Biometeorology @ Berkeley

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Welcome to Biometeorology. I am a professor of Biometeorology. I have worked at Cal since 1999. I received my BS in Atmospheric Science from UC Davis, a PhD in Bioenvironmental Engineering from the University of Nebraska, Lincoln. I then spent 17 years at the NOAA Atmospheric Turbulence and Diffusion Division in Oak Ridge, TN working as a Biometeorologist and Physical Scientist. Those interested in the work of my lab, you can get information on our research and publications at nature.berkeley.edu/biometlab

Outline

- Introduction:
  - What is Biometeorology?
  - Scope and Breadth of the Field
  - Scientific Issues and Questions
- Goals of the Course
  - , Philosophy and Expectations
- Course Outline

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What Is Biometeorology?

- It is a science that deals with the relationship between living things (plants, microbes, animals) and atmospheric phenomena (wind, temperature, humidity, sunlight).

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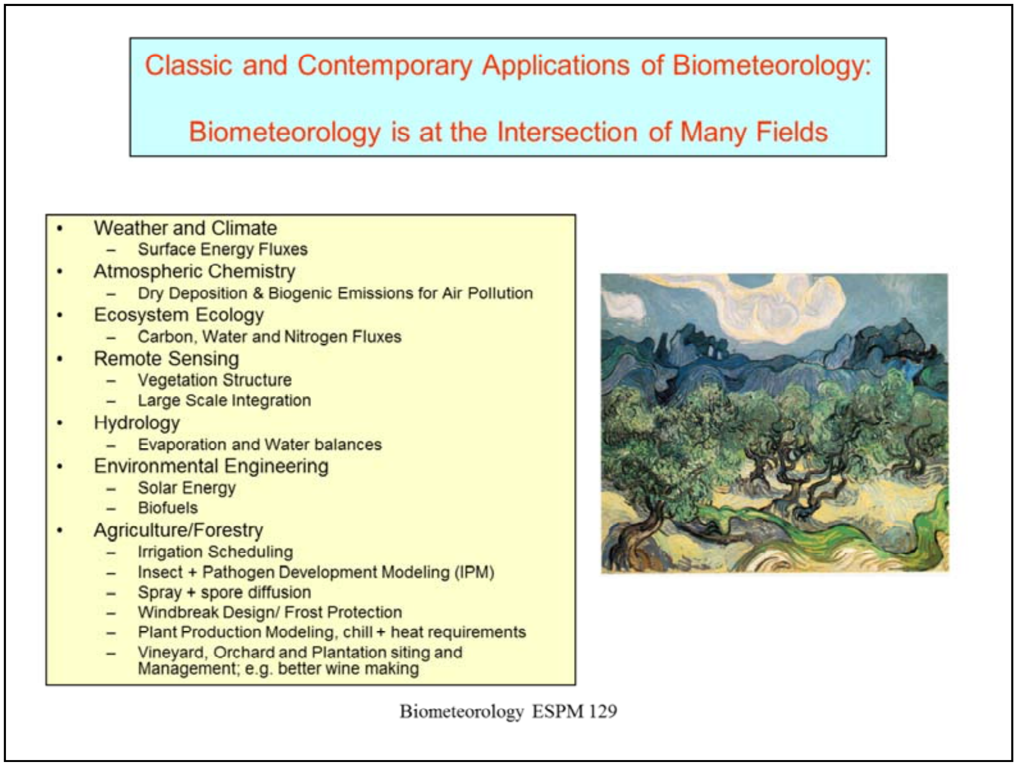
The field of Biometeorology can be very broad, including roles of weather on: 1) human health; 2) outbreaks of insects and pathogens, 3) the health and production of dairy, cattle, pigs and chickens, 4) frost prevention, 5) irrigation management, 6) modeling of crop growth, yield and crop management, 7) study of phenological growth stages, 8) integrated assessments with remote sensing and 9) future change in these systems with global warming and land use change



List of topics that hopefully relate with and engage with the diverse background of students taking this course. I hope it serves as a motivation for your interest and need to take biometeorology as it serves the many multifaceted goals of these other fields. In short many of these fields need to predict the rate of fluxes given the state of the environment. Our job is to translate information from distance weather stations to the site of the organism to better assess these fluxes.

Goals of Biomet Research @ UCB

'Breathing of the Biosphere'

Study the physical, biological, and chemical process that control trace gas fluxes between the biosphere and atmosphere which in turn define the state (temperature, humidity, trace gas concentrations) of the surface boundary layer, and Vice Versa

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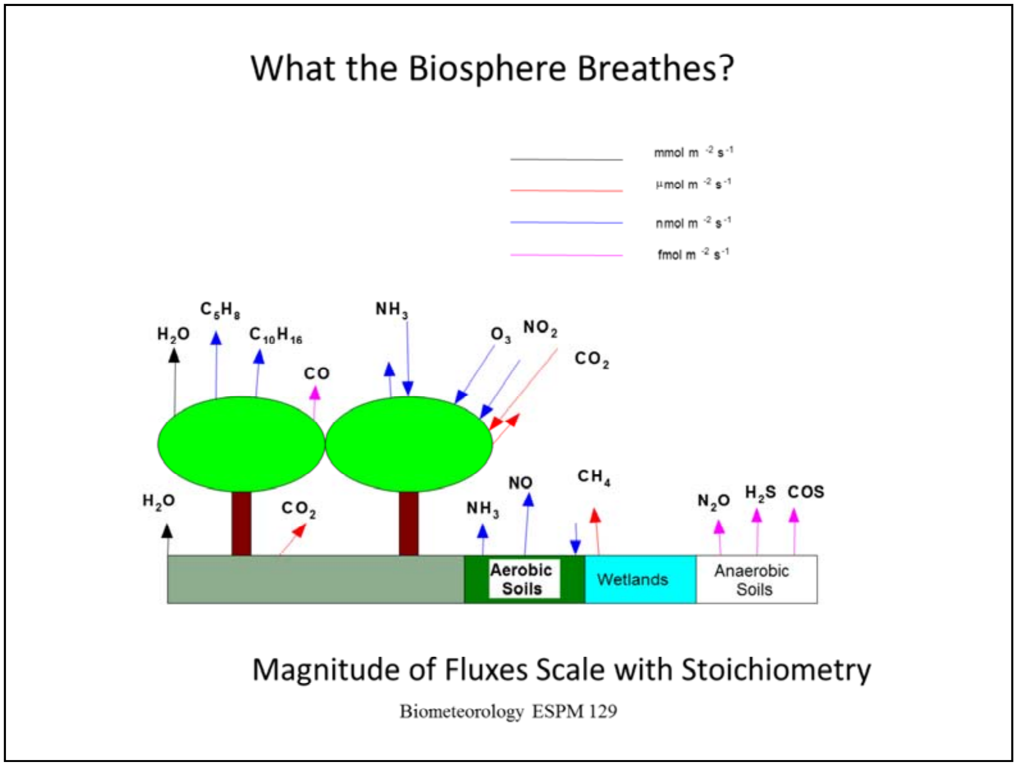
There is a two connection between the atmosphere and underlying biosphere. Meteorological conditions affect the activity of life in the soil and plants. But the exchange of mass and energy to and from the plants and soils also affect the state of the atmosphere. It is these connections that are at the heart of the study of this field and class.



This is an example of the gases that are exchanged between the biosphere and atmosphere. Note some are taken up and others emitted. Important gases include water vapor, carbon dioxide, methane, volatile hydrocarbons, nitrous oxide, ozone.

Big Picture Question Regarding Predicting and Quantifying the 'Breathing of the Biosphere':

- **How can We Predict Trace Gas Exchange 'Everywhere All the Time?'**

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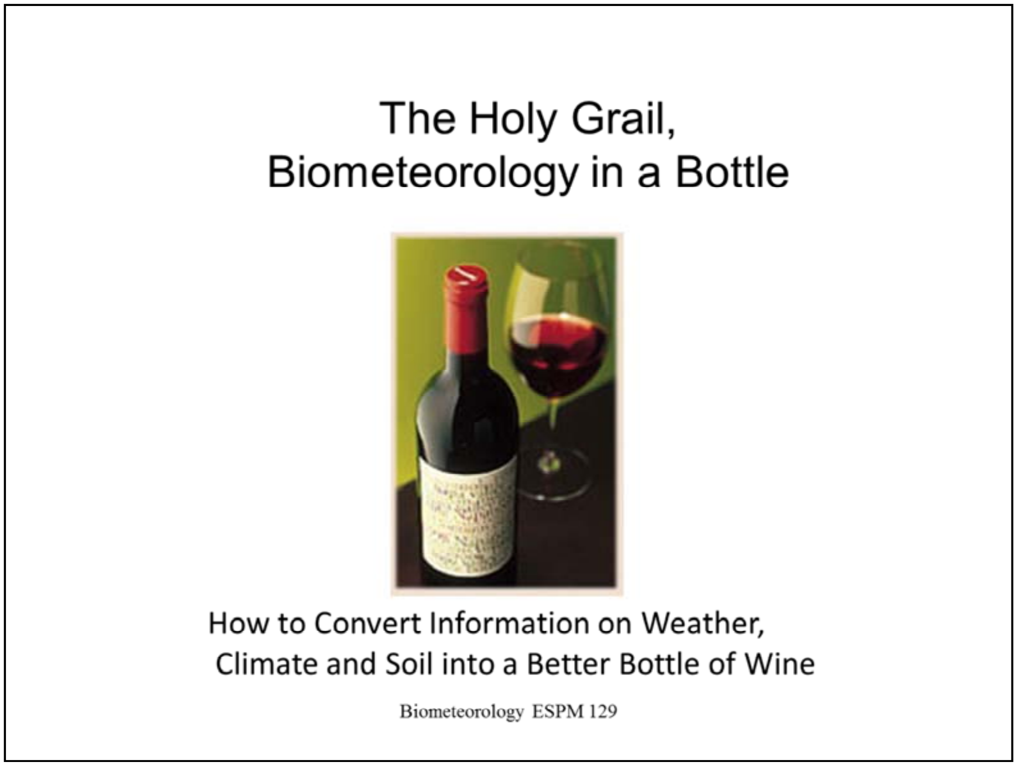
Principles taught in this class have the goal and aim to revolutionize how global models assessing such processes as global primary productivity and evaporation.

