Lecture 32

Evaporation and Transpiration Observations, Part 2

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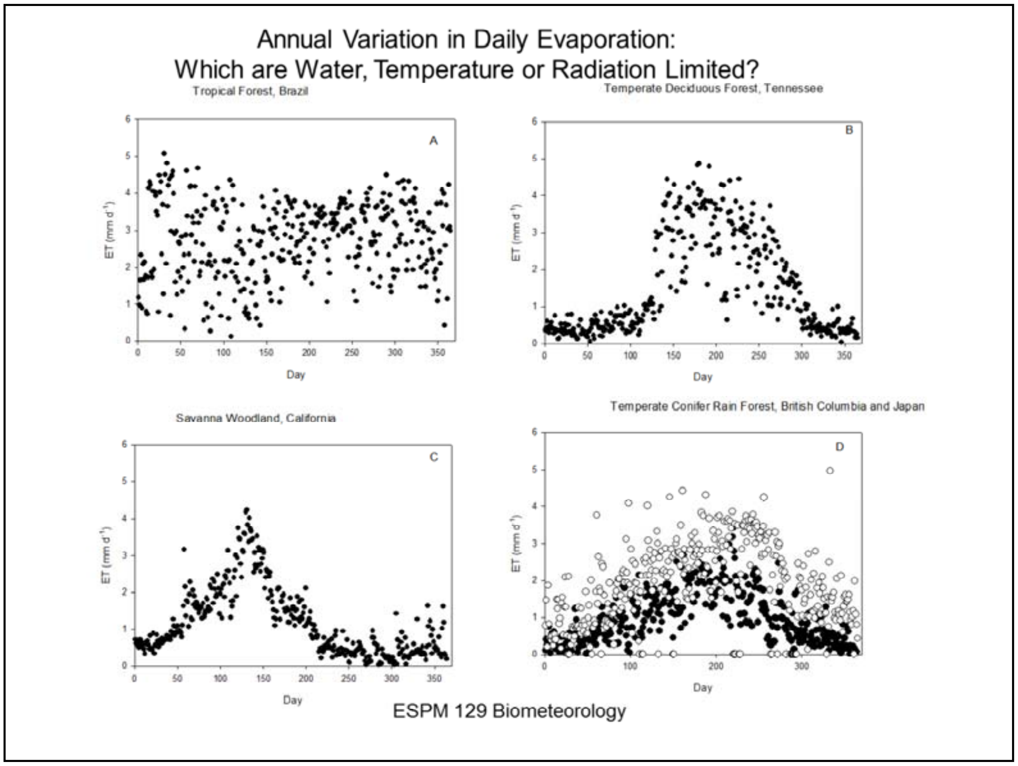
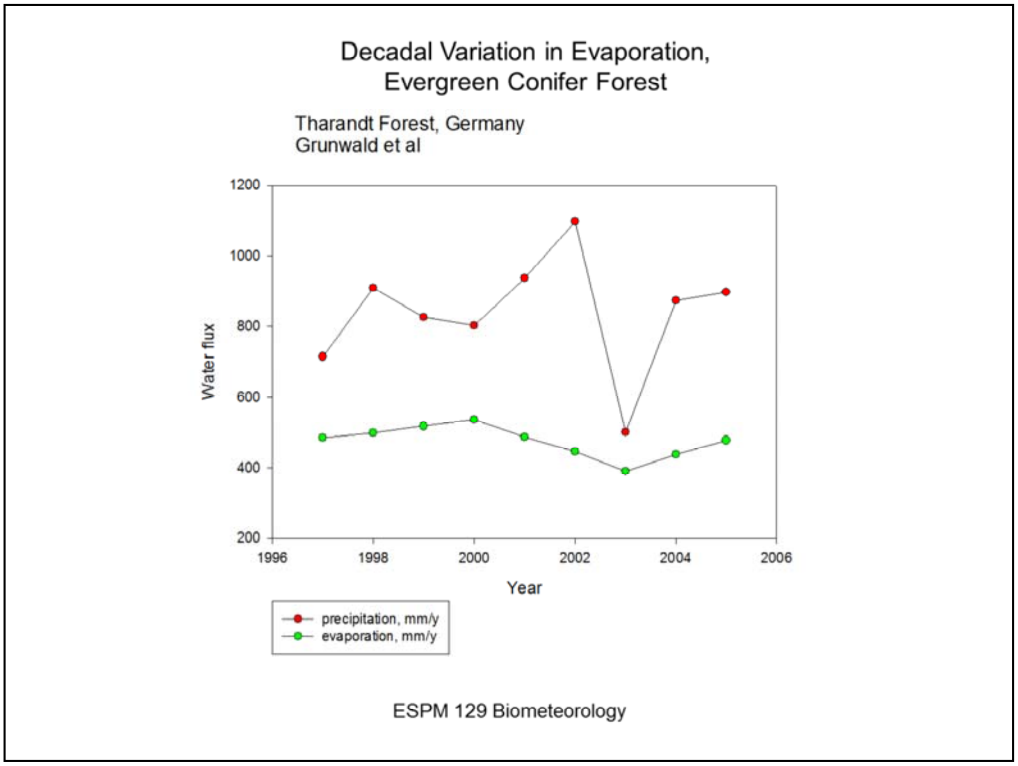
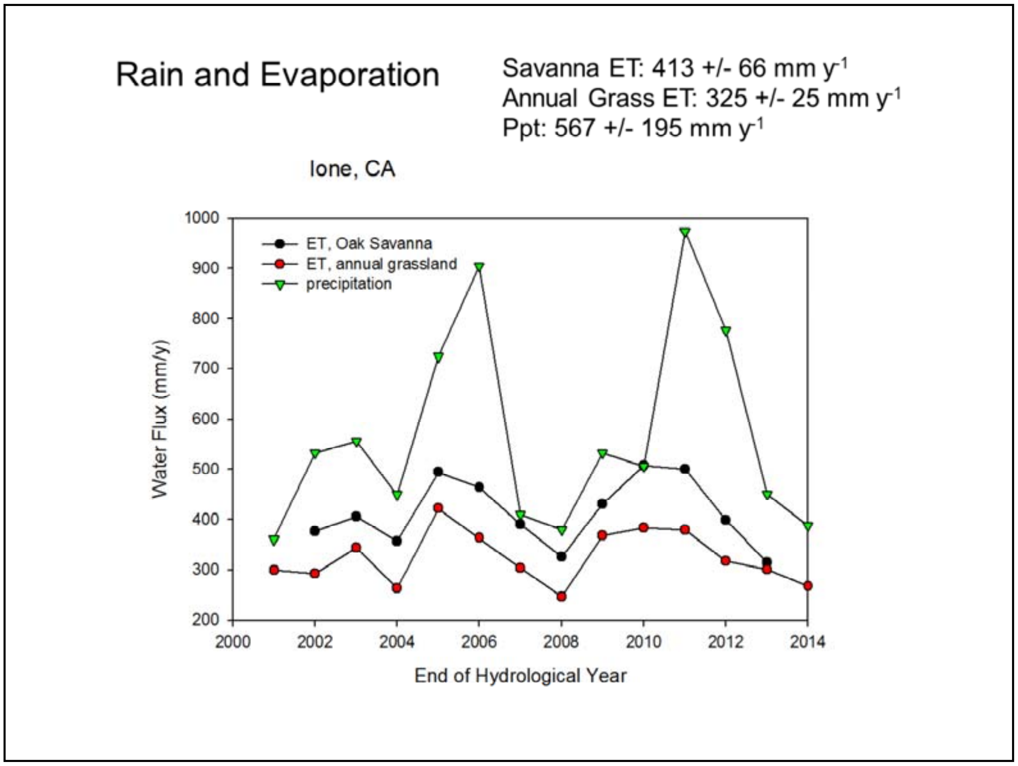
In this part of the lecture we will discuss some of the lessons associated with use of global flux networks and looking across climate and ecological spaces.



