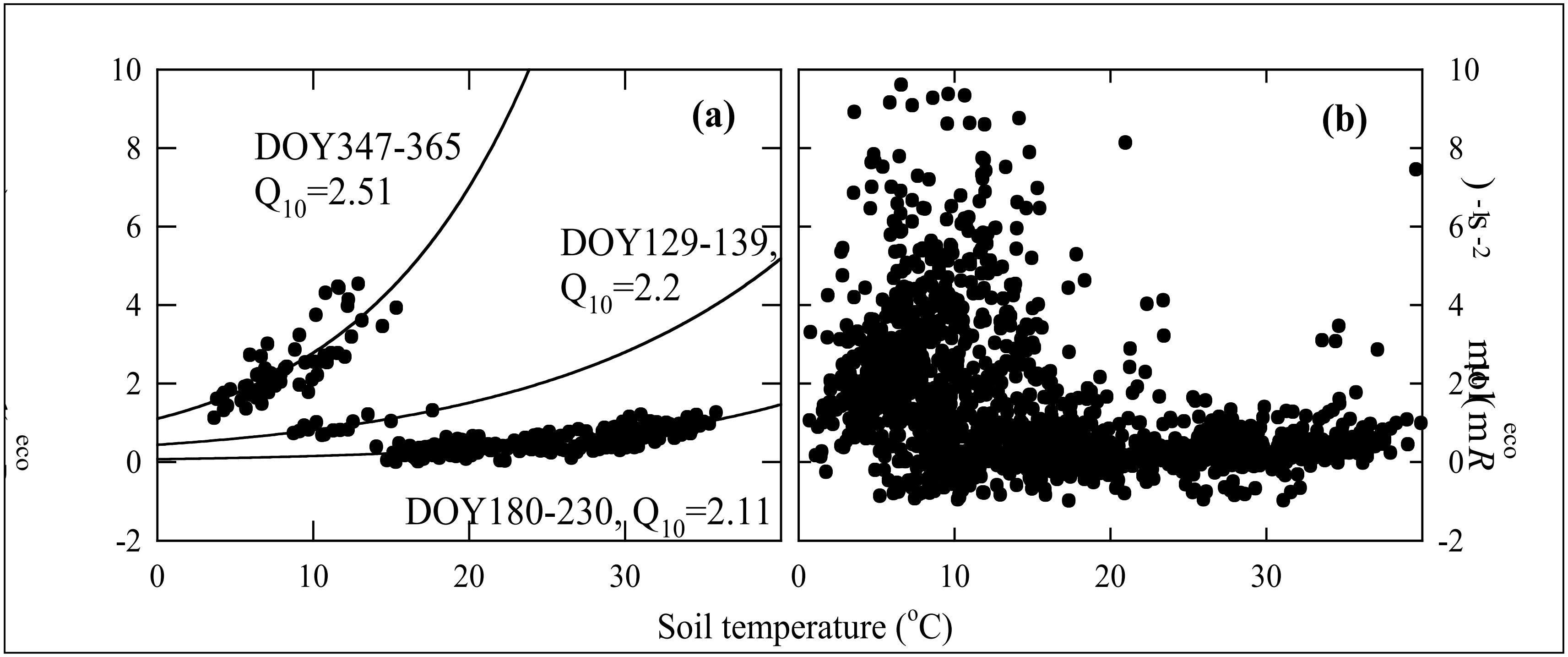
Pasture is a Carbon Source



NEE = +27 gC m^{-2} y^{-1}, 2008

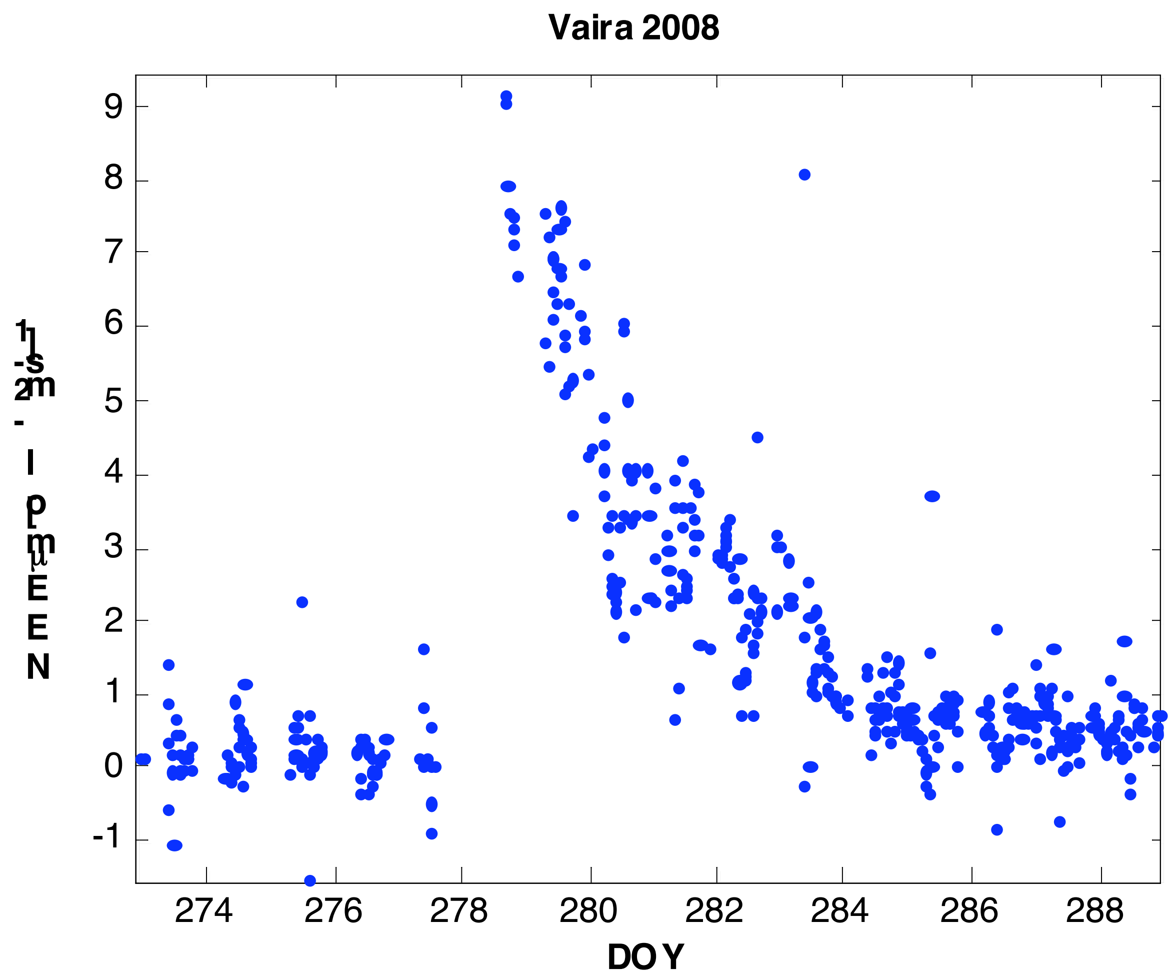
NEE = +82 gC m^{-2} y^{-1}, April, 2007-April ,2008

Ecosystem Respiration scales with Temperature and ???