Wedding at Cana, Veronese, the Louvre, Paris



While I include this slide as a ‘tongue in check’ metaphor, in a way it is true. A bottle of wine is a integration of all the weather that a grape vine experienced over a growing season (plus the role of soil, terroir, exposure, and the art of the wine maker and the yeast that does the job of fermentation).

Climate

- Derived from the Greek word, Klima, meaning slope
  - Example is all the Microclimates in the Bay Area

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Origins of words like Climate

Uncle Vanya, Anton Chekhov (1899)

- *"... forests tremble under the axe, millions of trees are lost, animals and birds have to flee, rivers dry out, beautiful landscapes are lost forever.....waters are polluted, wildlife disappears, the climate is harsher...".*
- *"...the forest teaches us to appreciate beauty, it softens the harshness of the climate",*

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The idea that change in land affects the climate has been appreciated for a long time. I like this quote from Uncle Vanya, circa 1899. But appreciation of climate and vegetation goes back to the ancient Greeks and Thales of Miletus.

Climate-Plant Interactions

- How does Climate Constrain Vegetation Structure and Function?
  - Why do certain plants have big leaves and others have small ones?
  - What biophysical factors limits plant height, density and vigor?
  - How many trees can grow on a landscape and how big will they be?
  - How did Past Climates affect the shape and function of plants?; what will happen in the future
  - Better Interpretation of Climate Proxies like Tree Rings and Stable Isotopes

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Questions we ask that motivate our work. By posing compelling questions, I think it helps guide the curiosity in the field and the tools and skills needed to be achieved.

Plant-Atmosphere Interactions

- How does the presence or absence of plants affect the microclimate and weather?
  - How does the weather change with land use change, like fire, deforestation/afforestation and logging?
  - How does Weather Change if the Trees are Leafless or Not?

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Land use change and the modification of the landscape are key questions in biometeorology. The feedbacks are complicated because there are direct effects on the mass and energy exchange at the surface. But these fluxes also affect the production or inhibition of clouds and rain, that have larger scale and longer time scale feedbacks.

Intellectual Framework

•Quantify Physical and Biological Processes that affect the State of the Microclimate, Plants and the Soil

•Understand how they vary with
  • Time, superposition of fast through slow processes
  • Space, Vertically and Horizontally

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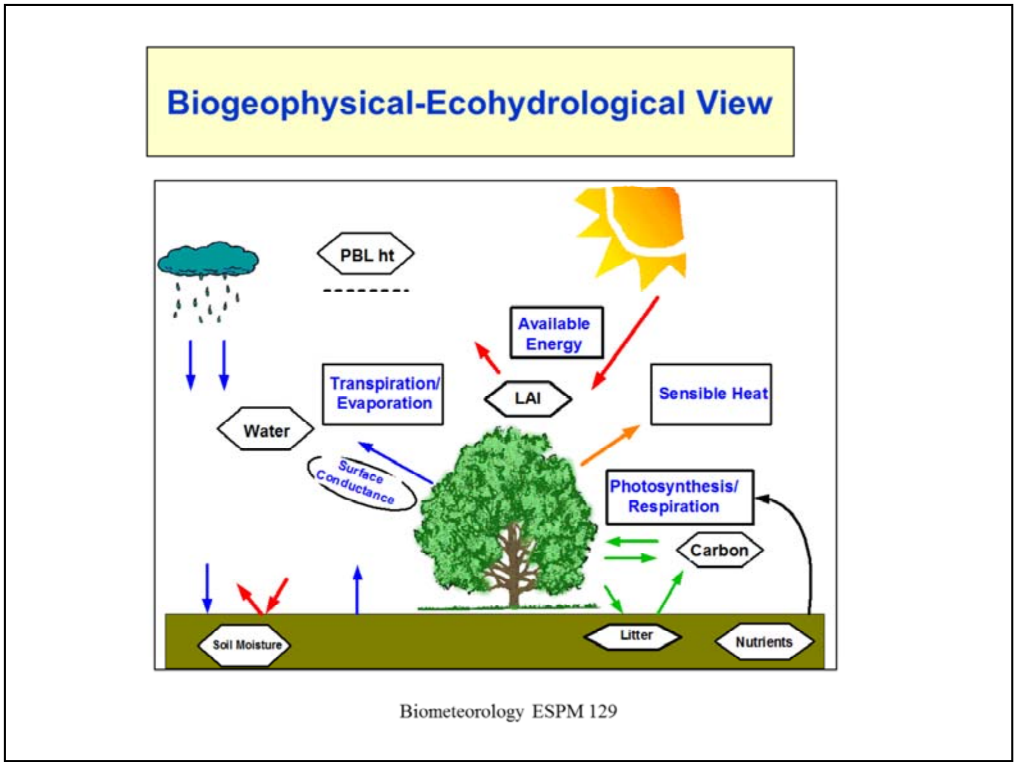
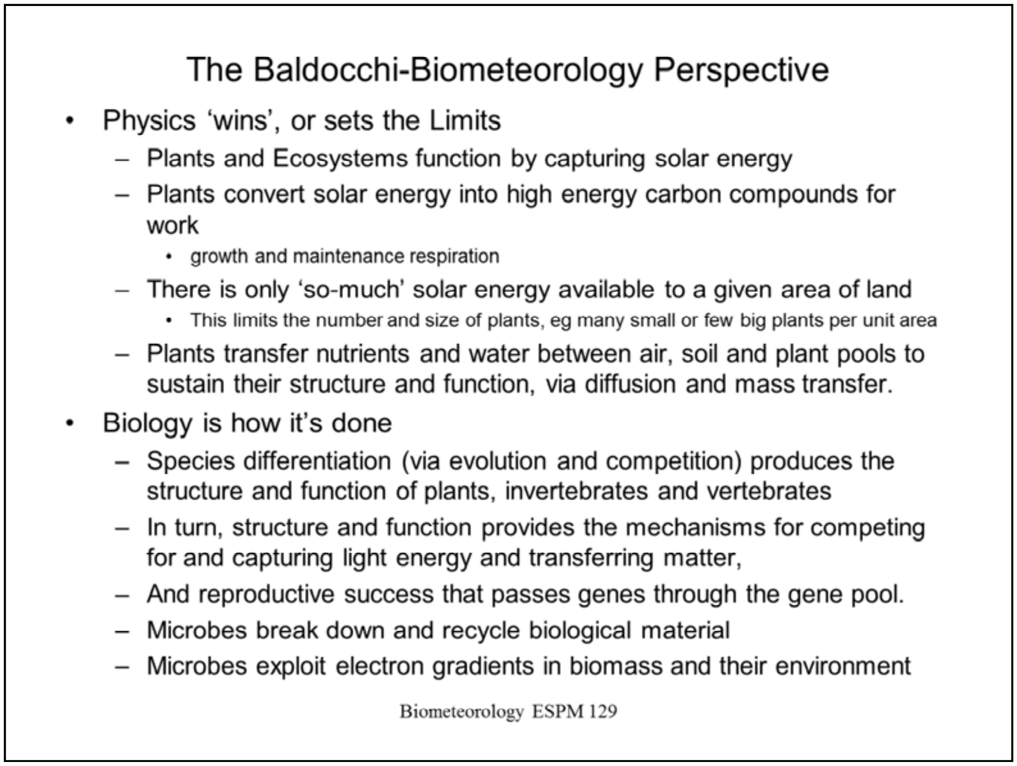
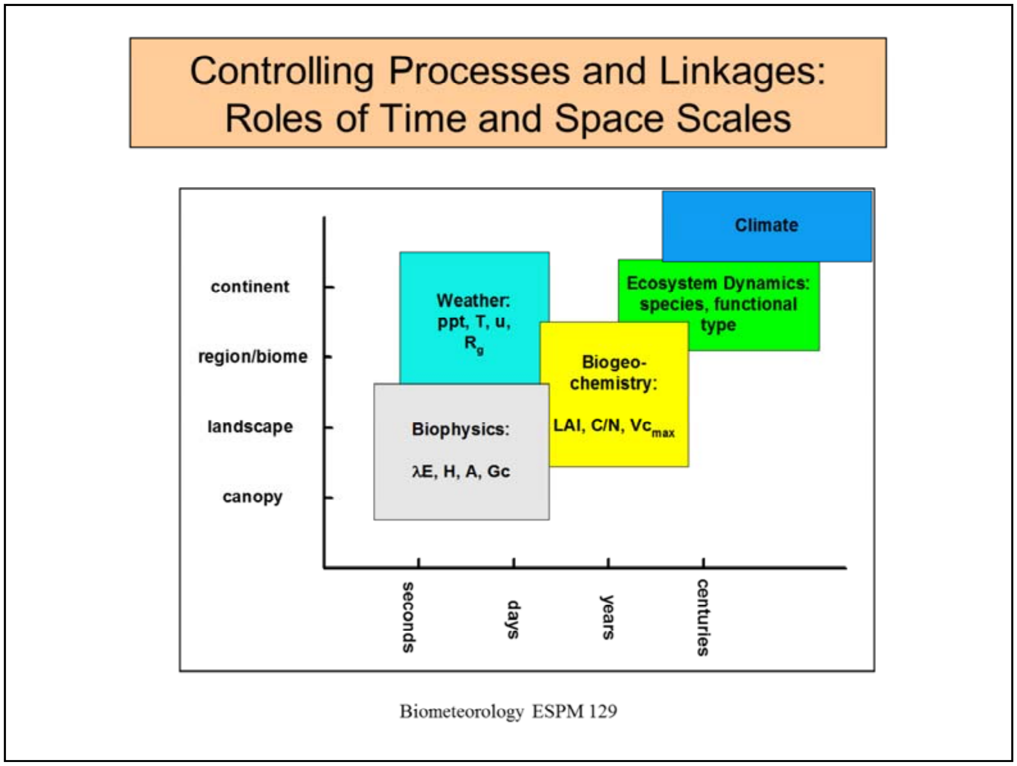
It is important to identify and study the sources of variability in the microclimate. We will study how meteorological variables and fluxes vary in time and space. It is further complicated as these will vary over several orders of magnitude. And if we hope to upscale information from the small to large scales, or short to long time scales we may experience a phenomenon of complex systems called ‘scale emergent processes’; sum of the parts do not functions in the same way as the whole system.