Ecosystems have their own signature on the seasonality of evaporation. Some are radiation limited, others are water limited and others temperature limited. Can you tell?

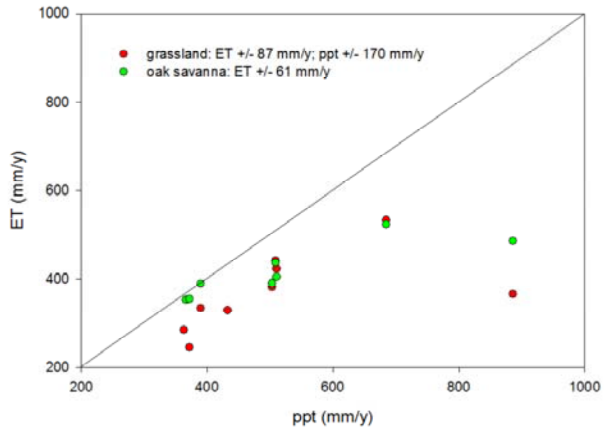


Interannual variability of evaporation of a German evergreen forest is much less than the rain inputs.



We are now in an era where teams are starting to report over a decade of flux data. Here is a comparison for the oak woodland and nearby grassland in California

In Semi-Arid Regions, Most ET is lost as Precipitation



Small Inter-Annual Variability in ET compared to PPT

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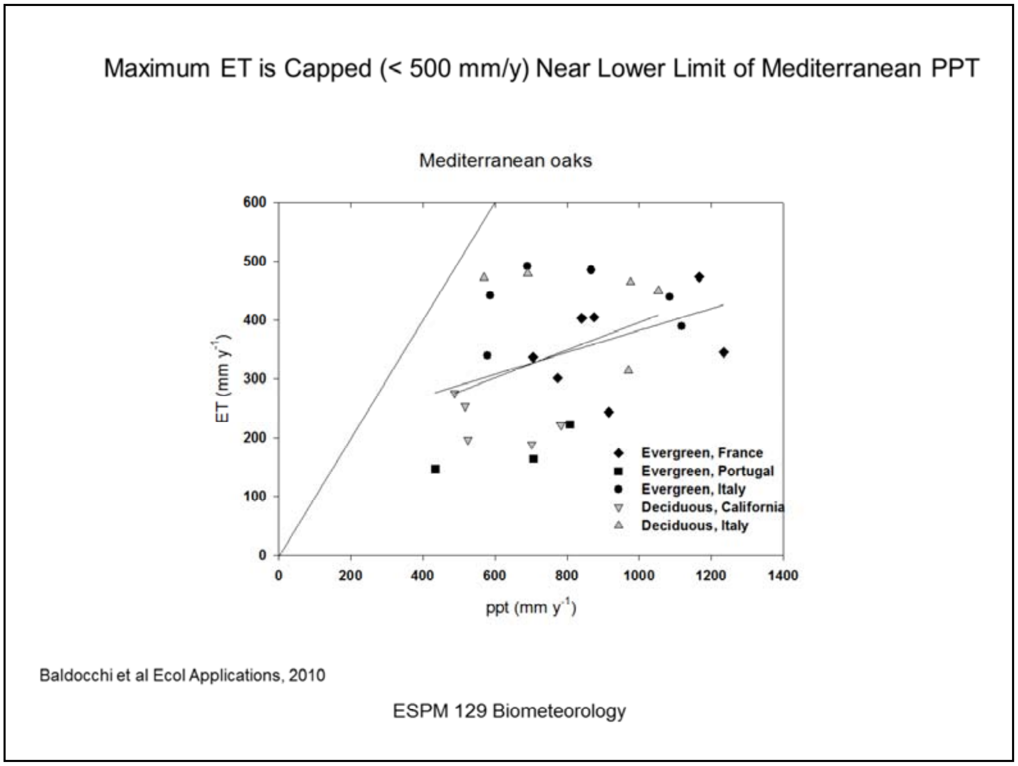
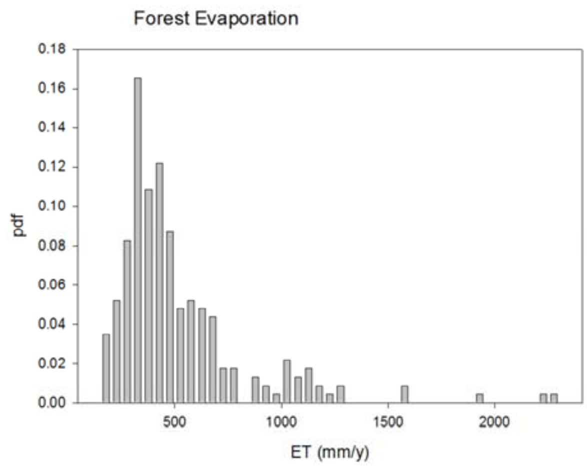


Savanna systems experience frequent and periodic drought. They are well adapted because they limit the amount of vegetation to keep max ET less than about 500 mm. This is a good lesson for humans exploiting our environment. We tend to experience more busts and booms as we set our infrastructure with the more plentiful years and resources and then suffer when there are droughts. Ecosystems may not boom during the wetter years, but they don't bust so much during the dry ones either.



TakeHome Points:

ET > 200 mm/y
Median = 402 mm/y
Skewed Distribution, Max ~ 2300 mm/y

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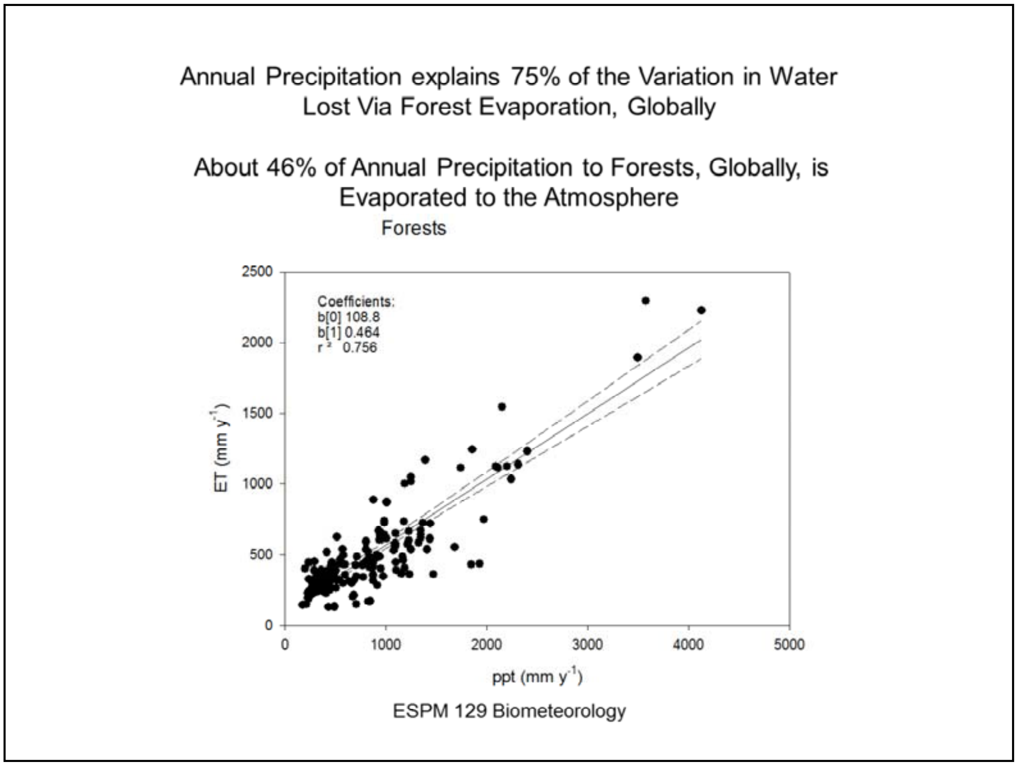
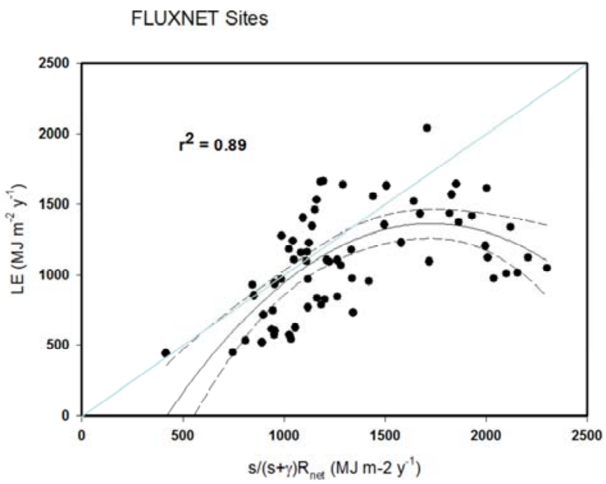
How much water do forests use? On average about 400 mm. They tend to need at least 200 mm to support the photosynthesis that supports woody biomass. Upper limits can reach 2000 m in tropical settings.