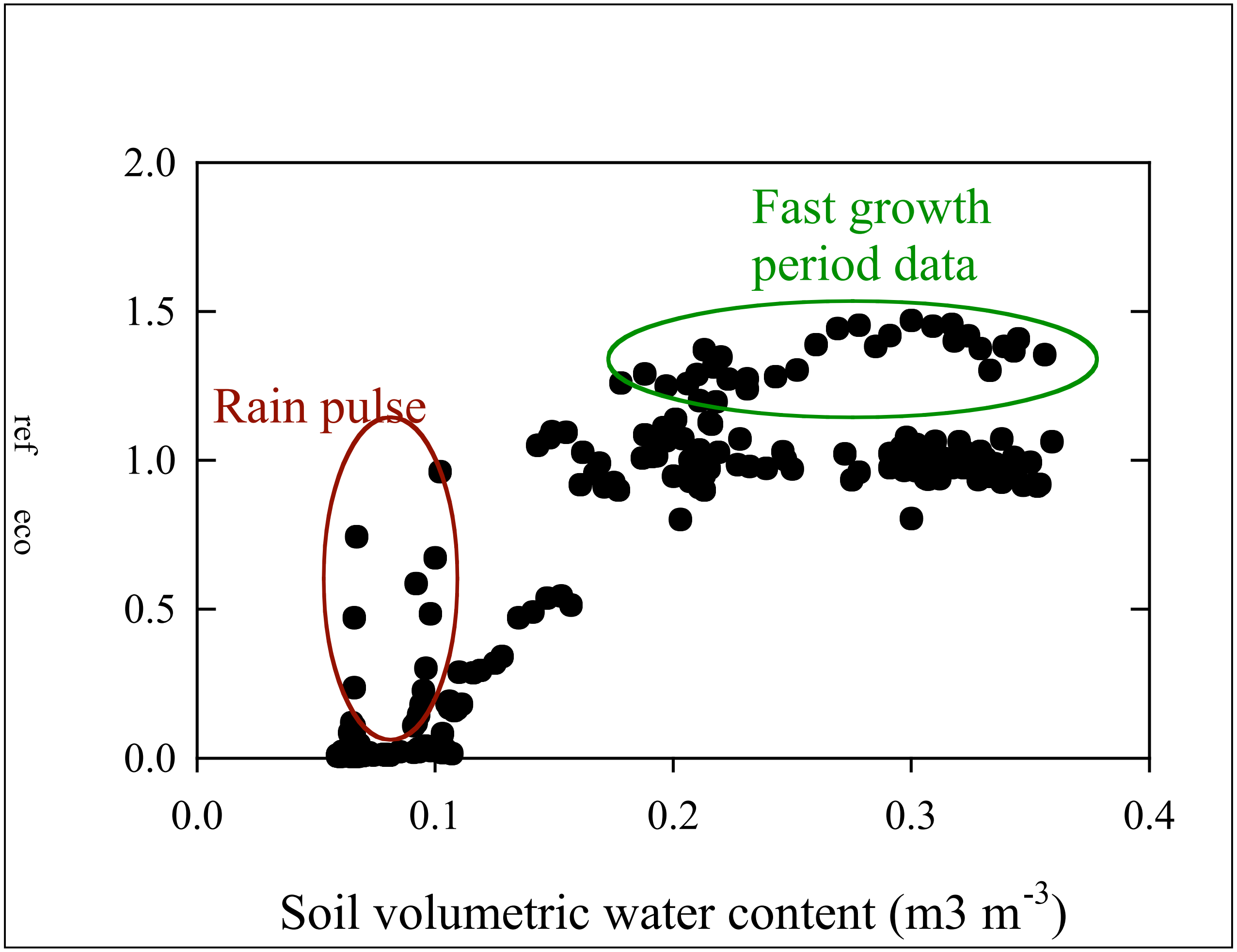


Xu + Baldocchi, AgForMet 2004

Sustained and Elevated Respiration after Fall Rain

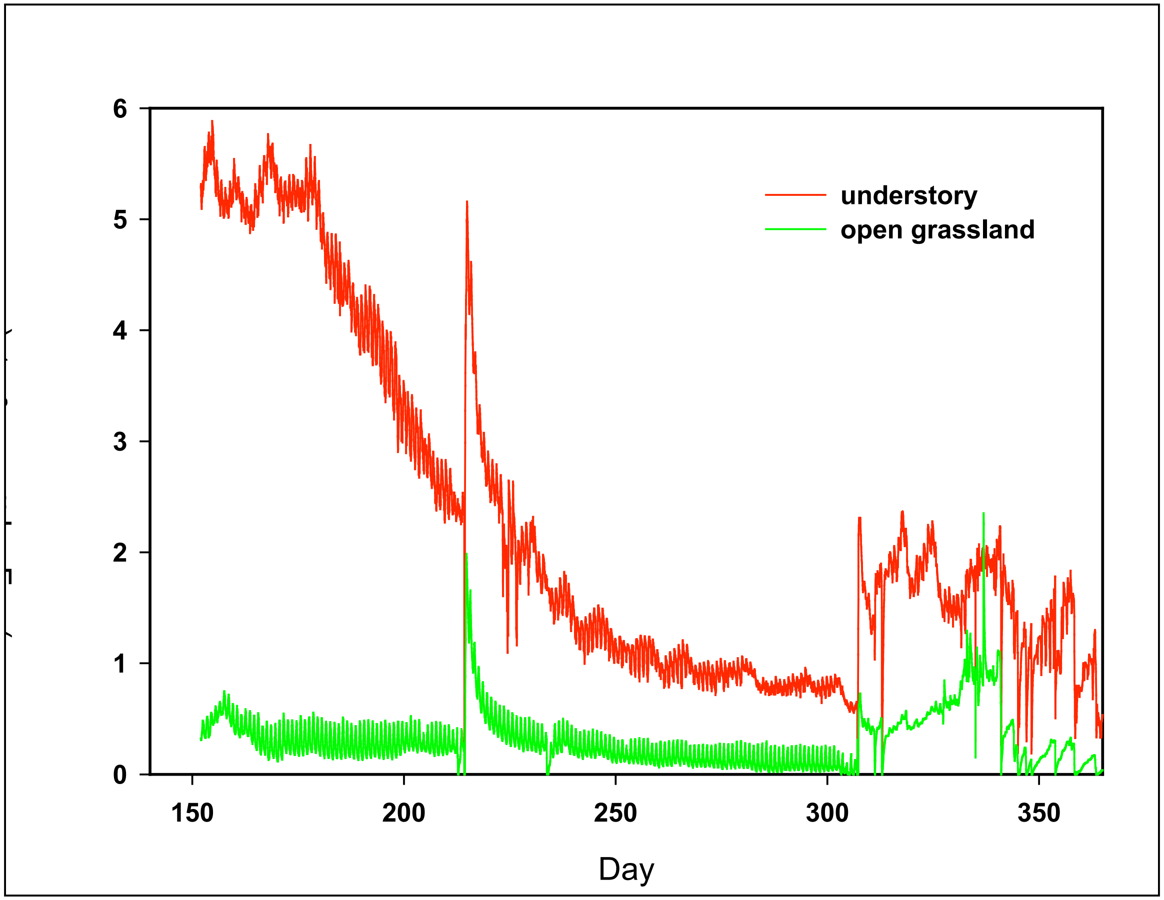


Controls on Ecosystem Respiration of the Grassland:
Soil Moisture, Phenology (reproduction), Temperature and Rain Pulses