Figures like this will summarize and integrate many of the topics studied over the course of the semester. This is a very fundamental and overarching conceptual diagram of the processes that will be studied during this semester. You should be able to understand this figure and its components by the end of the semester.



Physics wins is a retort to those who decline to where a seat-belt, based on Fallacious logic! But so often we cannot ignore the role of the laws of physics on how systems work, how big they can be, how many they can sustain and how fast they can move and grow and metabolize.



The spectral relation between small to large and slow to fast is illustrated in this figure. Large scale weather will dominate the rates of evaporation, heat exchange and photosynthesis on short time scales. The state of the vegetation will rely on factors relating to biogeochemical and ecological processes affecting the amount of leaf area and its nutrition. Who is where and how many is a slower process, dependent upon human disturbance and ecosystem dynamics. And all this is forced by the state of the climate of that biome or eco-region.

Processes and Scales of Inquiry

- Leaf
  - Photosynthesis
  - Transpiration
  - Stomatal Conductance/Plant Water Relations
- Plant
  - Transpiration
- Soil
  - Soil Physics and Biogeochemistry
  - Root and microbial Respiration
  - Heat and water transfer
- Canopy
  - Carbon, Water + Energy Exchange
  - Turbulence/Micrometeorology
  - Trace Gas Emissions + Deposition
  - Microclimates
- Landscape
  - Flux Footprints
  - PBL Growth and Feedbacks
- Regions
  - Up Scaling
  - Synthesis of Biophysics/Biogeography/Ecology

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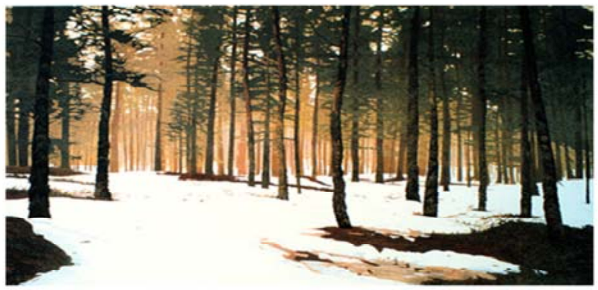
While this course has one goal, to familarize biologists with the laws of physics, that affect microclimate, we will also familiarize the physicists and engineers in the class with the roles of biology on the microclimate

To characterize the canopy microclimate Scalars like CO_2, temperature and humidity, we must measure and model carbon dioxide, water vapor and energy FLUXES of across vegetation/atmosphere interface.



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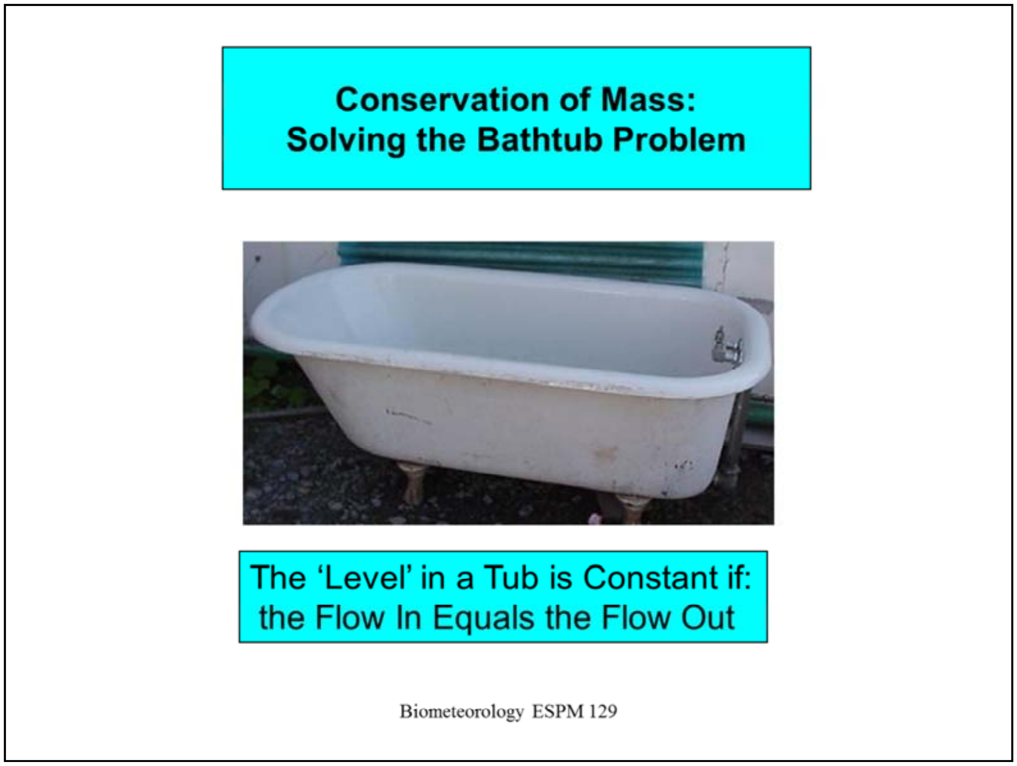
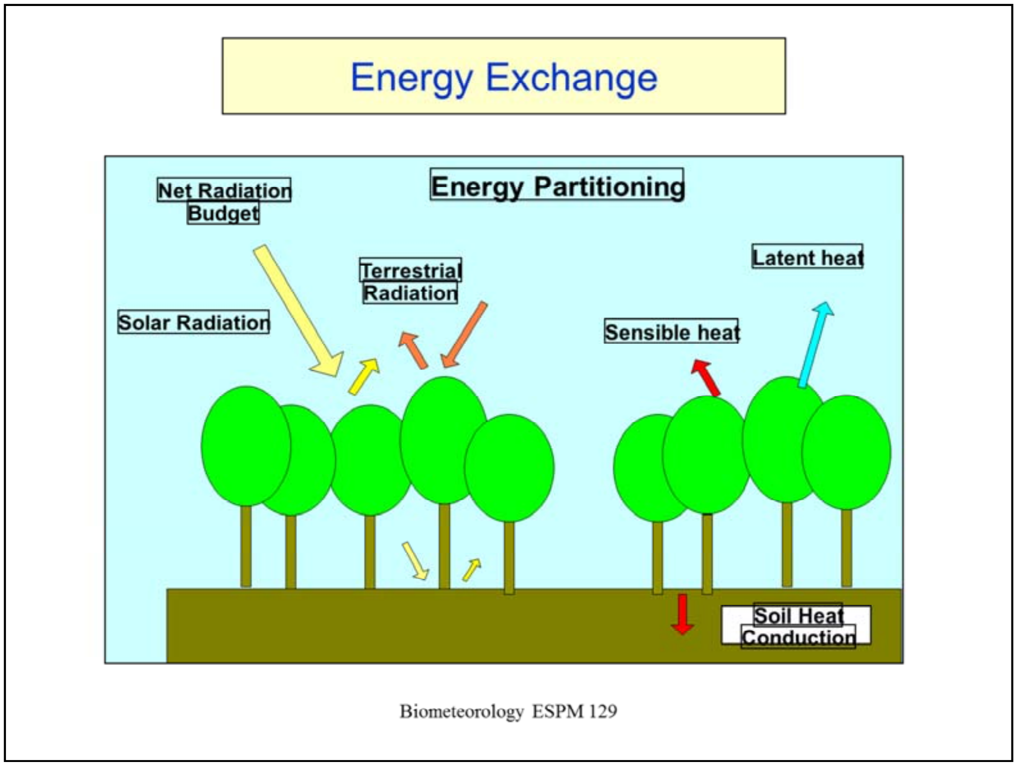
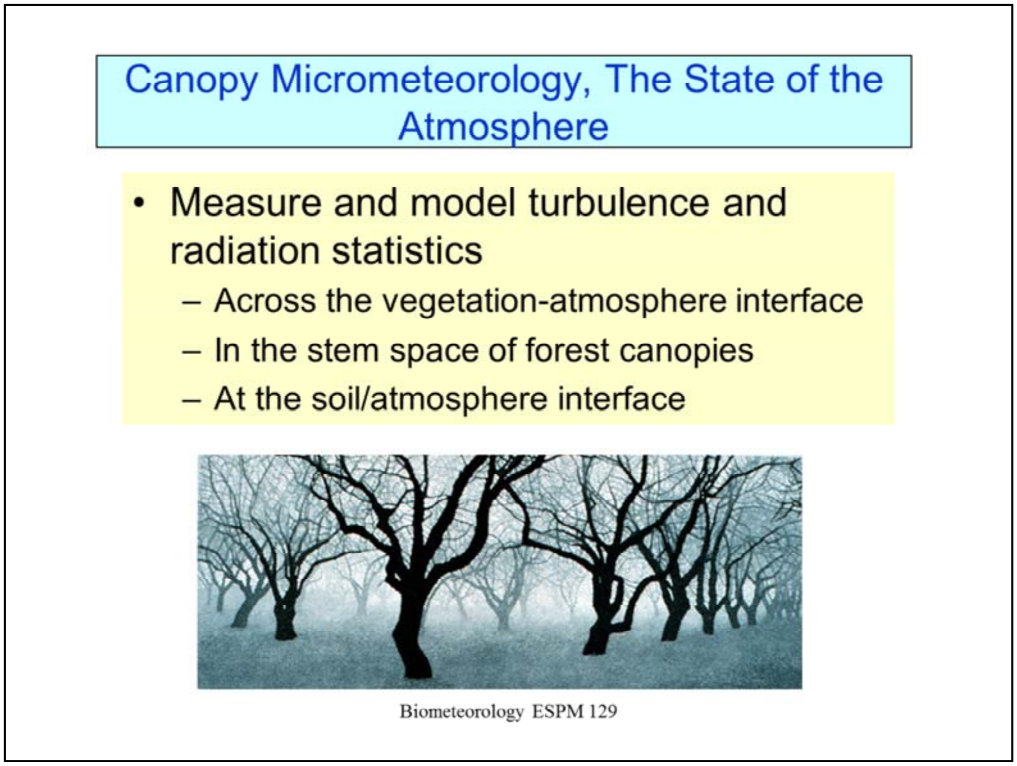
Explicit link between scalars and fluxes