Strong linear relation between annual ET and precipitation. Over 75% of the variation in ET is explained by ppt.

Annual Sums of Latent Energy Scales with Equilibrium Energy, in a Saturating Fashion



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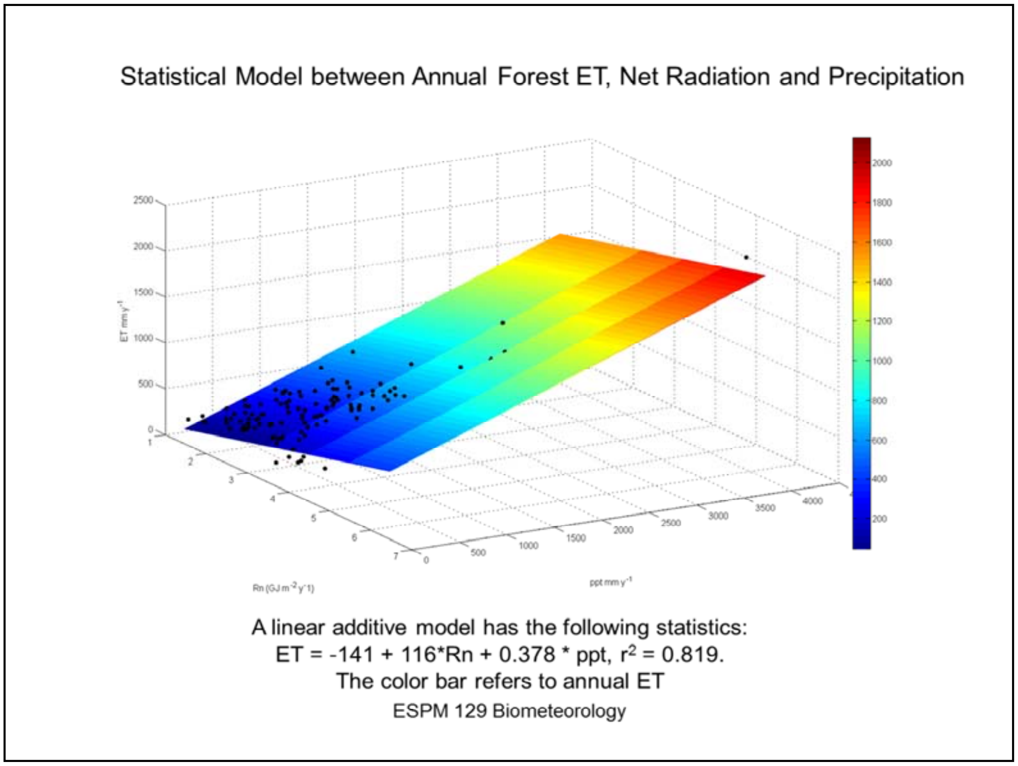
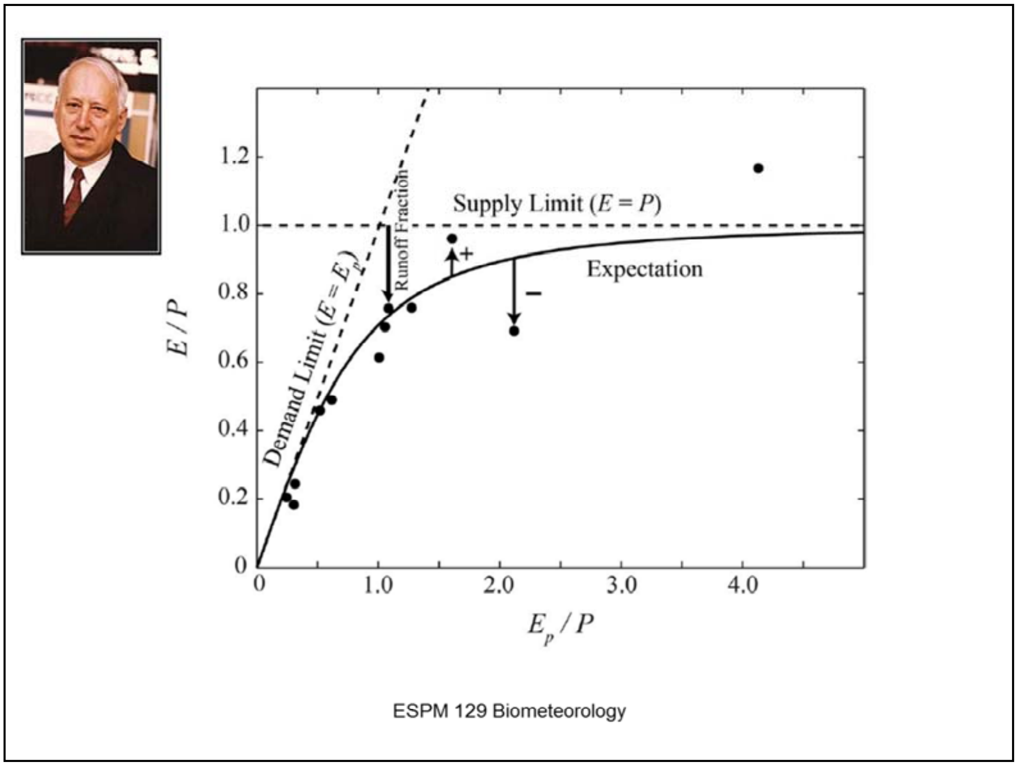
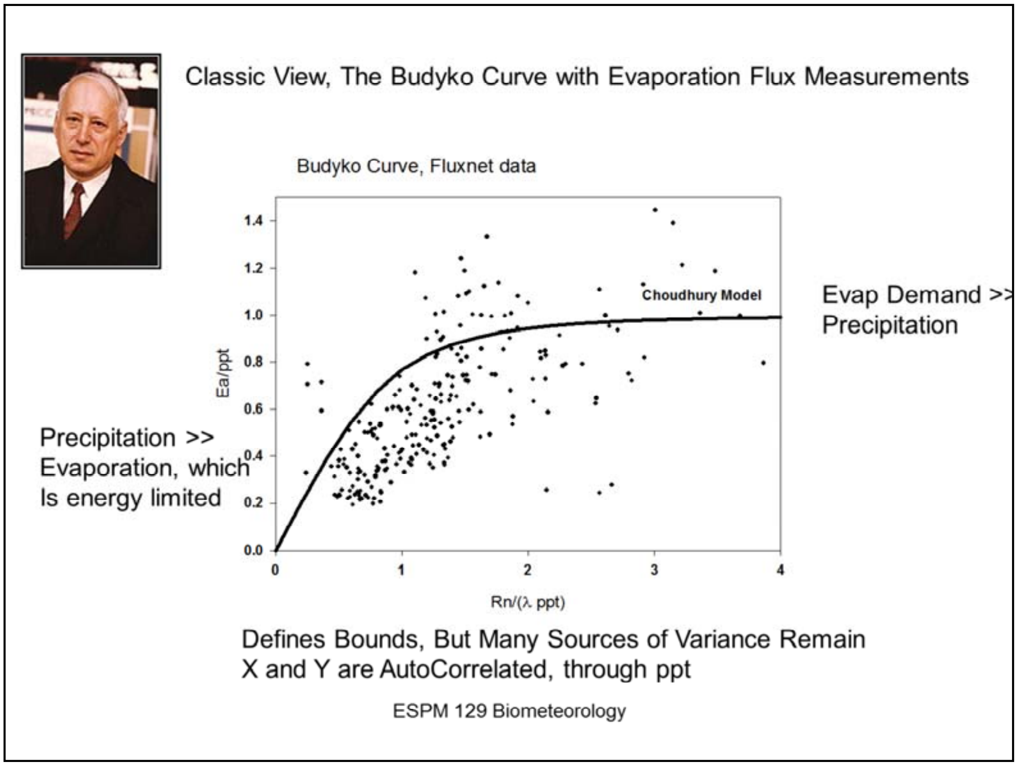
We can also see correspondence between evaporation and equilibrium evaporation, though here it experiences a saturating response.