Xu + Baldocchi, AgForMet 2004

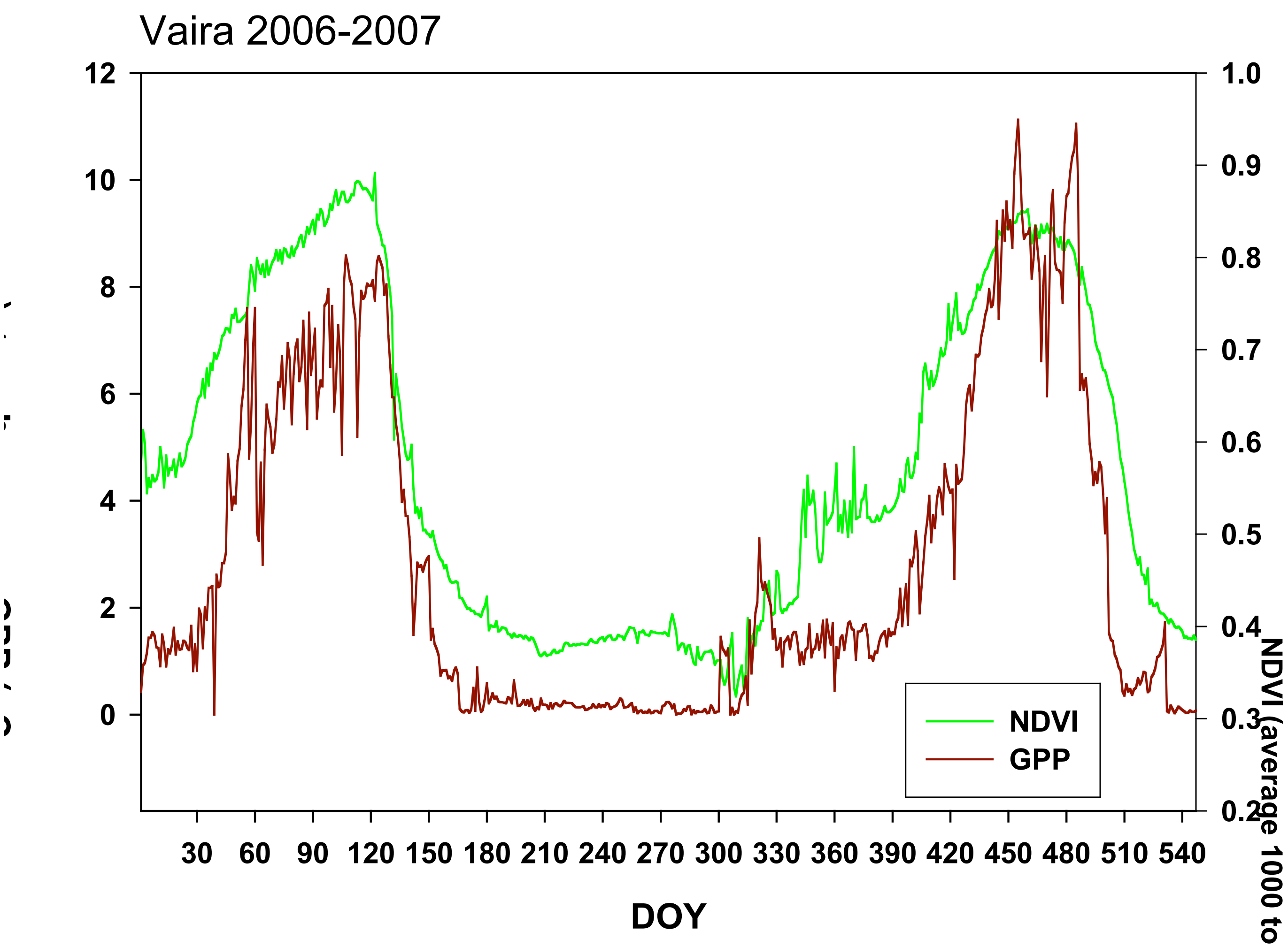
Impacts of Photosynthesis and rain pulse on ecosystem respiration of the Oak Woodland



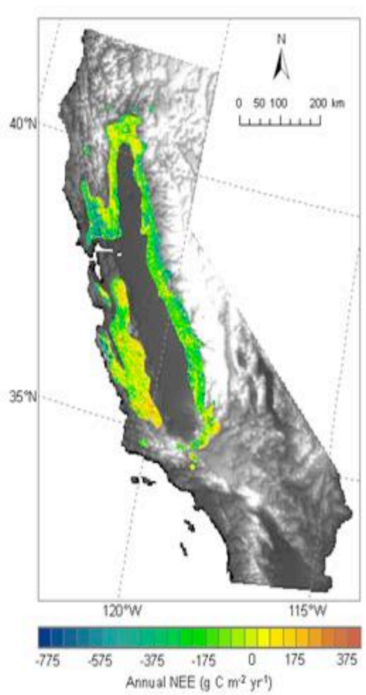
Baldocchi et al, JGR, Biogeosciences, 2006

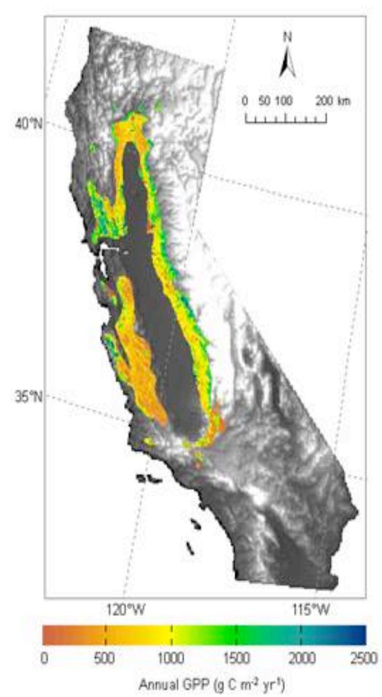
Remote Sensing of Canopy Structure and NPP

Canopy Photosynthesis Follows changes in Canopy Structure



Upscale GPP and NEE to the Biome Scale





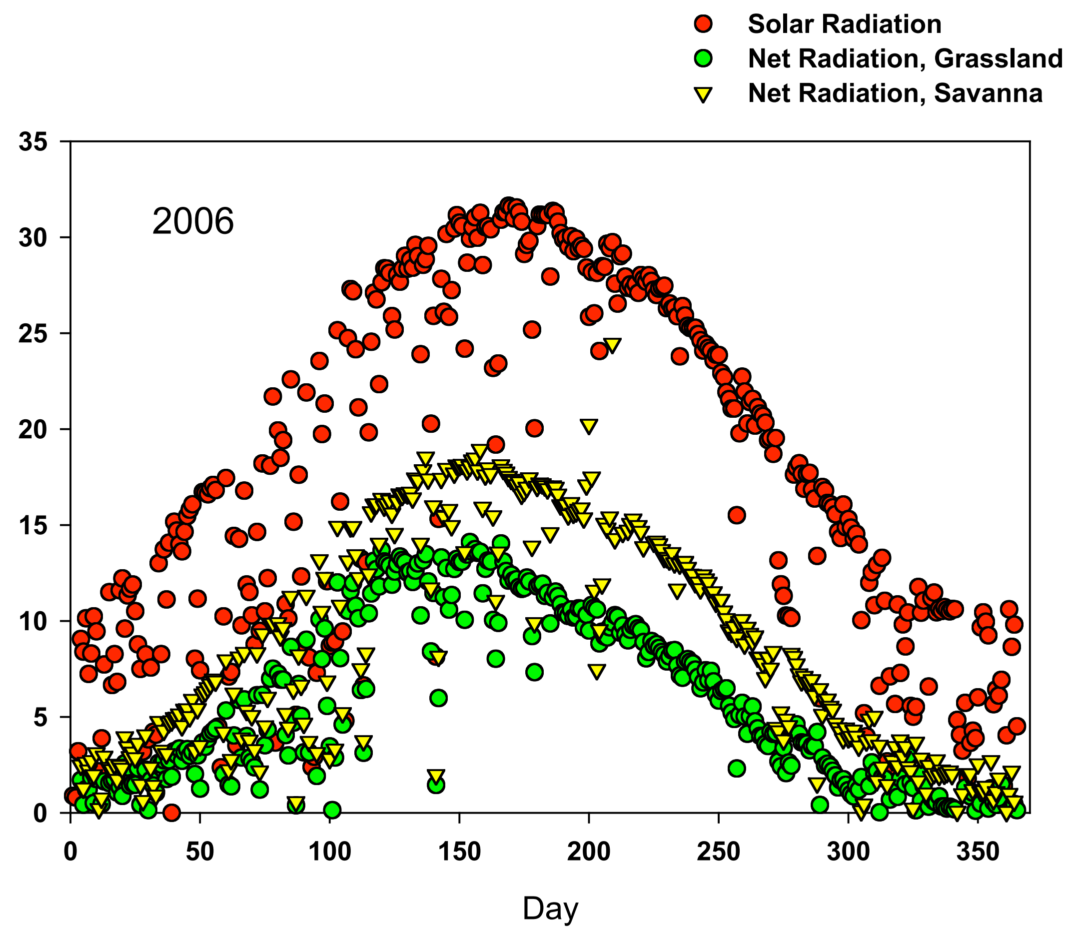
area-averaged fluxes of *NEE* and *GPP* were -150 and 932 gC m^{-2} y^{-1}