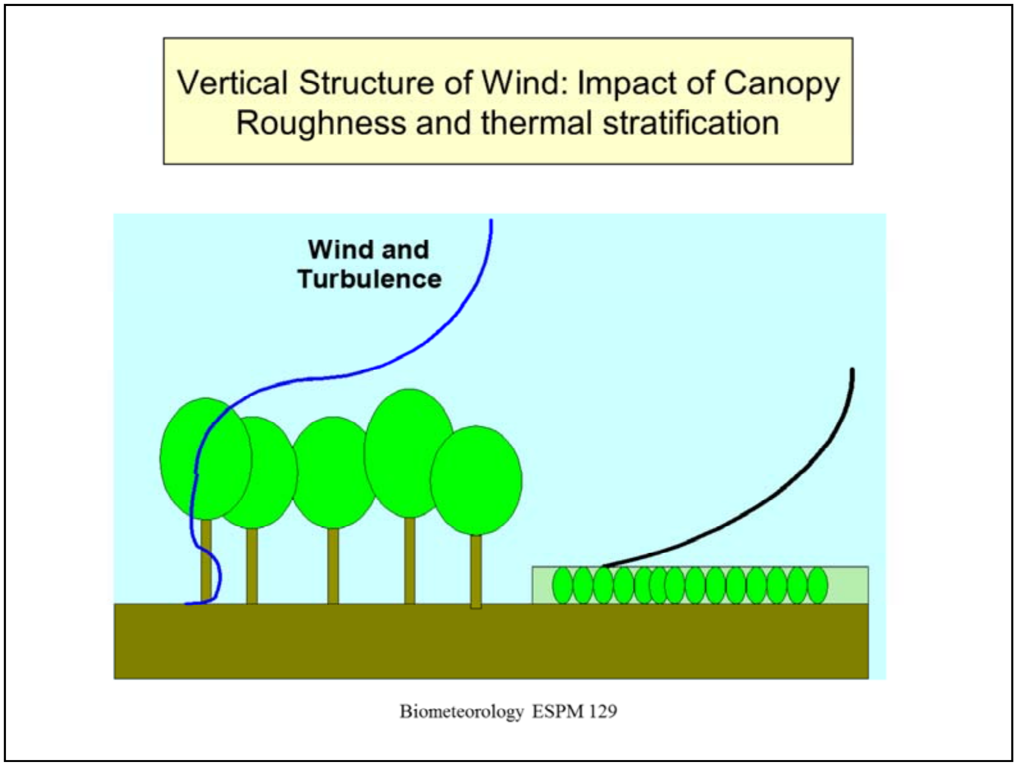
A conceptual understanding of stocks and fluxes comes from the bath tub, with the level of water representing the size of stocks or pools. Fluxes are associated with the rate of water flowing into and out of the tub. The atmosphere is a bit more complicated because it is more like a leaky colander than a well defined bath tub.



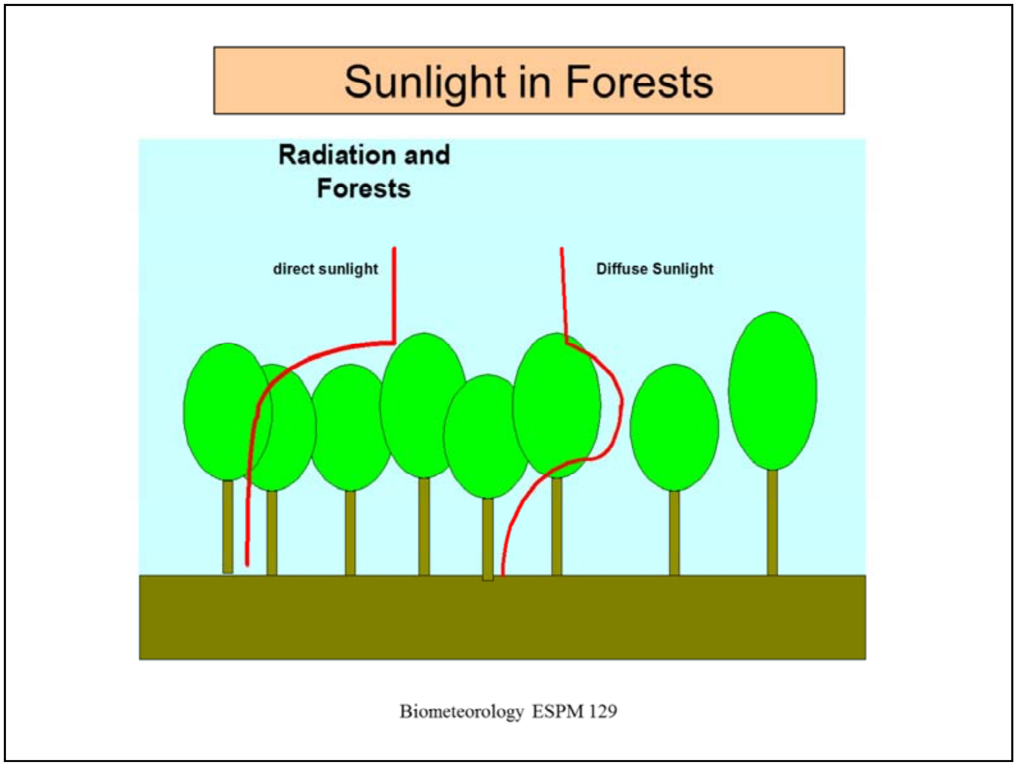
Over the semester we will focus much on the exchange of energy between vegetation and the atmosphere and how that energy is consumed into heating the air and soil and evaporating water