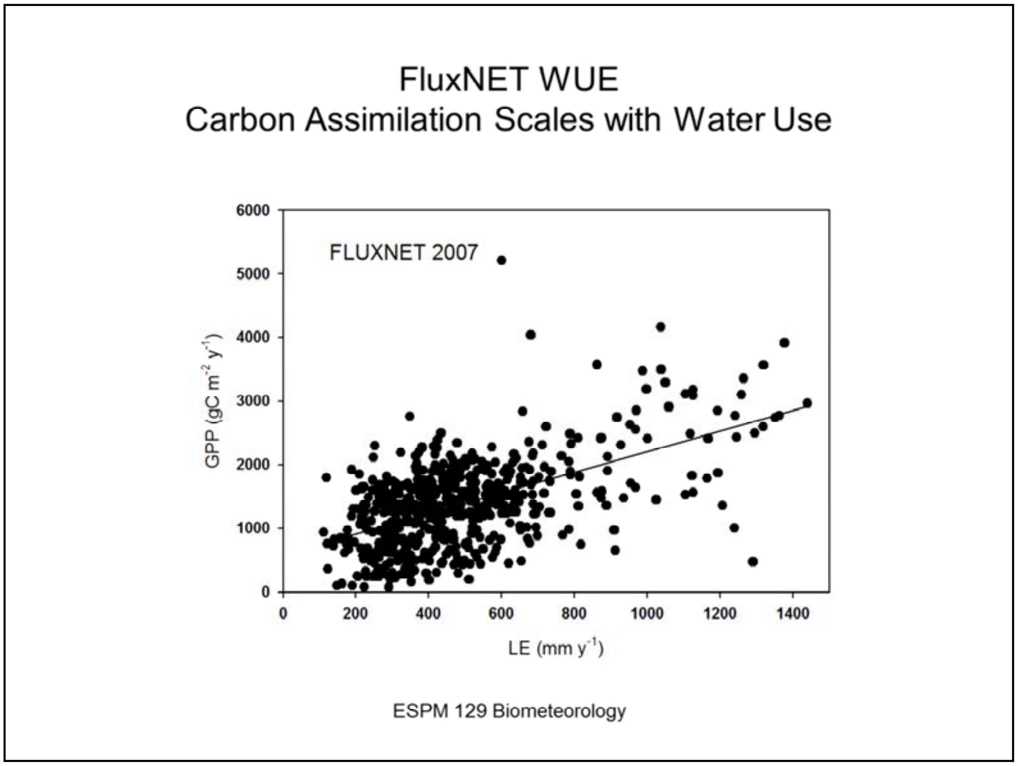
Covary with net radiation and precipitation increases the explanation of variance a bit more.



Budyko Theory Adapted from Williams et al.WRR

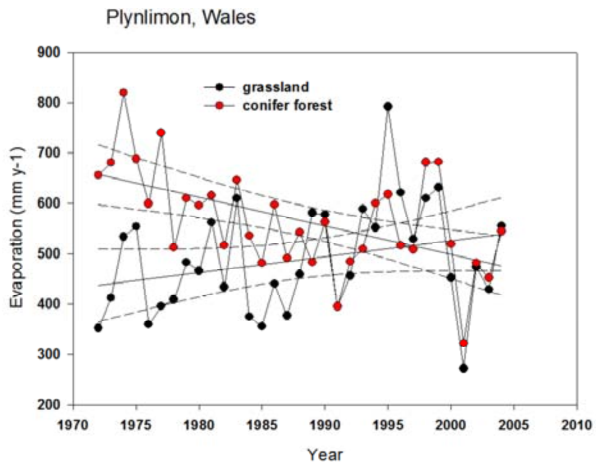


Prior to eddy flux data Budyko developed this theory on how evaporation is limited by energy and rainfall



As we discussed with optimal stomatal conductance theory there is a link between photosynthesis and water use, eg evaporation

Stand Age also affects differences between
ET of forest vs grassland



Marc and Robinson, 2007 HESS

Conventional wisdom was that there was greater water yield by deforestation. Some of the key data came from gauged watersheds in Wales. Yet it is really important to take long term measurements because ecosystems operate on long time scales. What they discovered after 20 years is that there was a switch in the comparison. With time the grassland became a greater evaporator of water than the forest.

Does Biodiversity affect Evaporation?