net and gross carbon fluxes equal -8.6 and 53.8 TgC y^{-1}

Jingfeng Xiao and D Baldocchi

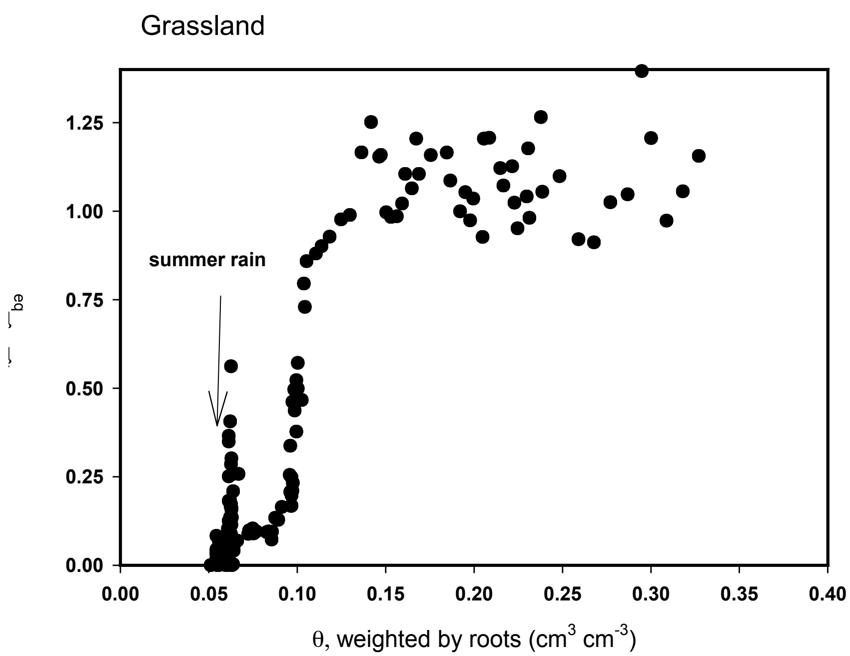
Energy, Water and Evaporation

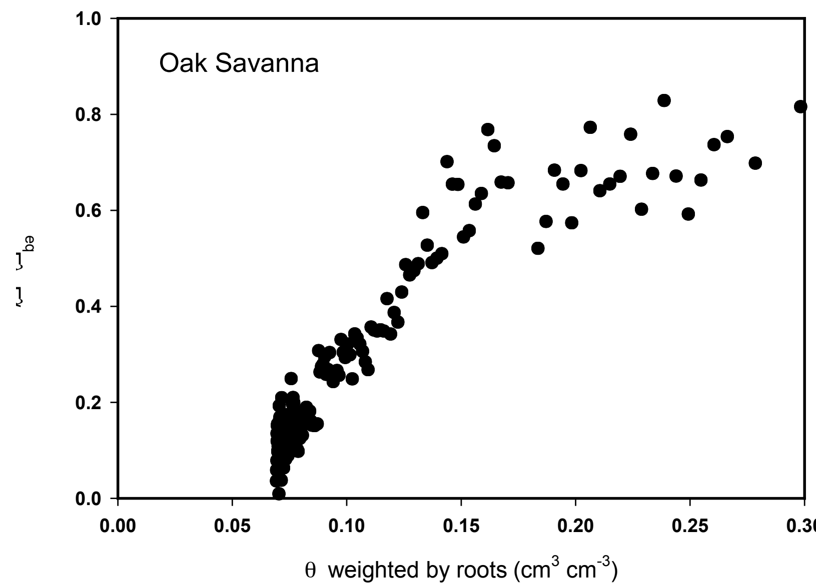
Case Study:
Savanna Woodland adjacent to Grassland



1. Savanna absorbs much more Radiation (3.18 GJ m^{-2} y^{-1}) than the Grassland (2.28 GJ m^{-2} y^{-1}) ; dRn: 28.4 W m^{-2}

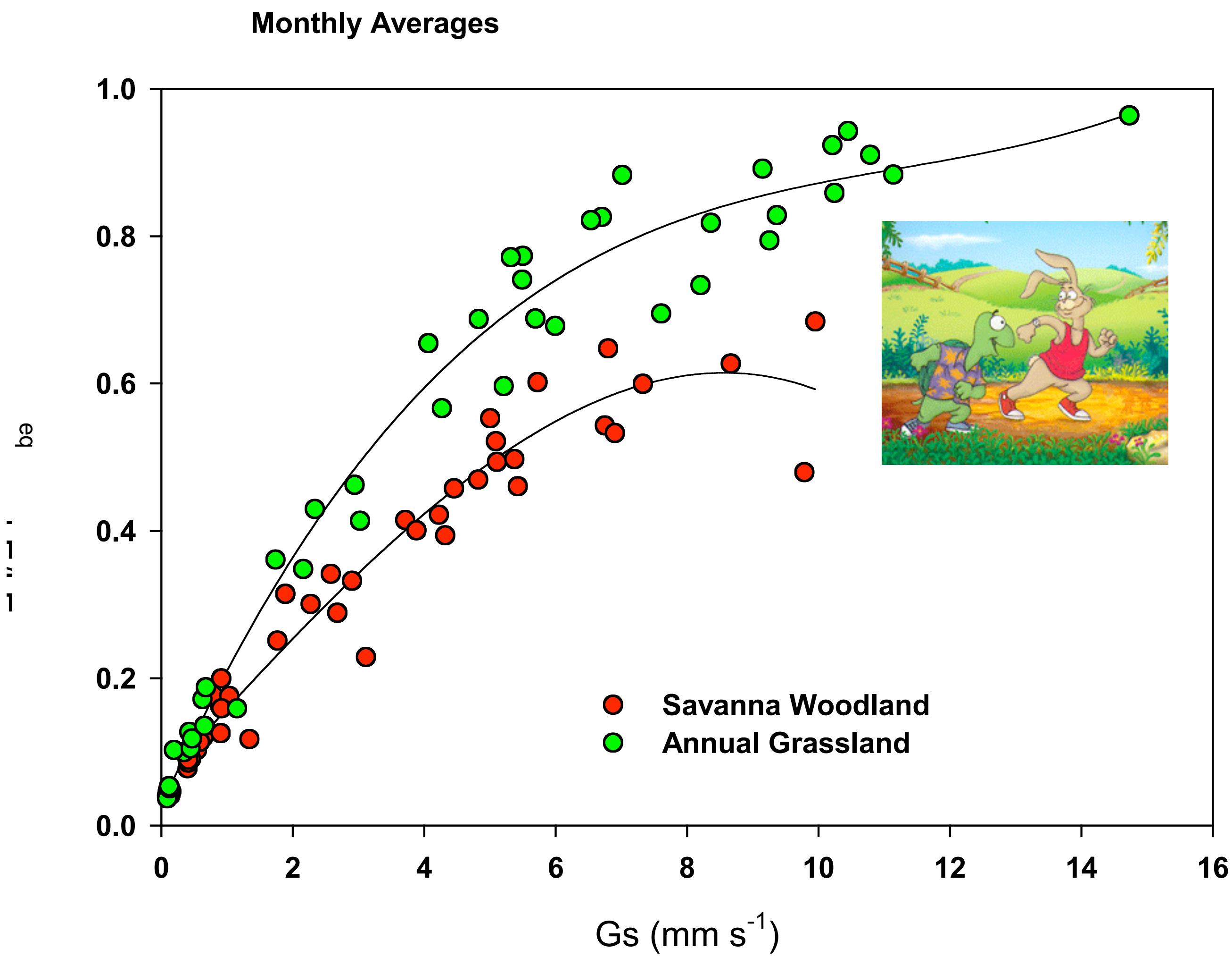
ET and Soil Water Deficits: Root-Weighted Soil Moisture