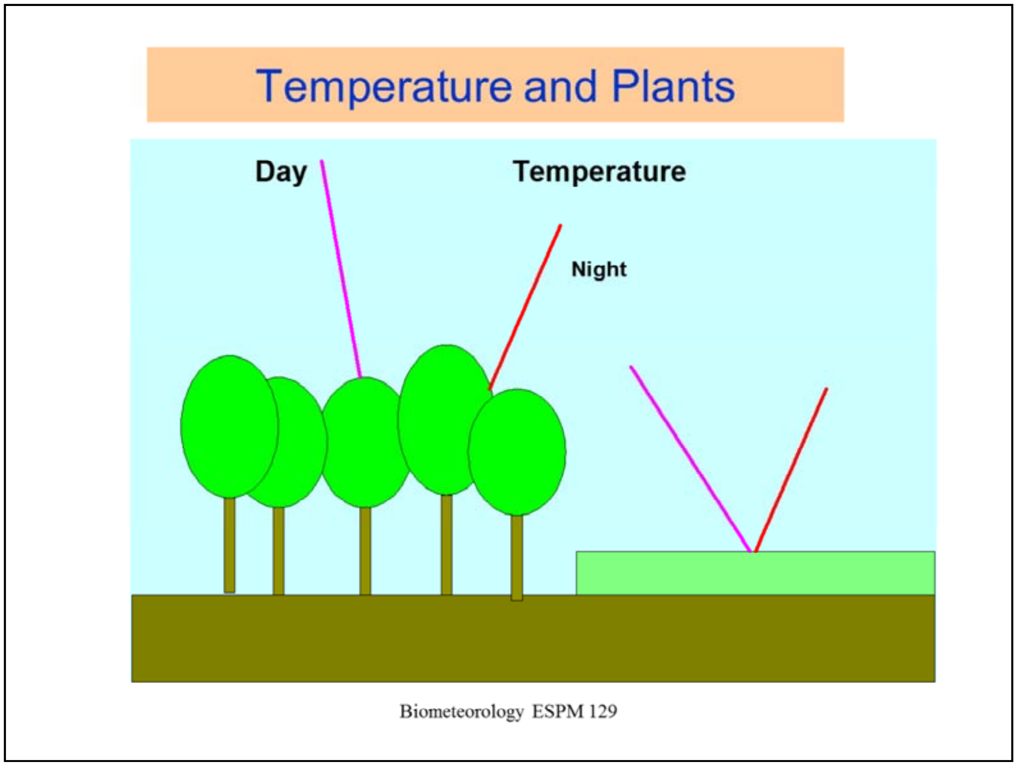
Much of the exchange of mass and energy is due to turbulence and diffusion. Another section of the class with focus on wind and turbulence above and within vegetation. Many new and exciting paradigm shifts have occurred over my scientific career, making this topic quite exciting and interesting.



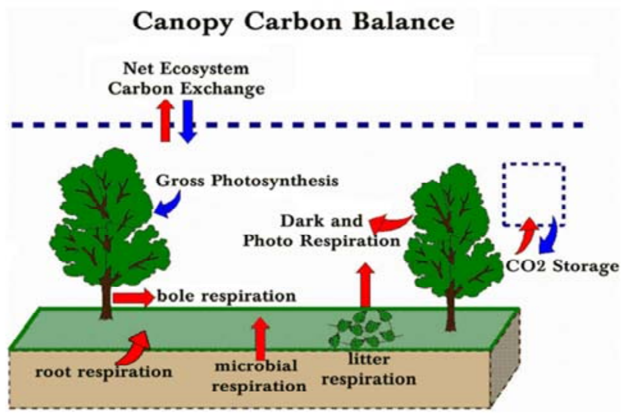
You can see from this cartoon that wind fields are different above and within tall and short vegetation. How and why this occurs will be topics of discussion.



Foliage intercepts and reflects photons. If we want to interpret the land from space or assess how energy is used to drive photosynthesis we must have a thorough understanding of the exchange of photons within vegetation.



Together, energy exchange affects the temperature of the air and foliage. How this varies with time and space will differ during the day and night, summer and winter.



- What types of landscapes are better or worse sinks for Carbon?
- How does Carbon Assimilation and Respiration respond to Environmental stresses, like drought, heatspells, pollution?
- Are Forests Effective Mitigators for stalling Global Warming?

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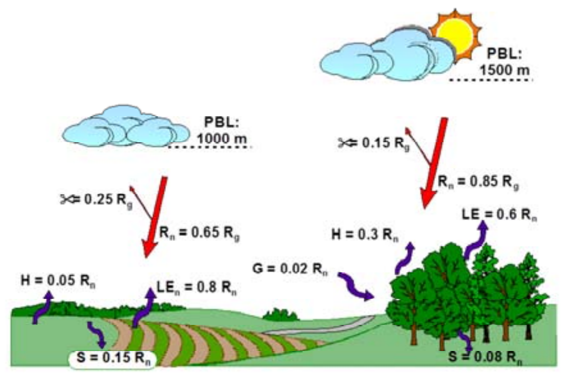
One goal of pulling all this information together on mass and energy exchange is to better understand the fluxes of carbon dioxide, as it is a potent greenhouse gas and is causing global warming.

Energy Exchange



- How much Solar Energy is Available?
  - Pros/Cons solar cells vs biofuels
- How does Land Use Change affect Climate, Weather and Water Availability?
  - How Crops differ from Nearby Forests
  - Tropical Deforestation
  - Large-scale Biofuels Plantations
  - Re-Forestation

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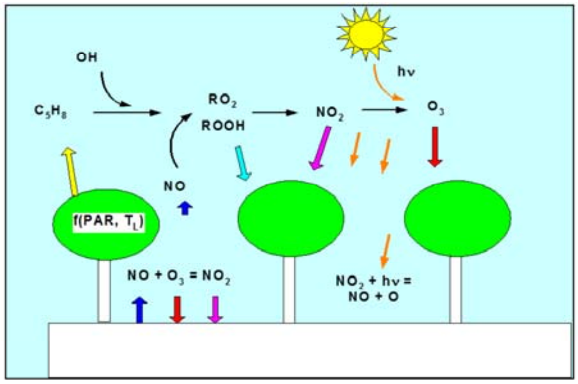
Energy exchange is pertinent as it is the bottom boundary condition of weather and climate models. With today's interest in biofuels and land use change its study is a critical component of ecological engineering.

Atmospheric Chemistry



- How effective is Vegetation as a sink for Pollution?
- To what extent are forests sources of precursors for pollution?
- How do the sources and sinks vary with weather and climate?

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With our ability to measure and model fluxes, we can also contribute towards better knowledge of the chemistry of the atmosphere and environmental pollution.

Modes of Research

- Field Measurements at Canopy scale
- Process-level Studies on Plants and Soil
- Mathematical Integration Models

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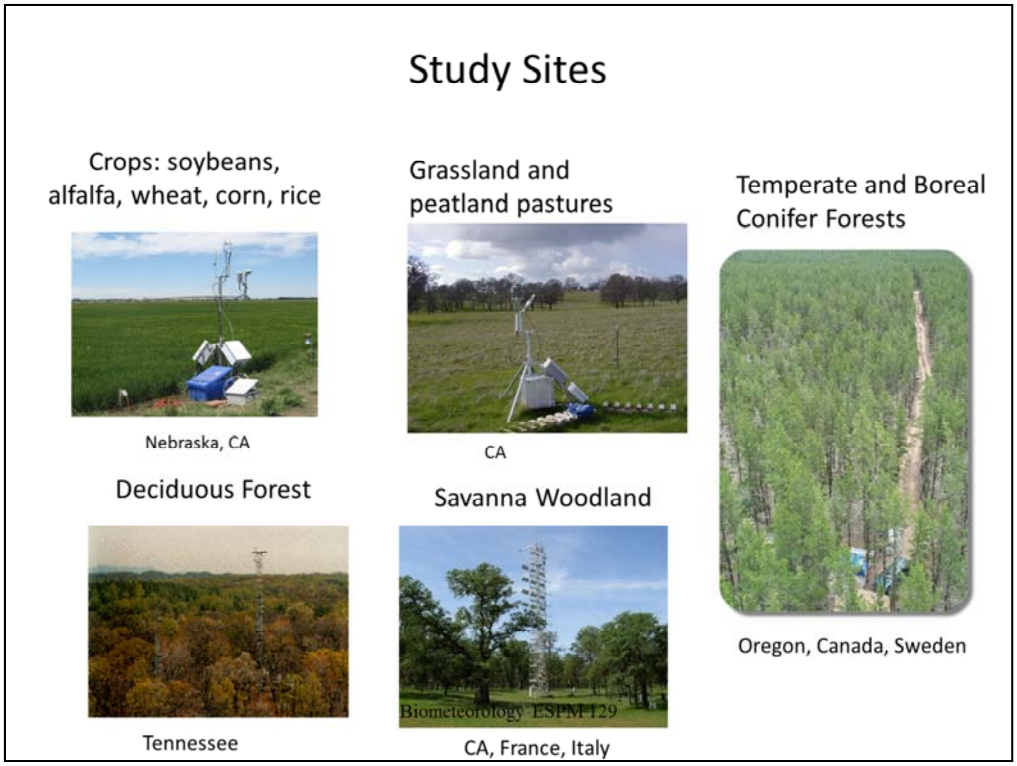
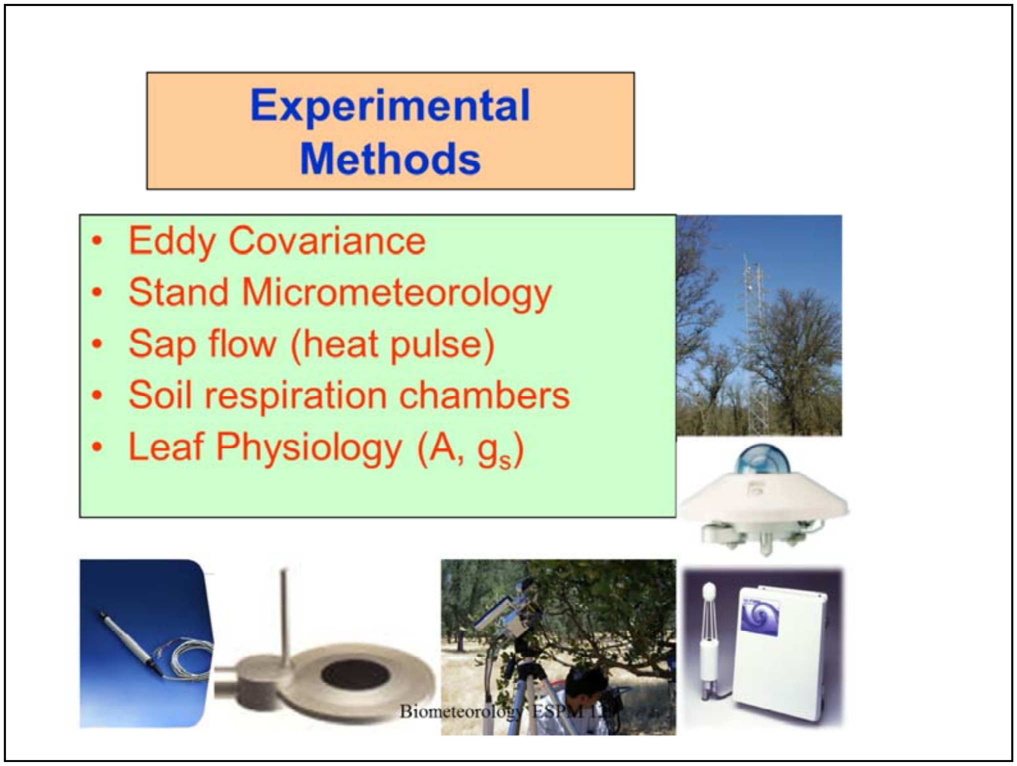
How do we do this work?