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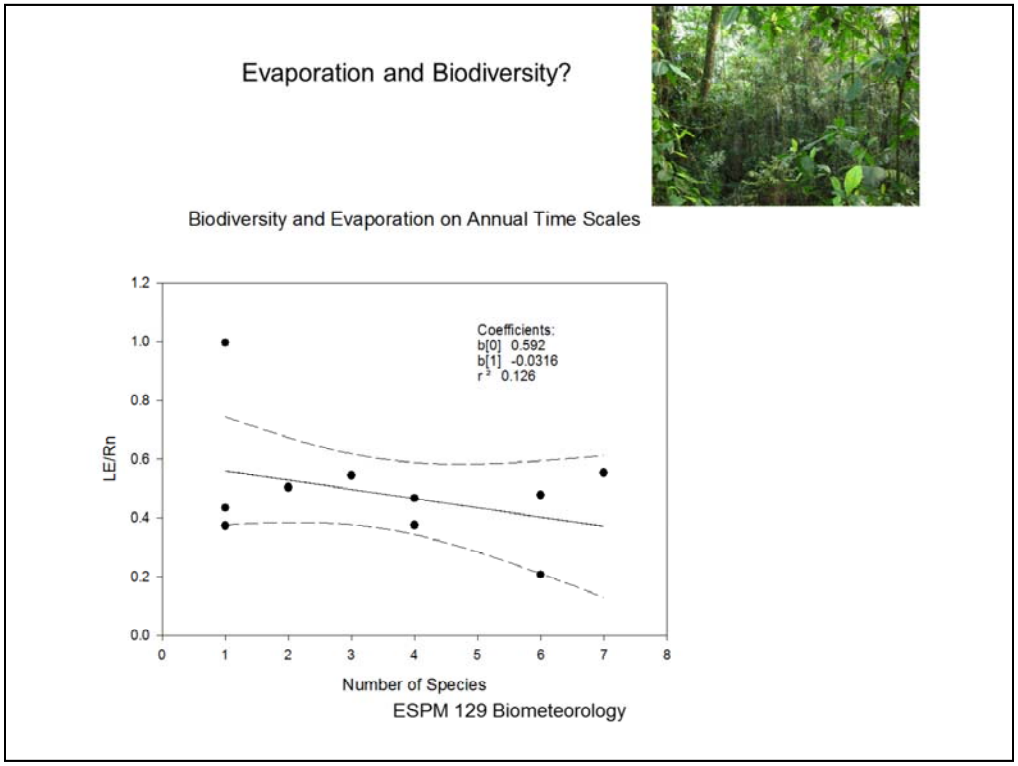
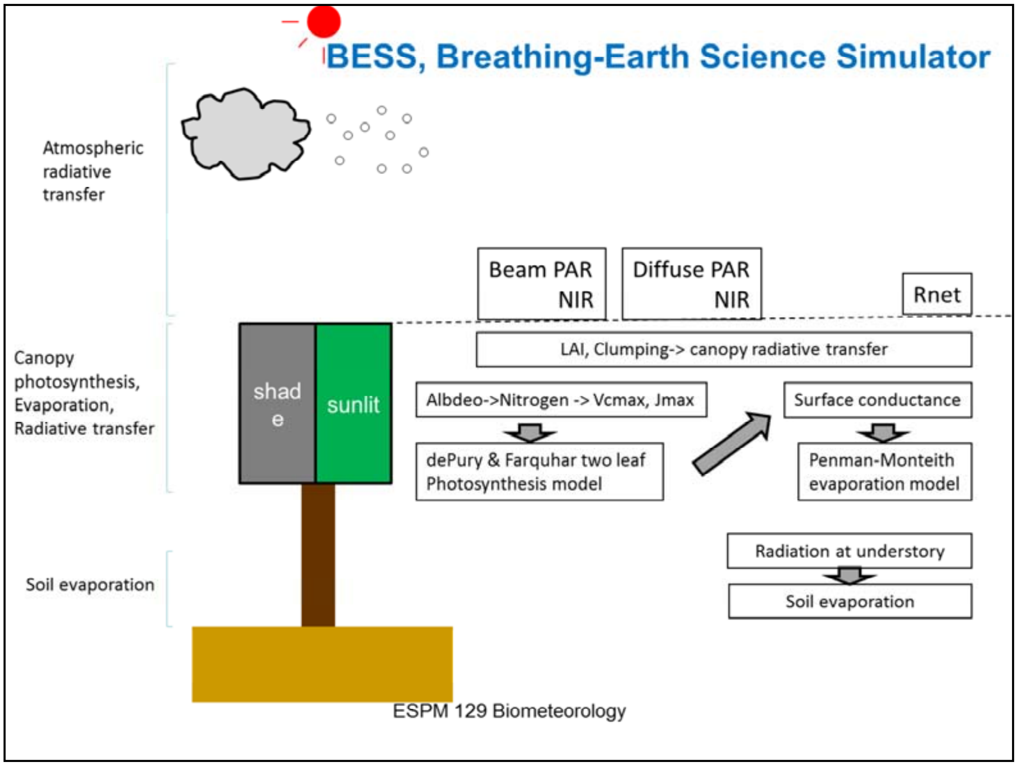
We know different species exert different resistances on transpiration and on stomatal control. To what degree should we see an effect of biodiversity on evaporation?



Does Biodiversity affect evaporation. Using long term data from the Fluxnet Project we find the answer is very little. This is consistent with the fact that energy drives much evaporation and scaling theory shows that energetics is scale invariant. Yet, there can be some role in the case that different species may have different hydraulic conductances and stomatal capacity.



How can we apply the lessons learned in this class to start simulating evaporation everywhere?

Berkeley Evaporation Science Simulator, Biometeorology-Lab Evaporation Science Simulator

Lessons Learned from the CanOak Model and Teaching ESPM 129

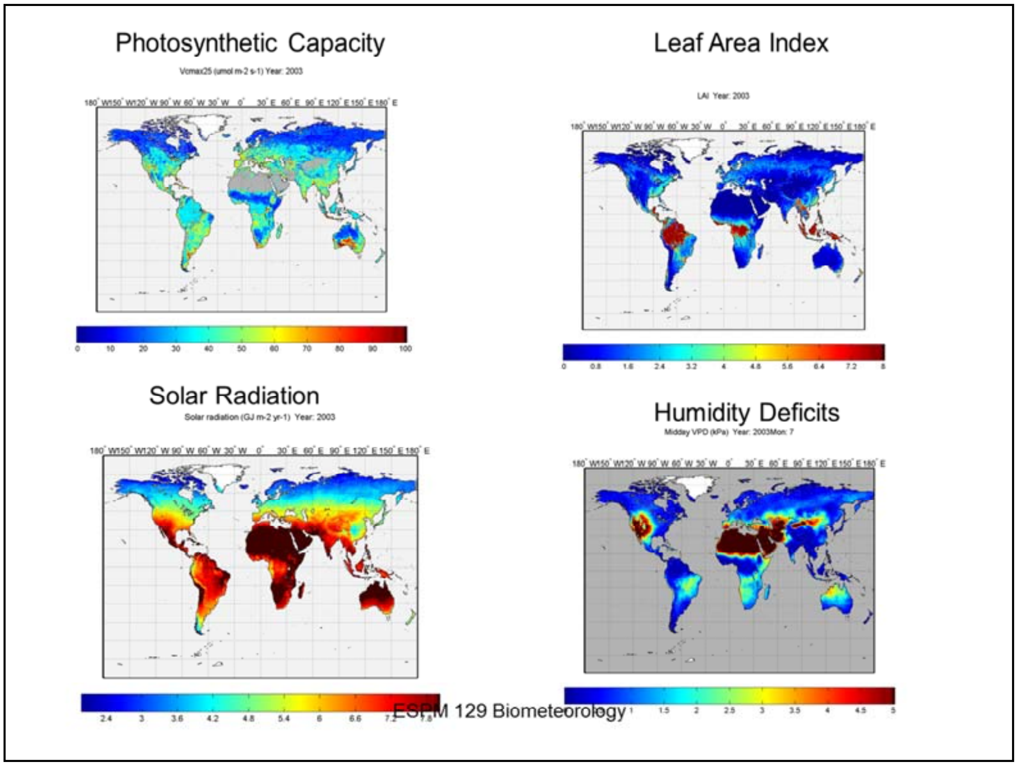
25+ years of Developing and Testing a Hierarchy of Scaling Models with Flux Measurements at Contrasting Oak Woodland Sites in Tennessee and California

We Must:

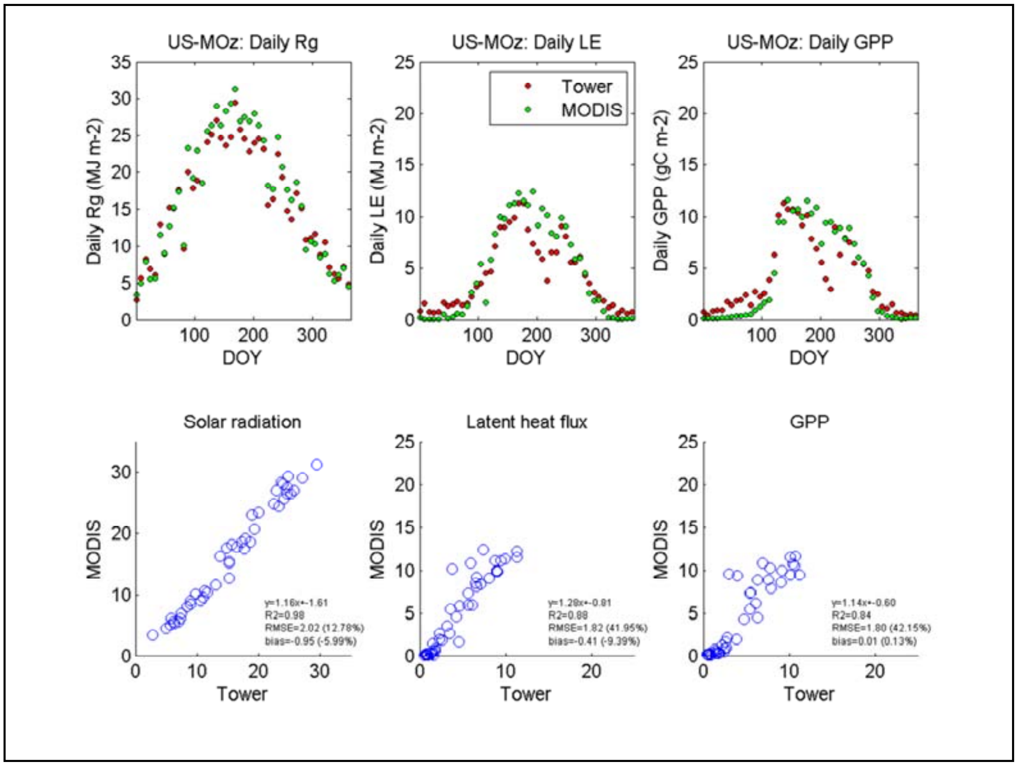
- Couple Carbon and Water Fluxes
- Assess Non-Linear Biophysical Functions with Leaf-Level Microclimate Conditions
- Consider Sun and Shade fractions separately
- Consider effects of Clumped Vegetation on Light Transfer
- Consider Seasonal Variations in Physiological Capacity of Leaves and Structure of the Canopy

Necessary Attributes of Global Biophysical ET Model: Applying Lessons from the Berkeley Biomet Class and CANOAK

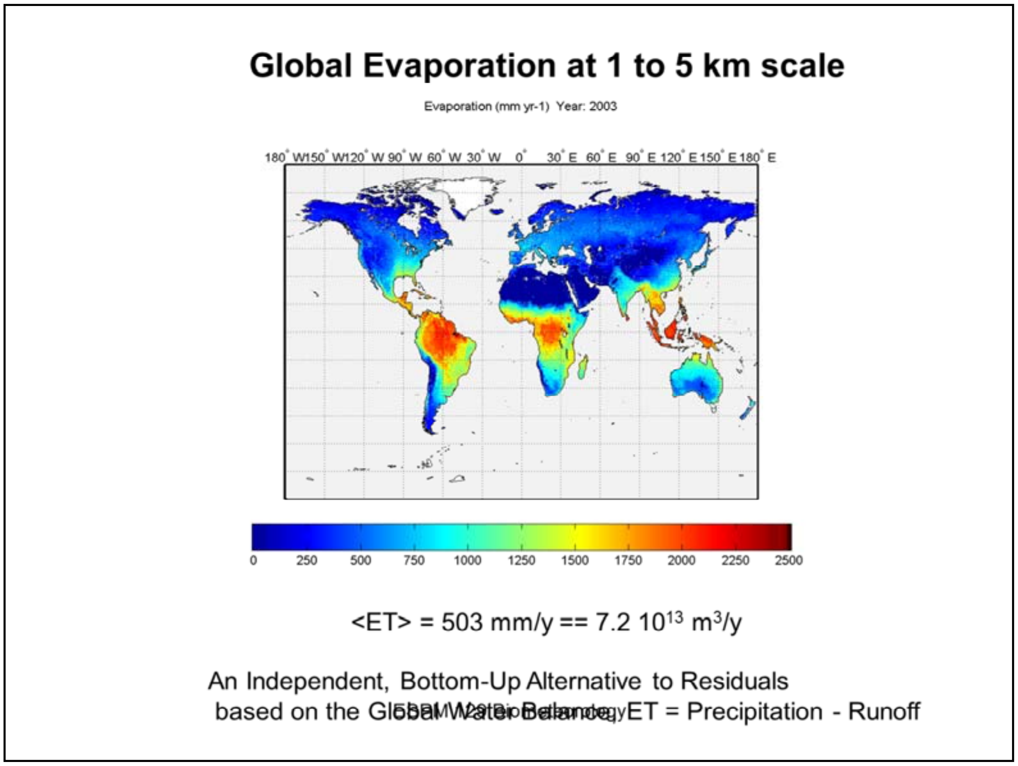
- Treat Canopy as Dual Source (Sun/Shade), Two-Layer (Vegetation/Soil) system
  - Treat Non-Linear Processes with Statistical Rigor (Norman, 1980s)
- Requires Information on Direct and Diffuse Portions of Sunlight
  - Monte Carlo Atmospheric Radiative Transfer model (Kobayashi + Iwabuchi,, 2008)
- Light transfer through canopies MUST consider Leaf Clumping
  - Apply New Global Clumping Maps of Chen et al./Pisek et al.
- Couple Carbon-Water Fluxes for Constrained Stomatal Conductance Simulations
  - Photosynthesis and Transpiration on Sun/Shade Leaf Fractions (dePury and Farquhar, 1996)
  - Compute Leaf Energy Balance to compute Leaf Saturation Vapor Pressure and Respiration Correctly
  - Photosynthesis of C_3 and C_4 vegetation Must be considered Separately
- Use Emerging Ecosystem Scaling Rules to parameterize models, based on remote sensing spatio-temporal inputs
  - Vcmax=f(N)=f(albedo) (Ollinger et al; Hollinger et al;Schulze et al.; Wright et al.)
  - Seasonality in Vcmax is considered (Wang et al.)