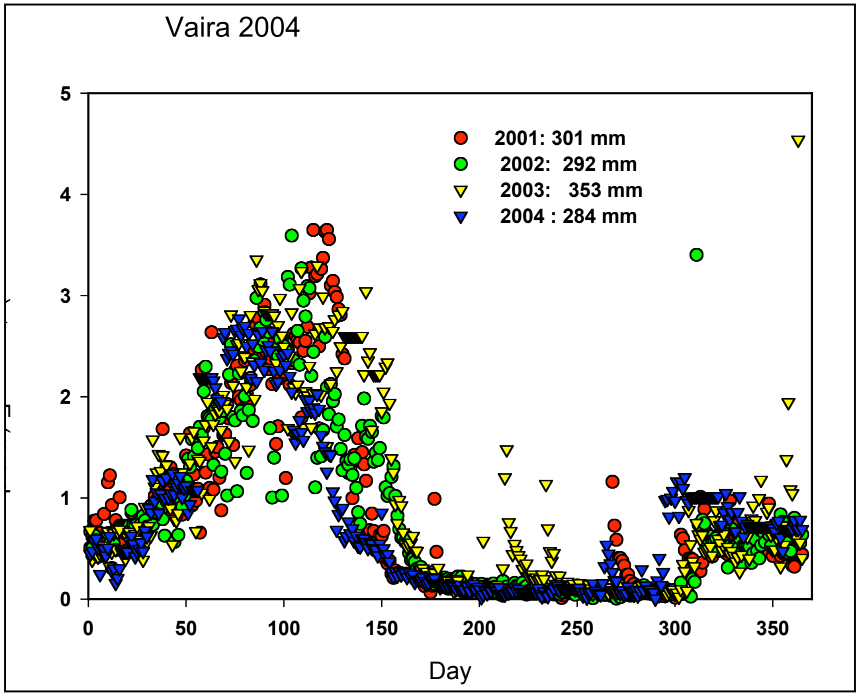
Baldocchi et al., 2004 AgForMet

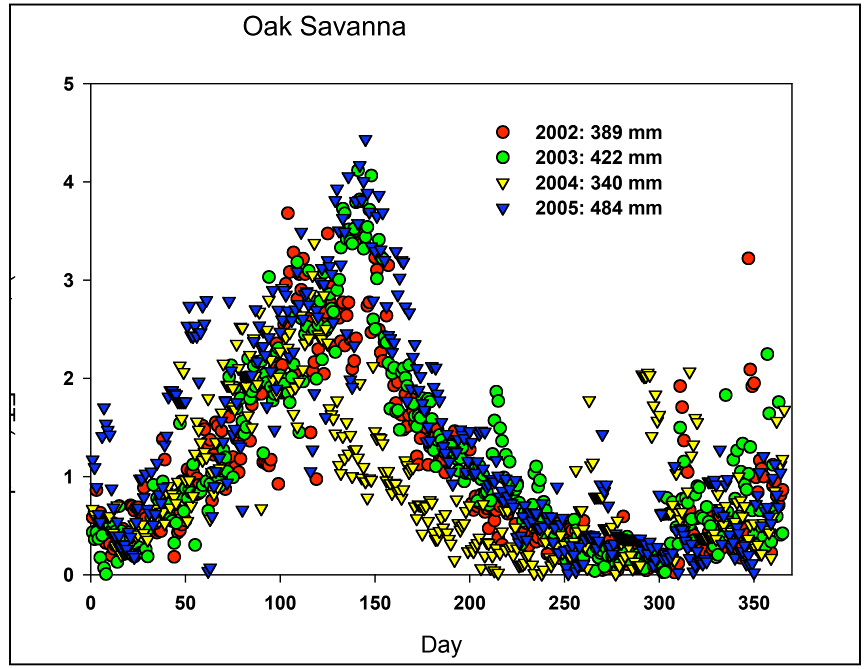
Landscape Differences
On Short Time Scales, Grass ET > Forest ET



Ryu, Baldocchi, Ma and Hehn, JGR-Atmos, submitted

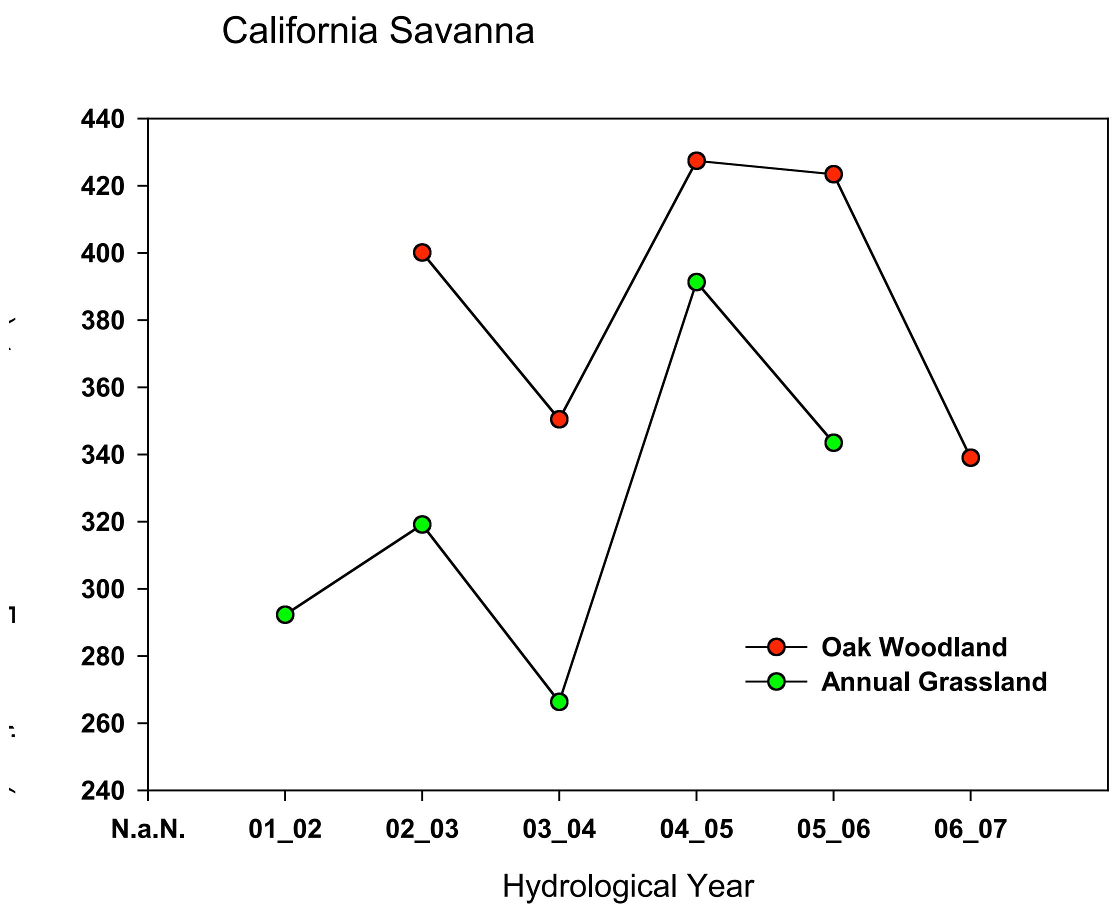
Annual ET and Interannual Variation





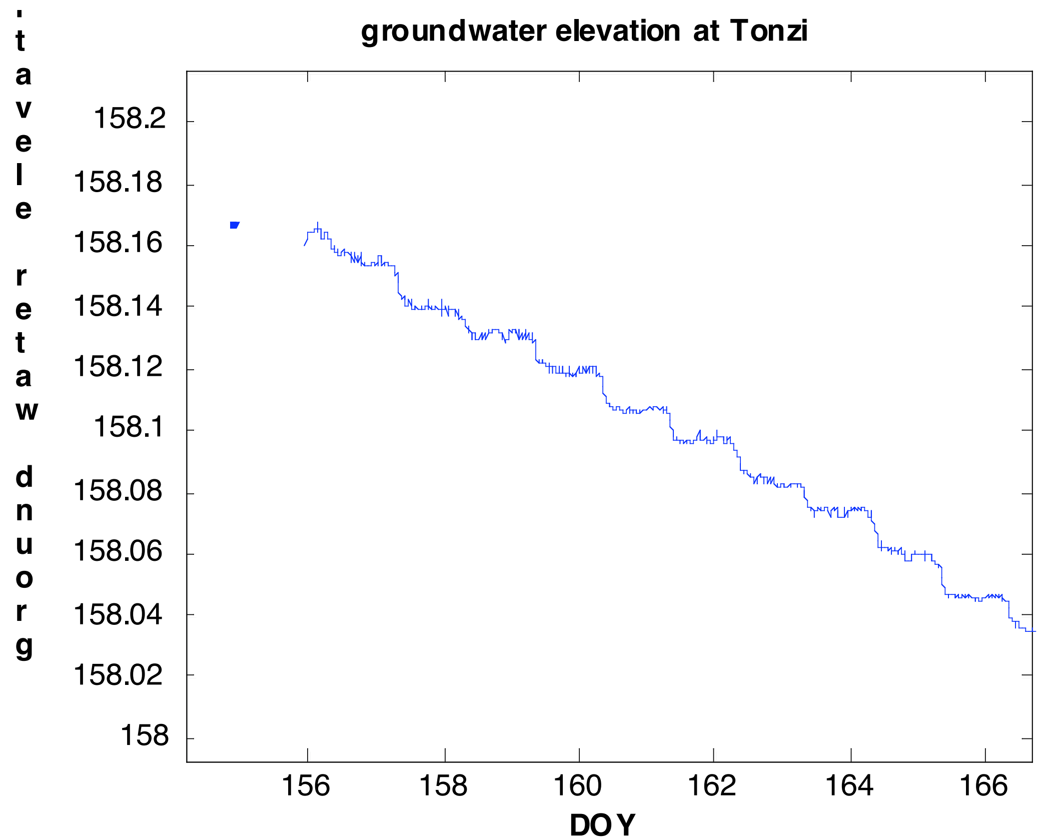
Savanna Soil Stores about 80 mm water and uses that much extra to sustain a sparse woodland, over a grassland