Many of us operate field stations with arrays of sensors to measure fluxes and the state of the atmosphere. Here is a cross section of locales I have worked on. I've been fortunate to conduct studies in Scandinavia, Canada, Tennessee, Europe, California and Oregon.



List of methods used at the stand, leaf and soil scales

Methodology

Eddy Covariance Method is use to measure Fluxes of CO_2, water vapor and energy exchange

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

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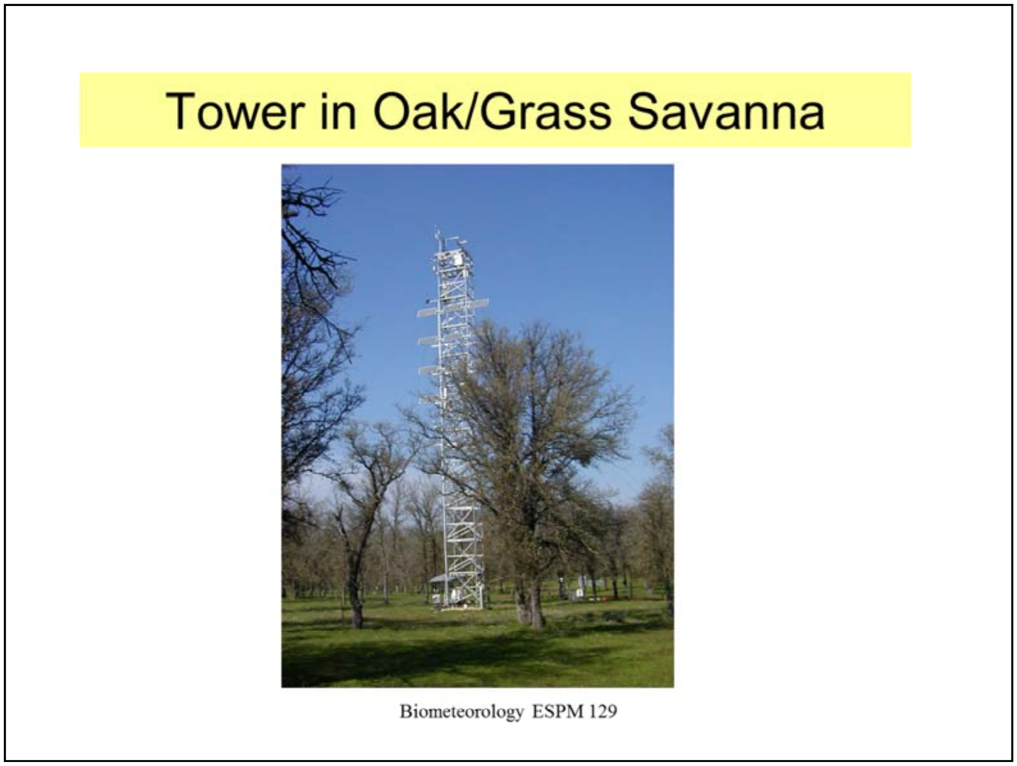
Eddy covariance is the workhorse of our field. It is a direct measure of fluxes of mass and energy across the canopy-atmosphere interface.



Example of our flux tower near Ione, CA

Meteorological Instruments

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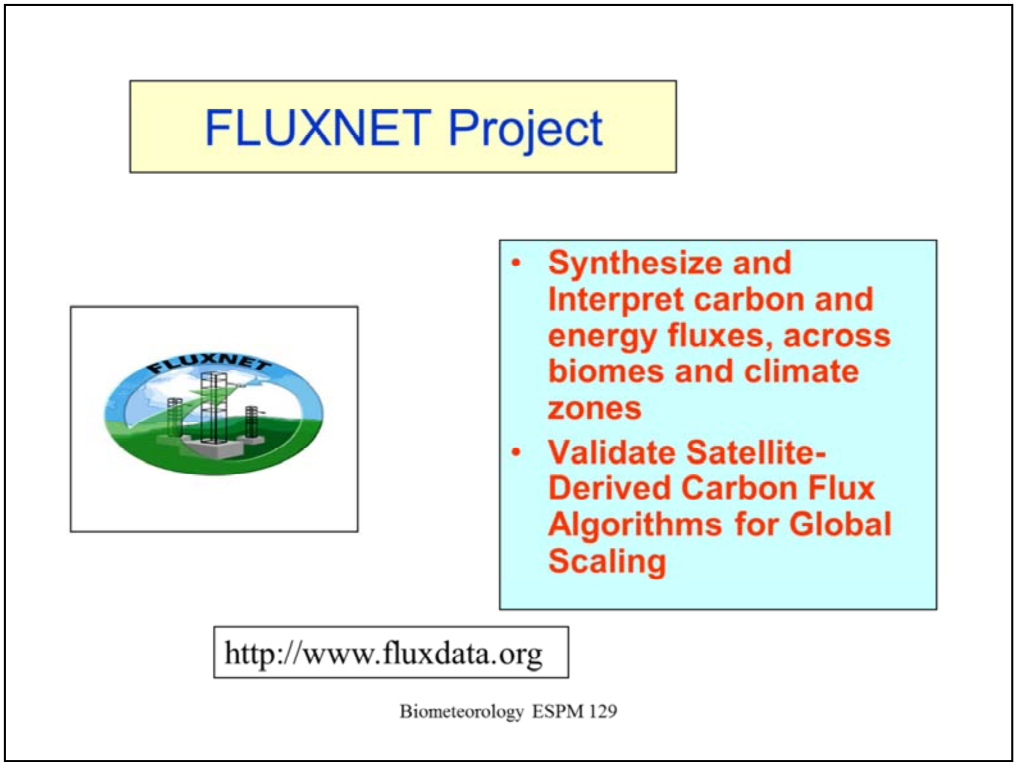
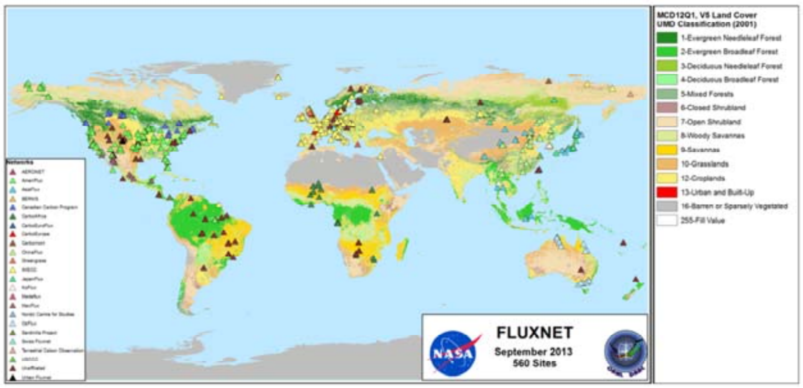
Set of meteorological instruments over a grassland near Ione.



I am PI of a global project called Fluxnet that coordinates flux measurements across the globe.