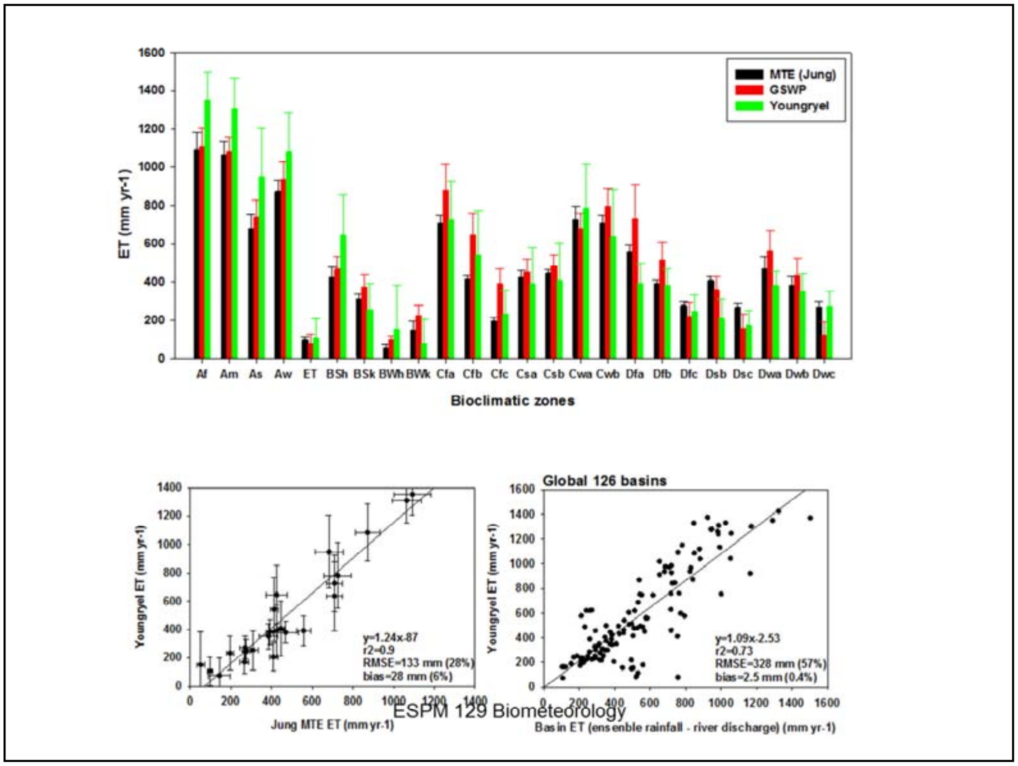
We can create maps of drivers



Tests of fluxes with data from an assortment of fluxnet sites

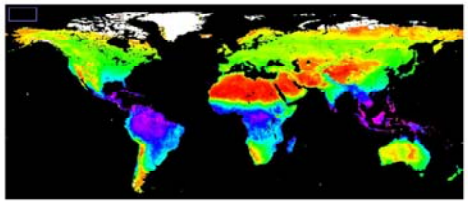


Global map of ET from bottom up.



Comparisons of mapped ET with proxies from data driven machine learning exercises using fluxnet data and from watersheds

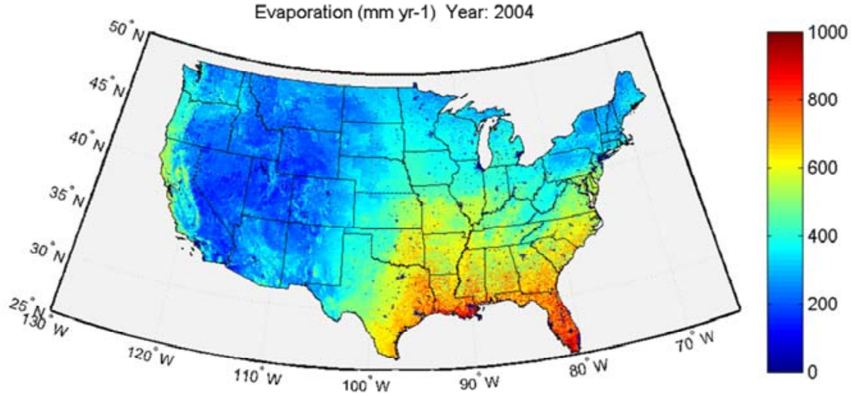
Global ET What is the Right Answer?



Why range?
Errors in ET?
Differences in Land area?
Cartesian vs Area-Weighted Averaging?
Grid Resolution?

<ET> (mm/y)	reference	ET (m^3/y)
613	Fisher et al	
550	Jung et al 2010, Nature	6.5 10^{13}
286	Mu et al. 2007	
539 +/- 9	Zhang et al. 2010, WRR	
467	Van den Hurk et al 2003	
649	Boslilovich 2006	
560	Jackson et al 2003	
410	Yuan et al 2010	
	Dirmeyer et al 2006	5.8-8.5 10^{13}
	Alton et al., 2009	~6.5 10^{13}
	Miralles et al 2011, HESS	6.8 10^{13}
	Ryu et al 2011 GBC	**6.3 10^{13}**

Van den Hurk et al 2003 JGR annual average land ET 1.28 kg m-2 d-1…467.2 mm/y; 649 mm/y Boslilovich; 560 mm from Jackson, land ET is 70,000 km3 and assuming 125 10^6 km2 land area; Mu et al 286 +/- 237 mm/y