Role of Land Use on ET:
Annual Oak ET (400 +/-35 mm/y) > Grass ET (322 +/-48 mm/y)



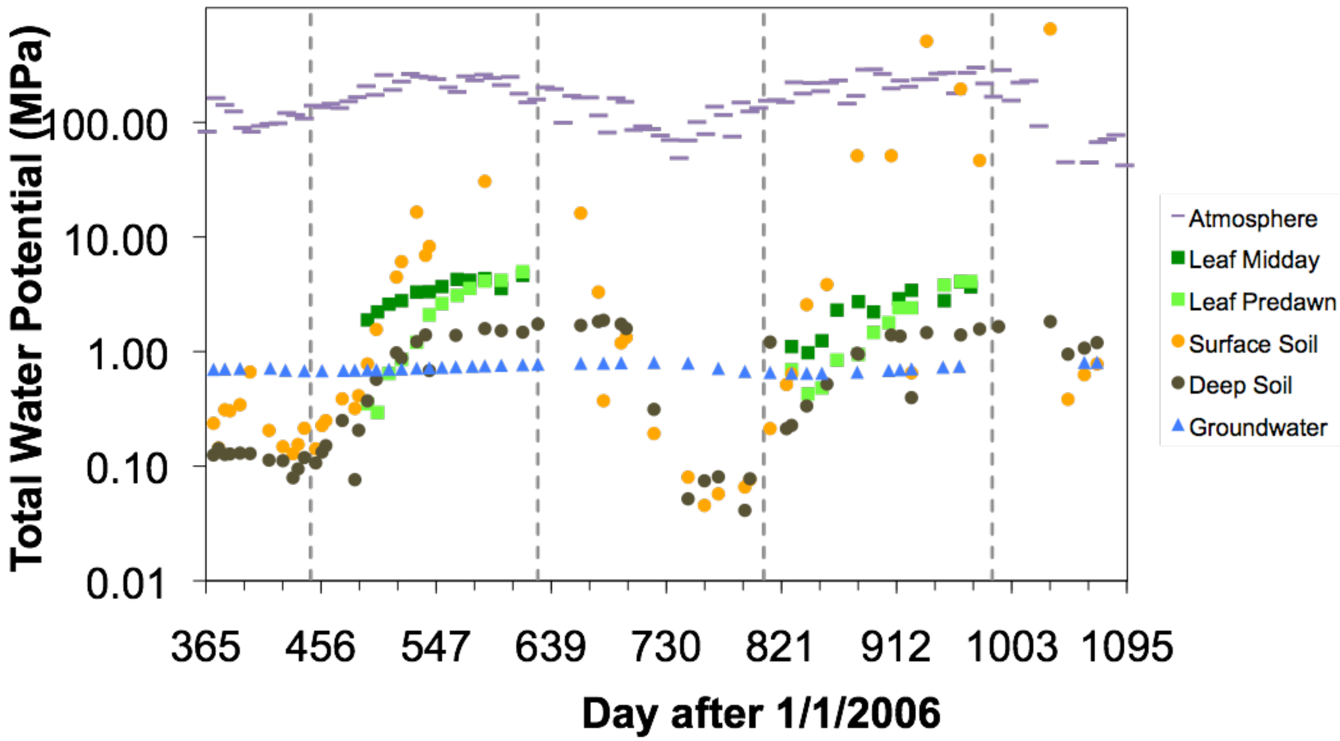
Ryu, Baldocchi, Ma and Hehn, JGR-Atmos, 2008

Oak Trees Tap Ground Water



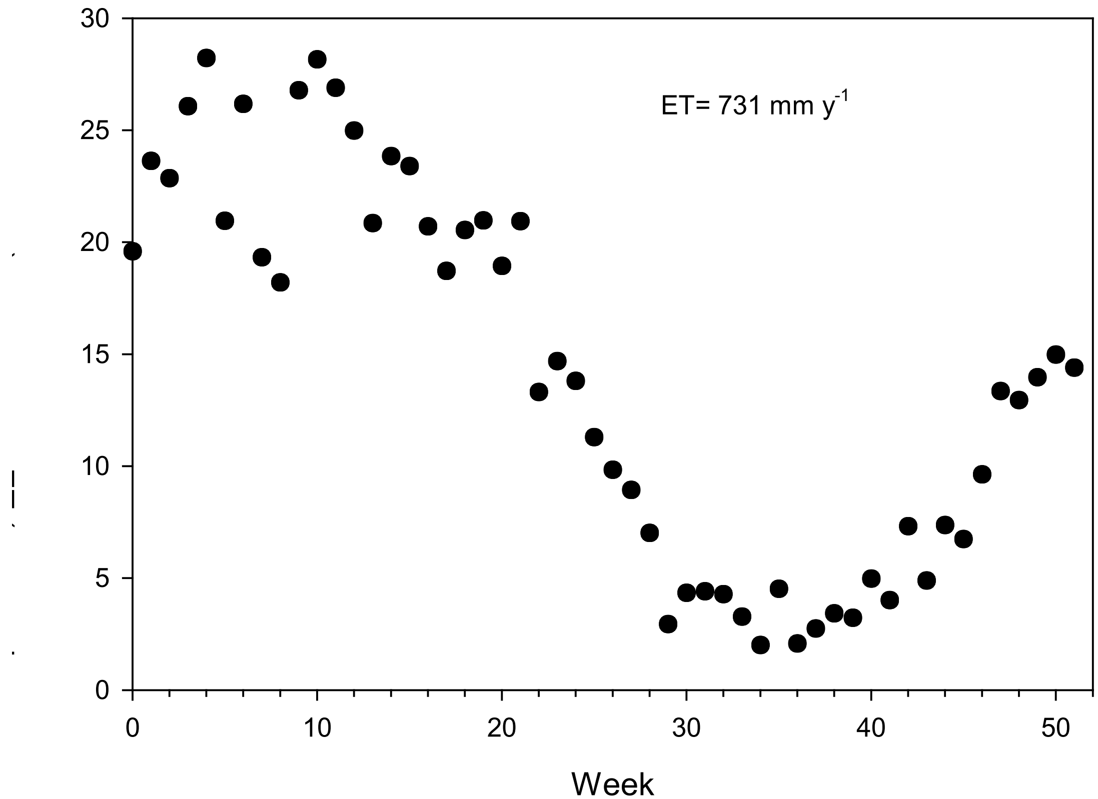
G. Miller, Y. Rubin, D. Baldocchi unpublished data