FLUXNET: From Sea to Shining Sea
500+ Sites, *circa* 2014
www.fluxdata.org



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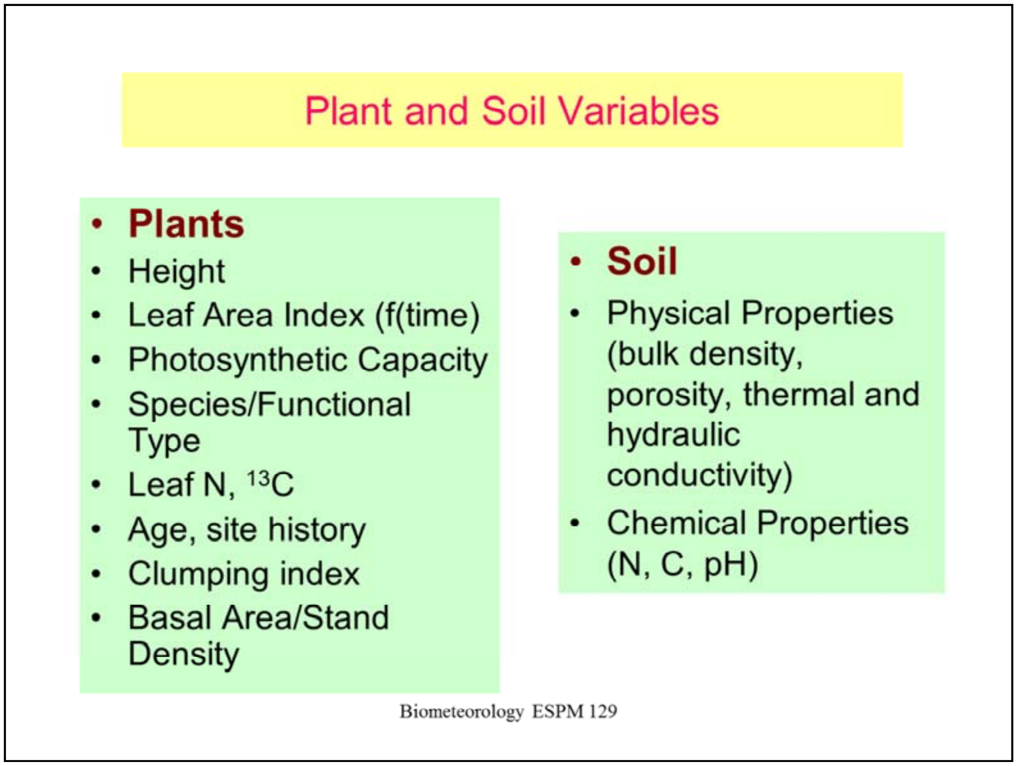
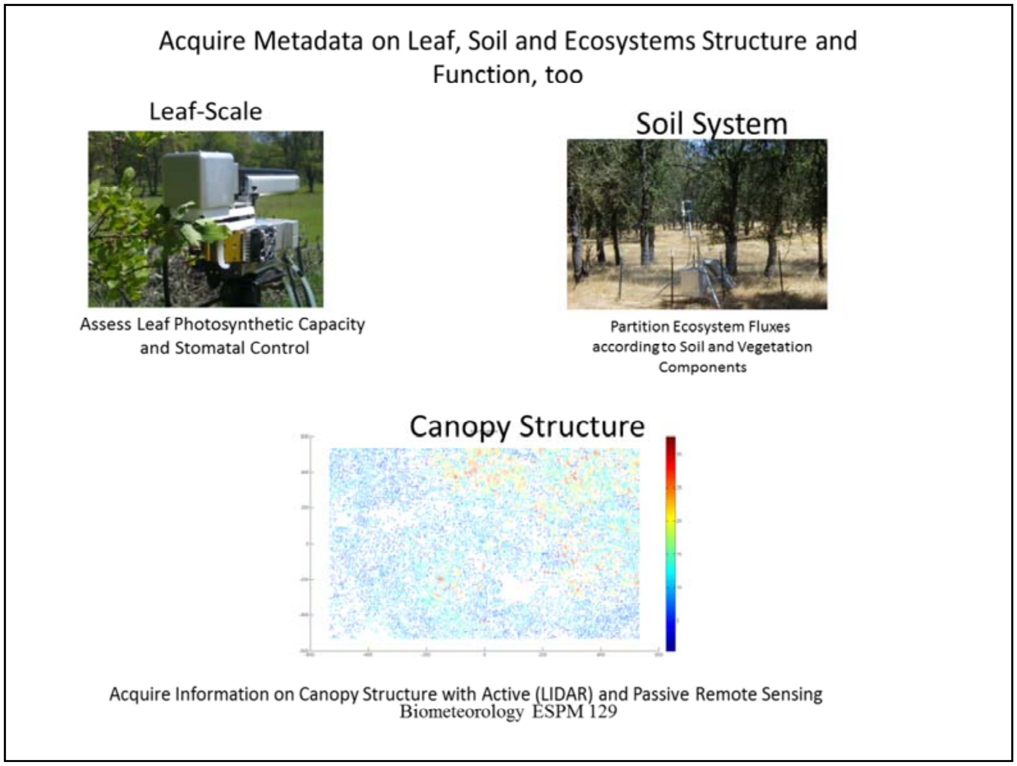
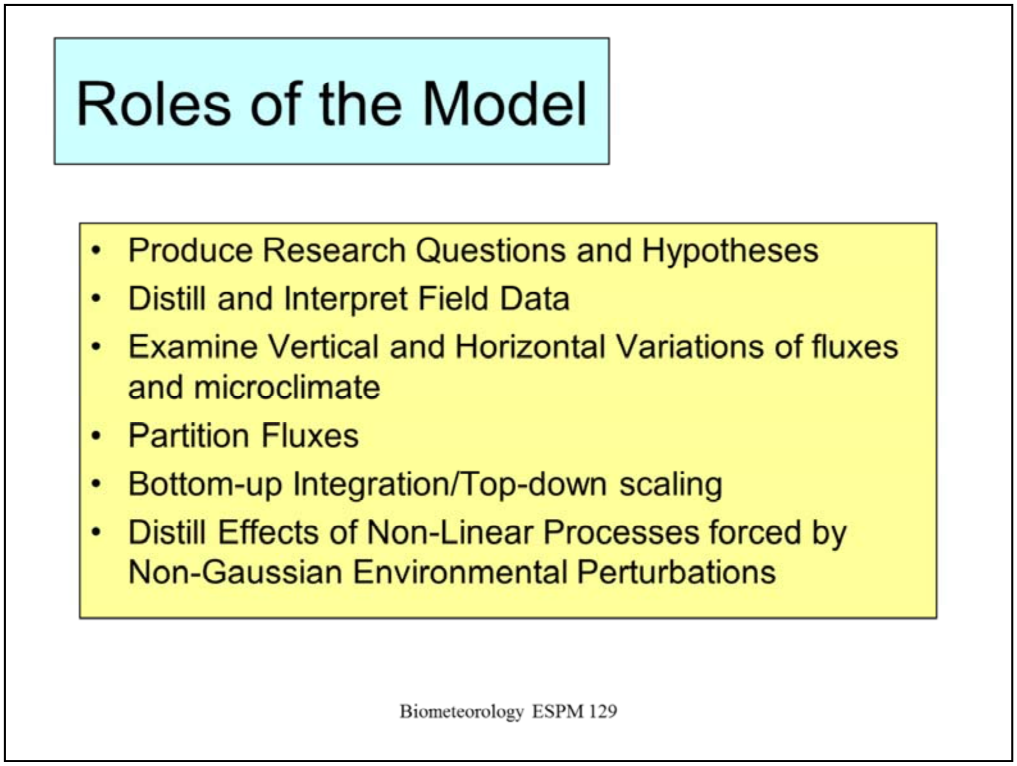
Map of the location and number of flux towers across the globe



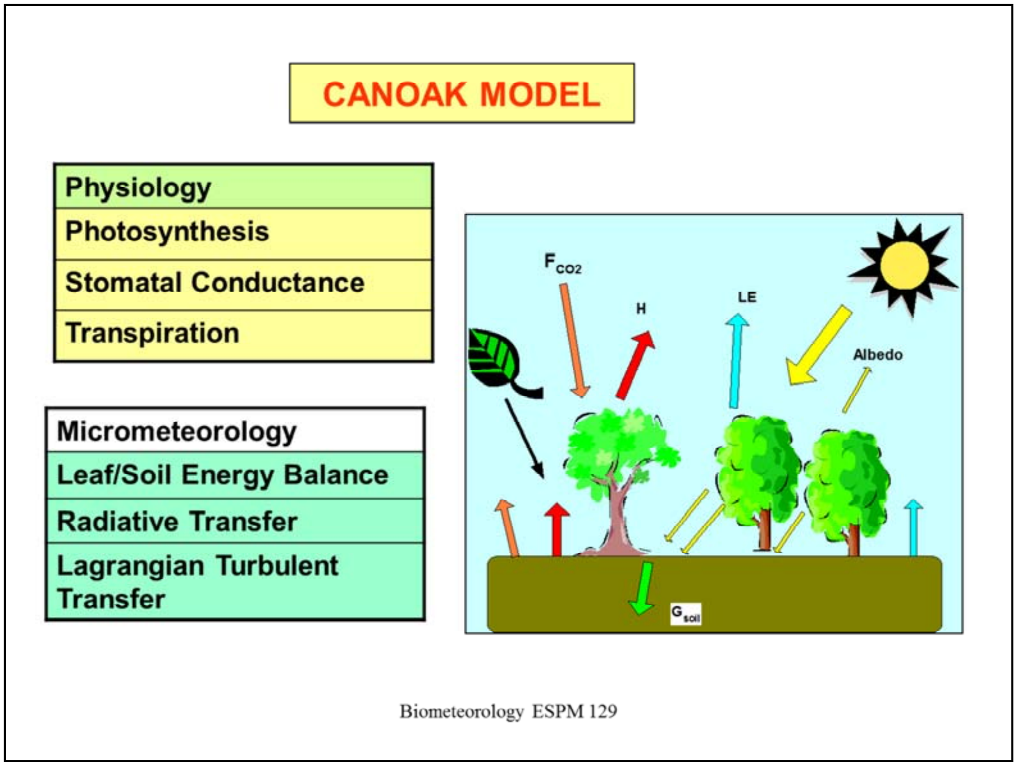
To interpret fluxes and meteorology we must know the state of the vegetation and underlying soil. So a lot of our work is consumed by measuring variables like these.