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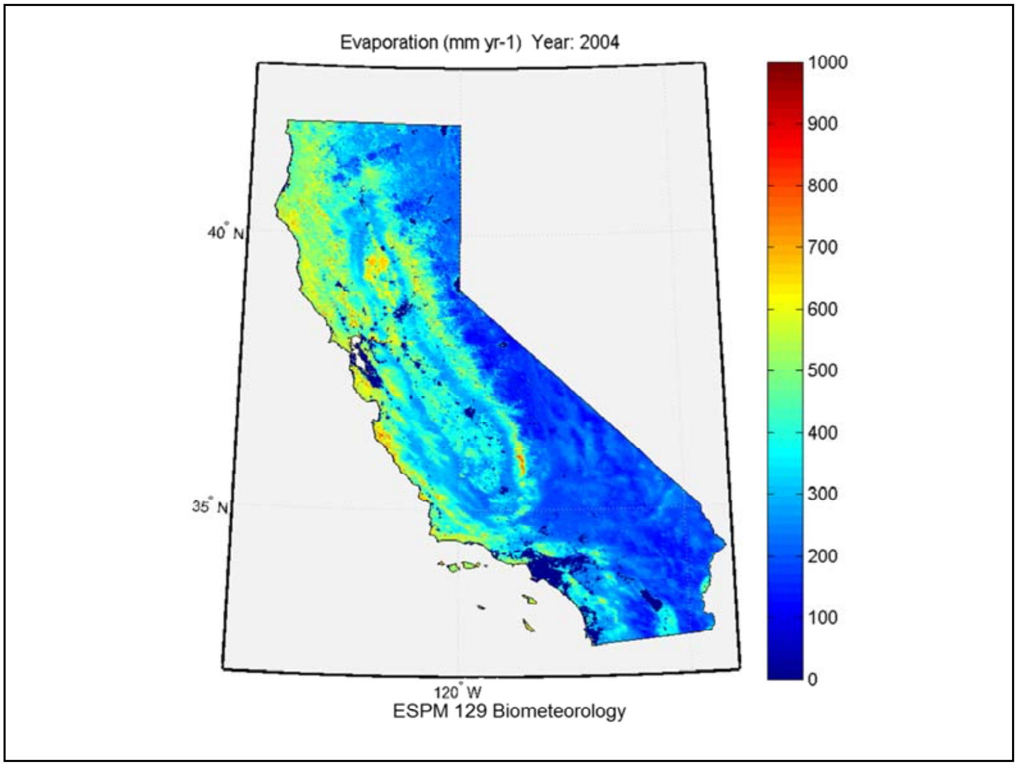
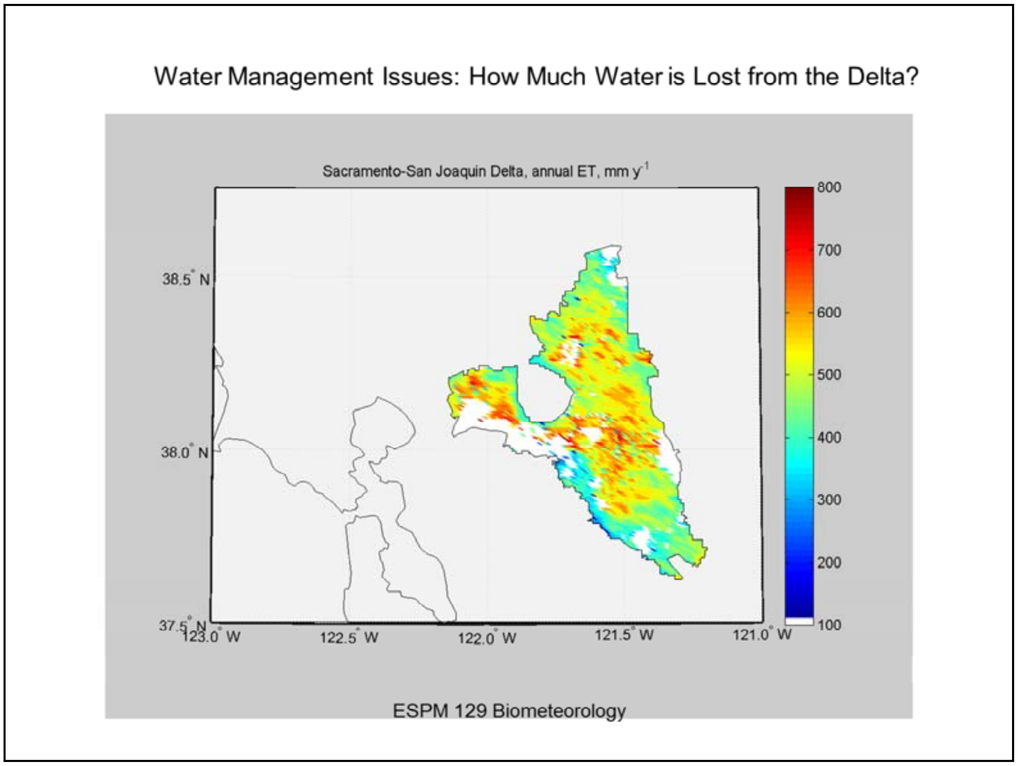
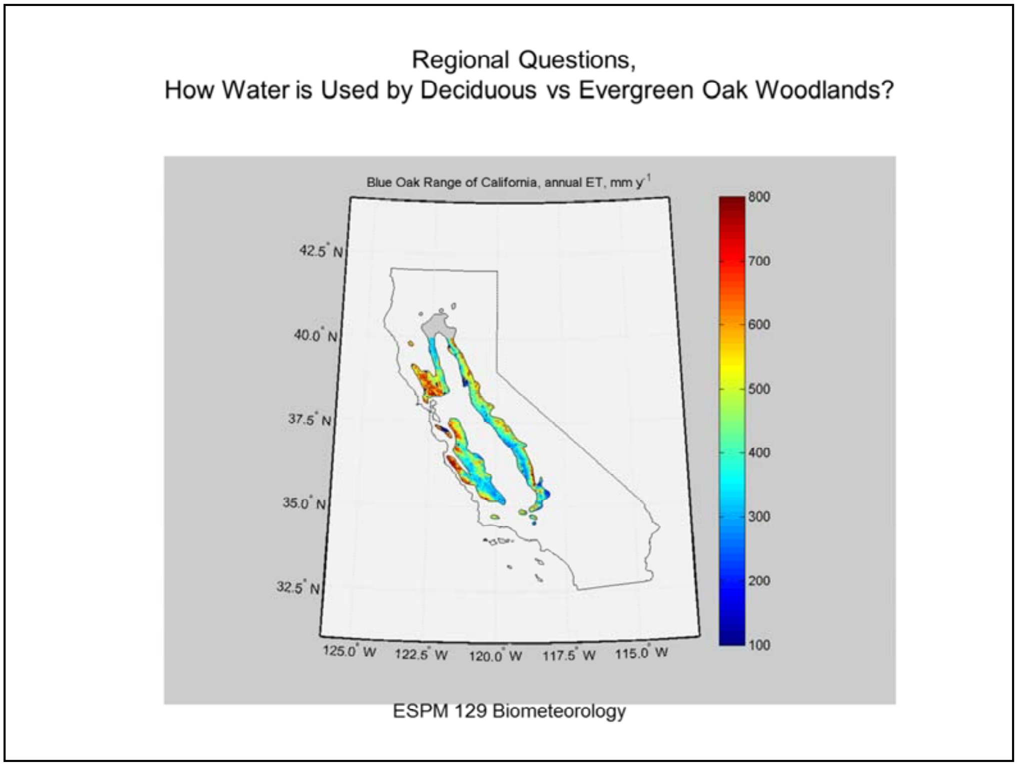
US map



California map



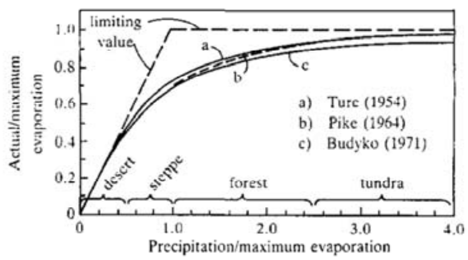
ET of the Delta



ET of oak woodlands

Conclusions

- Biophysical data and theory help explain powerful ideas of Budyko and Monteith that provide framework for upscaling and global synthesis of ET
  - ET scales with canopy conductance, which scales with LAI and Ps capacity, which scales with precipitation and N



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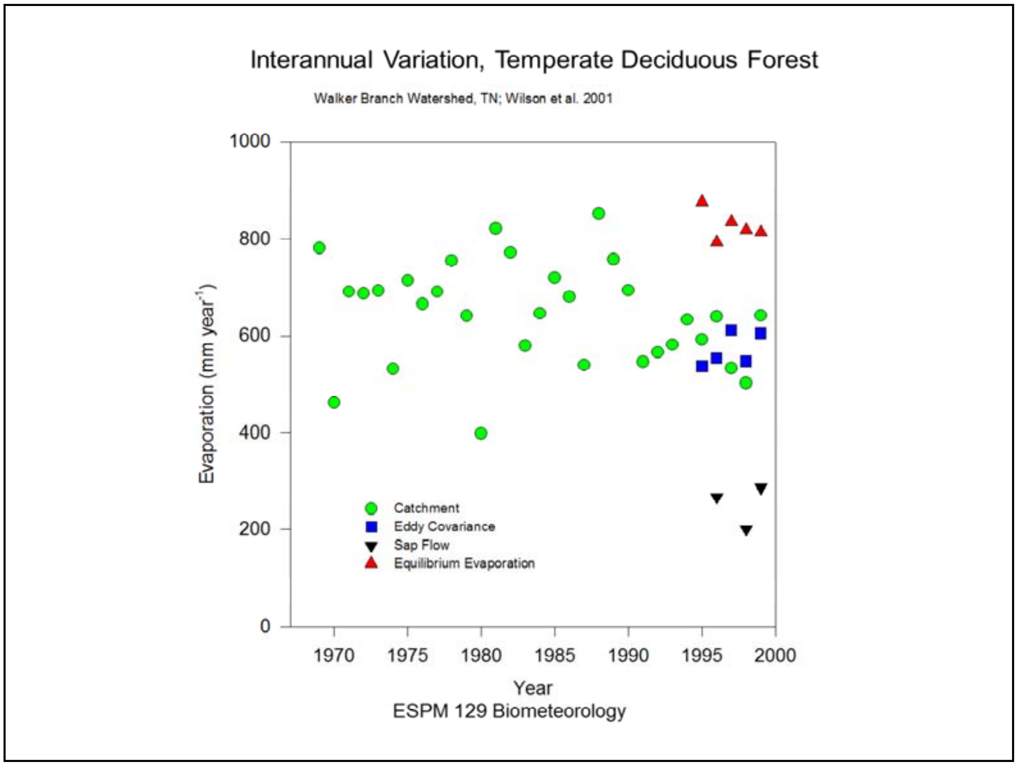

What is the interannual variation of ET at a site. Here are some data from Walker Branch Watershed in TN