Evidence of Trees Tapping Ground Water

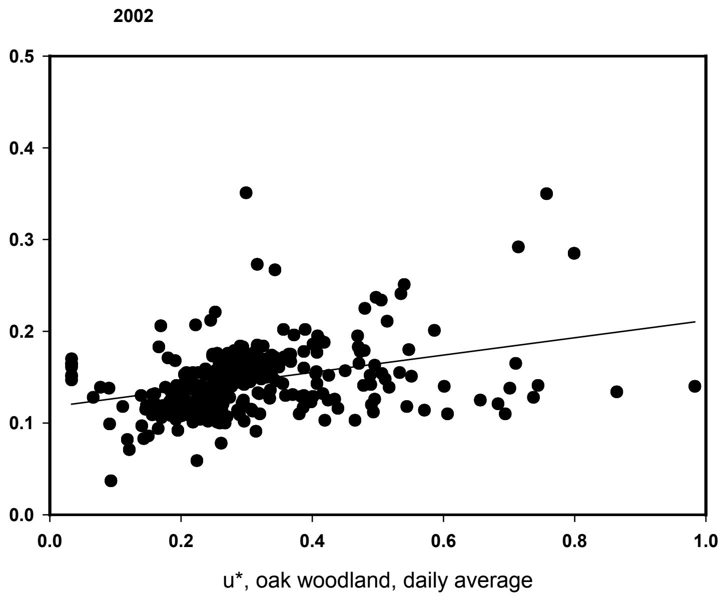


G. Miller 2009, PhD Dissertation

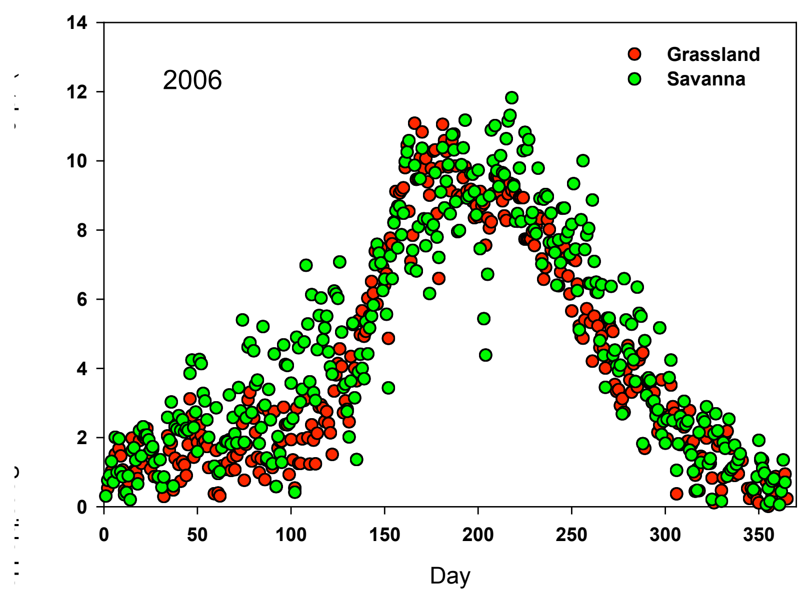
Sherman Island Peatland Pasture, April 2007-2008

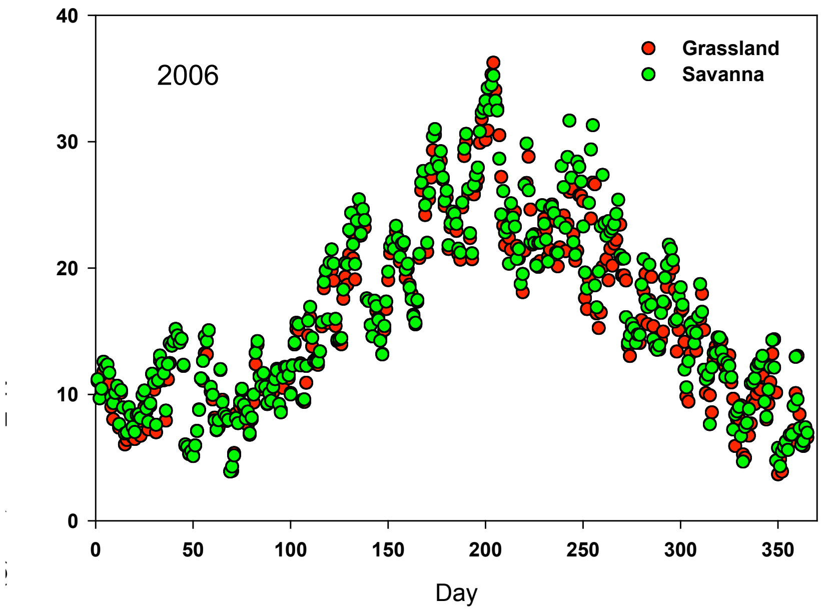


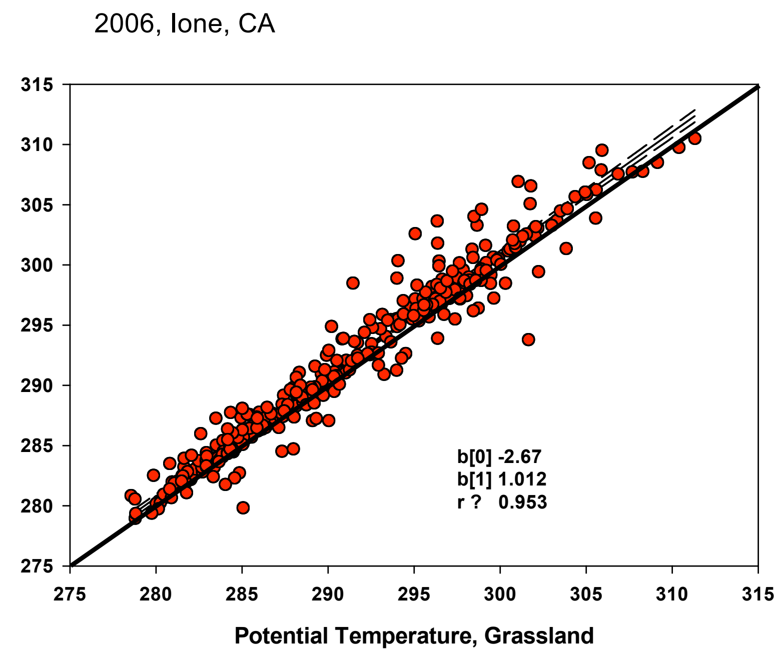
4a. U* of tall, rough Savanna > short, smooth Grassland



4b. Savanna injects more **Sensible Heat** into the atmosphere because it has more **Available Energy** and it is **Aerodynamically Rougher**



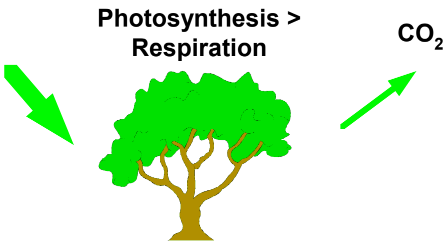


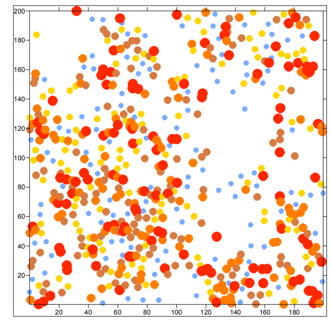


5. Mean **Potential Temperature** differences are relatively small (0.84 C; grass: 290.72 vs savanna: 291.56 K); despite large differences in Energy Fluxes--albeit the **Darker** vegetation is **Warmer**

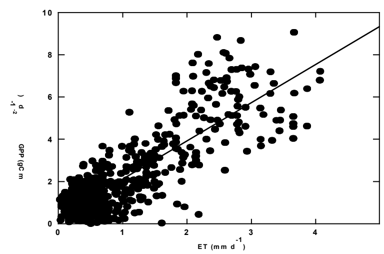
Compare to Greenhouse Sensitivity ~2-4 K/(4 W m^{-2})

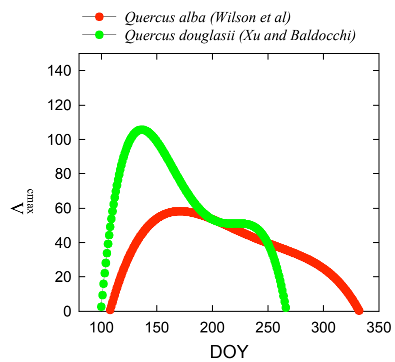
Synthesis/Conclusions



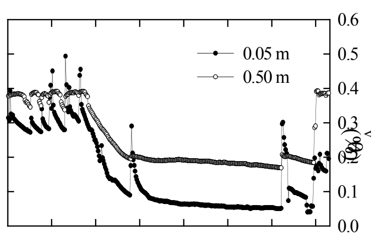


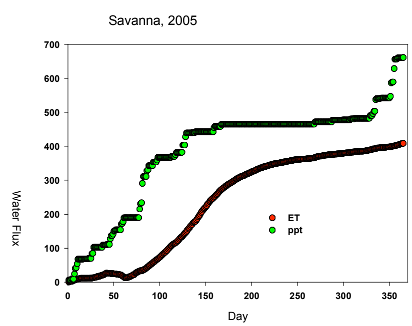
At Ecosystem scale Leaf Area is limited enabling the Sparse Canopy to Reduce ET, too

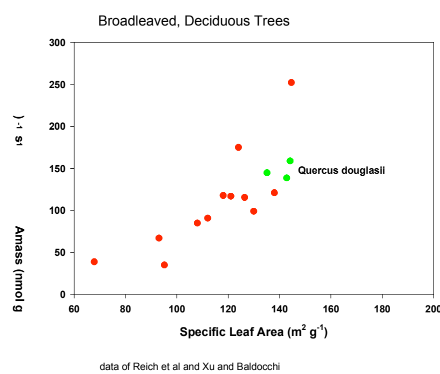




Ps Capacity must be Great, For Short Period to Facilitate high rates of photosynthesis







Leaf N and Leaf Thickness must be adequate to support Ps Machinery

Conclusions

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- Year to year variability in Carbon Uptake is due to length of wet season.
  - Oaks are risk adverse and experience less inter-annual variability in NEE than grasslands
- Photosynthesis and Respiration are tightly linked
  - Oaks need high N levels to attain sufficient rates of carbon assimilation for the short growing season
- Savanna woodlands need about 80 mm more water to function than nearby grasslands
  - Trees tap ground-water to sustain themselves during the summer
- Oaks are darker and warmer than grasslands

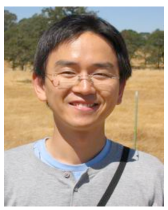
Questions

- How would you use these data to make land mgt Decisions?
  - Are you compelled to cut-trees for grass, to save water and cool the climate?
    - What about Topography and the role of trees to maintain soils and serve as habitat
  - Encourage trees on grasslands to sequester carbon?
    - Do you have enough rain?
  - Should Delta Peatland Pastures revert back to tules and wetlands?
    - What about methane emissions (20x CO_2), mosquitoes and water quality?

Biometeorology Team

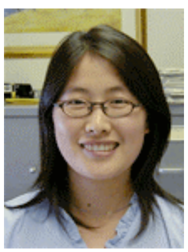


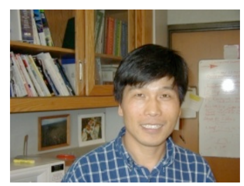








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Berkeley Faculty Roundtable on Environmental Services in Rangeland Production Systems

Part II:
Discussion

Notes compiled and synthesized by Kayje Booker, Roundtable GSR

Berkeley Faculty Roundtable on Environmental Services in Rangeland Production Systems

I. Issues and questions in response to Dennis' presentation:

- To sum up, erosion, water, and carbon sequestration all involve trade-offs between them
- Can you clarify the discussion about albedo?
  - Heat given of by trees in an oak woodland system probably outweighs their role as a carbon sink. This is different in tropical rainforests because they make clouds.
- The flux towers only work on very flat ground, but slope affects decomposition rates, so how do you upscale?
  - Need to correlate with lots of data from other sources.
- You show that there are about 100g/acre of C on woodlands. How much is in vegetation and how much in soil?
  - This has not been fully worked out yet.
- What is the relationship between research discussed in 1st Roundtable (Dr. Whendee Silver) and 2nd Roundtable (Dr. Dennis Baldocchi)?
  - Dennis is studying ecosystem/atmosphere exchange. Whendee is studying soil and vegetation composition to understand mechanistically where carbon is going. Their research complements each other. For example, at a site in the Bay Delta, he has a tower, and she has ground level tests. At this site, Dennis' research looks at how much methane is being released into the atmosphere, while Whendee looks at the mechanisms that control that release.
- How does precipitation fit in for determining or correlating with fluxes and pools of C?
  - Precipitation is not a good predictor of carbon pools, but it can be a good predictor at the ecosystem scale of plant/soil carbon flux. In Whendee's work, drought and late precipitation had a strong influence on fluxes, so if climate change alters precipitation patters, the fluxes may change.

II. Broader discussion of global warming and oak woodlands

Most of the broader discussion centered around the three broad themes: the potential scale of carbon sequestration in oak woodlands (as relevant to both concerns of global warming and payments to landowners), forest management for carbon sequestration, and fire effects on permanence of carbon sequestration.

A. Scale of carbon sequestration in oak woodlands:

- Under current conditions, although oak woodlands have a large carbon pool, they are not increasing that pool by much each year. Population growth and economic growth will swamp the modest mitigation provided through biological sequestration. Therefore, the more important information and research from these flux monitors may be on water exchange.
- But even if the carbon storage is a small amount globally, it can still make money for people. That is, even if storing carbon in oak woodlands does not contribute very much to global warming mitigation, it may matter to landowners in oak woodlands because they stand to make money from it.
- It could also make a difference globally. If you add up soil carbon sequestration, even if it is just 1 ton per year over ½ of California (rangelands cover ~ half the state) that offsets emissions from both electricity and industry in the state. It adds up, even if the amount of land per acre is small, because we are talking about a lot of land.

- Soil carbon also makes sense for other reasons. It has positive effects on production, sustainability, and water.
  - Dennis – the impact is flux times area, so a big flux over a small area or a small flux over large area can each have an impact.
- But there is evidence that rangelands are losing carbon worldwide. What if they turn out to be a source rather than a sink, especially under changing climate conditions?
- Is the general question whether these measures actually achieve mitigation or whether there is room for generating offsets (and, therefore, money for landowners)?
  - The question addressed by the roundtable is the role of rangelands in mitigating global warming. Within that, a key item of interest is how these carbon opportunities might affect landowner and policy decision-making.
    - Rangelands are leftover lands, not highly valued but extensive. They account for about half of earth's land surface, so their very size makes them an important topic of interest for global warming.
    - Landowners on rangelands make about $100/acre for fuel, grazing, etc. Maybe you could get about the same for carbon. That is not a large carbon benefit, but it could keep these extensive lands in production, which will have effects for both global warming and decision-making by landowners and policy-makers.

B. Forest management for carbon sequestration:

- If sequestration by forests is offset by heating effects, why not grow young forests, harvest them, and store them long-term? Some people are against harvesting any trees and want to let them grow (prefer to use metal), but they are ignoring these other effects (such as heat effects of temperate forests).
- There is some evidence that if you harvest trees and use the timber, the turnover time in houses is only about 30 years.
- United Nations has developed protocols for the lifetime of wood in houses: you get a 40% credit for lumber going into houses.
- Winrock has suggested that California should plant and harvest forests (on areas that are currently rangelands or agricultural land) for carbon sequestration, but they are ignoring several things: water dynamics, the fact that rangelands with a woody component could store more than forests, and fire. Carbon in rangelands could be safer because it is in soil, but we are not certain how much soil carbon would be safe from fire and how much would be oxidized.
- Dennis – another consideration with forest planting is that there is a physical limitation to oak density, so you could only increase them so much. Maintaining them is worthwhile because of erosion and other considerations, but increasing their density is more problematic.
  - However, there are places where oaks used to exist and do not anymore, or have been thinned, so you could model, based on physical limits, to find areas where we could increase the density of oak woodlands.
  - But also issues of the hydrological linkage with topography. Water availability shows a lot of variability and would place other limitations on oak planting.
- There is a forest management protocol accepted by the California Air Resources Board that allows storage of wood products, but this question of whether to prefer old versus young forests has people on both sides of the issue. Do you let forests stand for a long time or continually harvest them and plant new ones? It appears that they look about the same (for carbon) if they are managed.

- There is some evidence that frequent harvesting is better, but that may only be true in the near term. Carbon effects (of leaving stand in place versus frequent harvesting for wood products and replanting) appear to even out at about 200 years. That analysis, however, does not include possible benefits of harvested timber products offsetting production of other products which might make harvesting look better.

C. Permanence and fire:

- Very little has been done on fire and soil.
- There is a lot of room for improvement over current protocols in which you basically guess at the chance of fire over 100 years and roughly factor that into calculations.
    - Improving those protocols might not affect the economics of carbon credits because the risk of fire is already taken into account. When you get carbon credits, a reserve is set apart in case of something like fire, and if it happens, you take that money out.
    - But that still matters because your decision-making might change depending on the chance of fire. If you found that the chance of fire was 80%, you might make a different choice than if it was 10%.