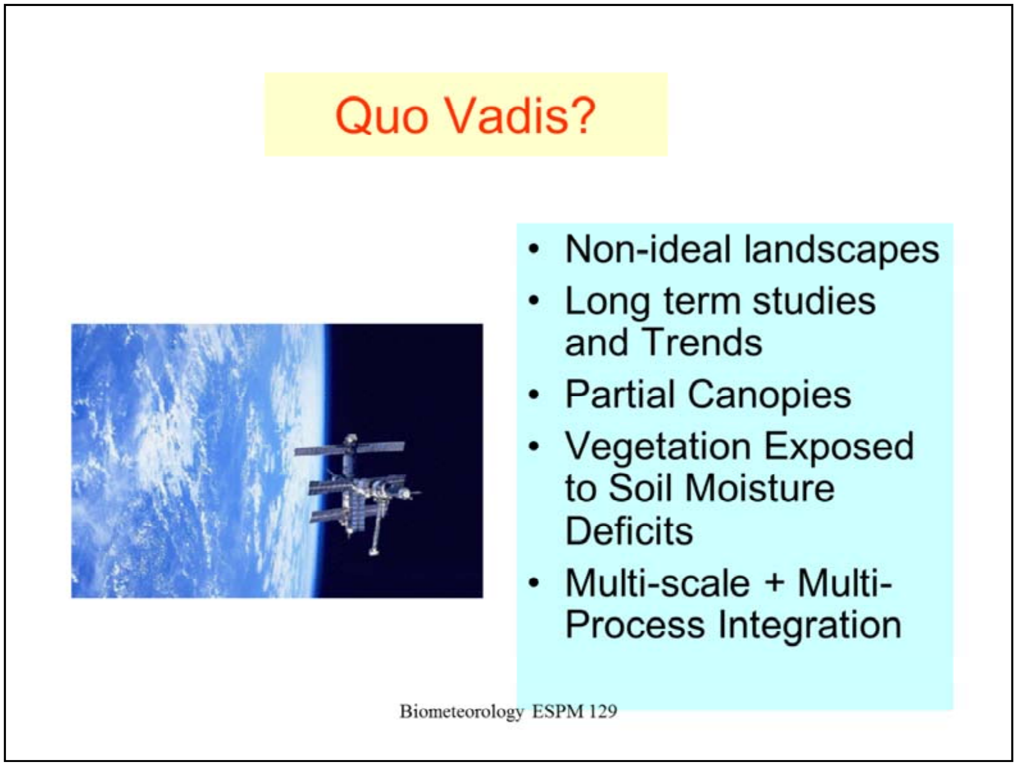
We can make direct measurements of gas exchange on leaves and soils with cuvette systems. We can assess canopy structure directly with destructive sampling or indirectly with remote sensing, including active (LIDAR) and passive (hyper spectral) remote sensing.



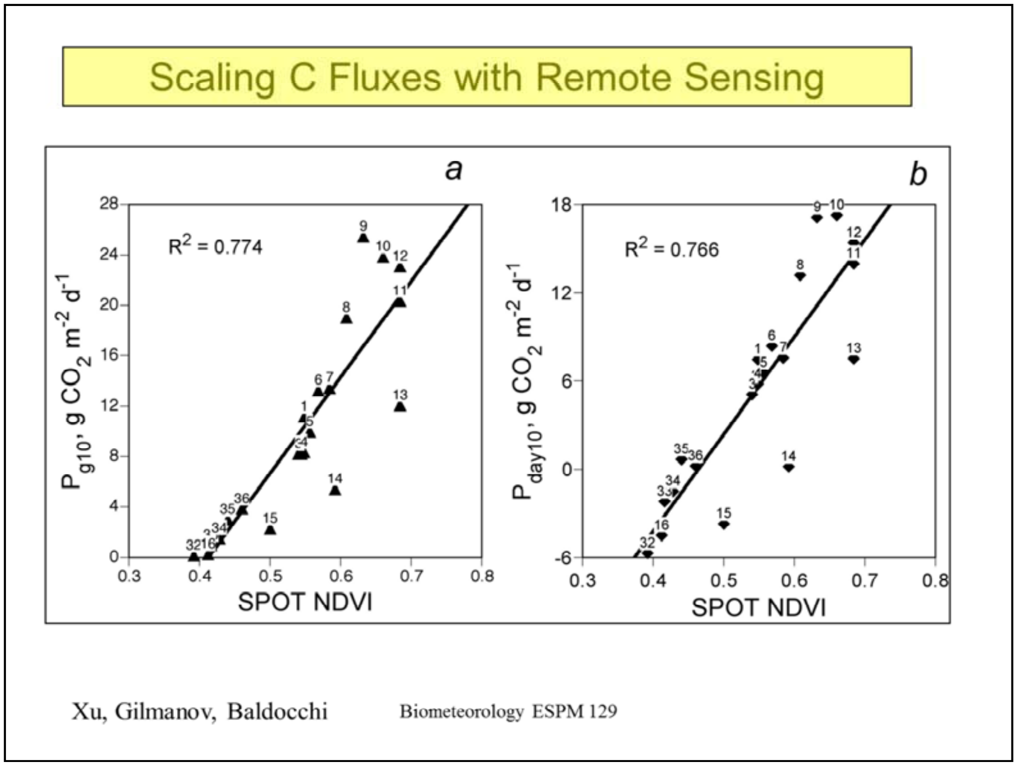
All this data needs to be turned into information and knowledge. Models are key work horses for the distillation, integration and extrapolation of meteorological and flux information in time and space.



Canoak/canveg is a biometeorological model I have developed for this work



In the future we will be less interested on what has been done (though the lessons and fundamentals are important) and we need to focus on where the field is going. The problems get harder and harder, but we have new and better tools to tackle biometeorology problems with.



Remote sensing is one way to upscale CO2 flux data

Class Website

- Bcourse
- Nature.berkeley.edu/biometlab/espm129

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We will use bcourse as a repository for copies of the lecture slides and my notes. I like to share to the outside world and post copies on my lab web site, later.

Grading

- Midterm I (250)
- Midterm II (250)
- Homework + Class Participation (4*50 =200)
- Final (300)
- Total (1000)

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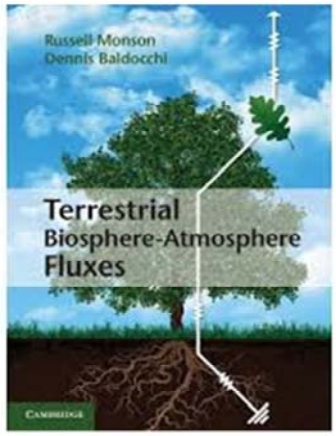
Everyone wants to know how you will be graded. I try to be fair and want you all to succeed, hence several midterms and a final are offered. One can boost one's grade with homework assignments. The homework is also intended to get you better engaged in the topic. We know we all learn better by doing.

Don't be afraid to consult me during office hours or by appointment. I want you all to do well and learn this material.

Reference, not Required



http://ebooks.cambridge.org/ebook.jsf?bid=CBO978113962
9218

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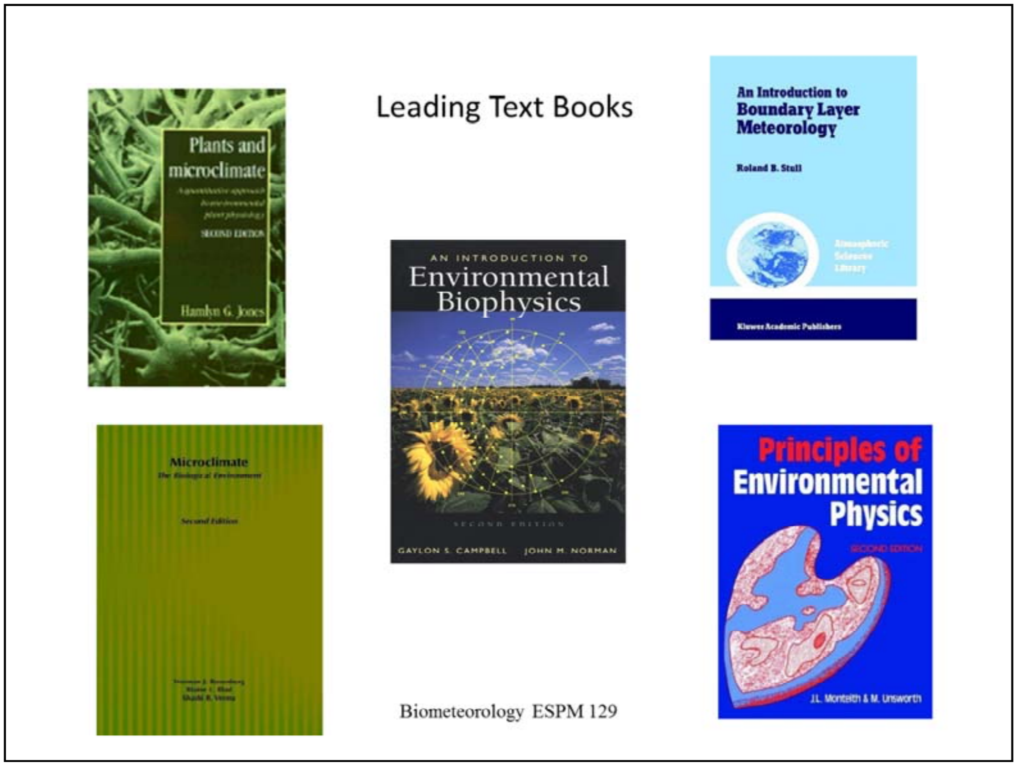
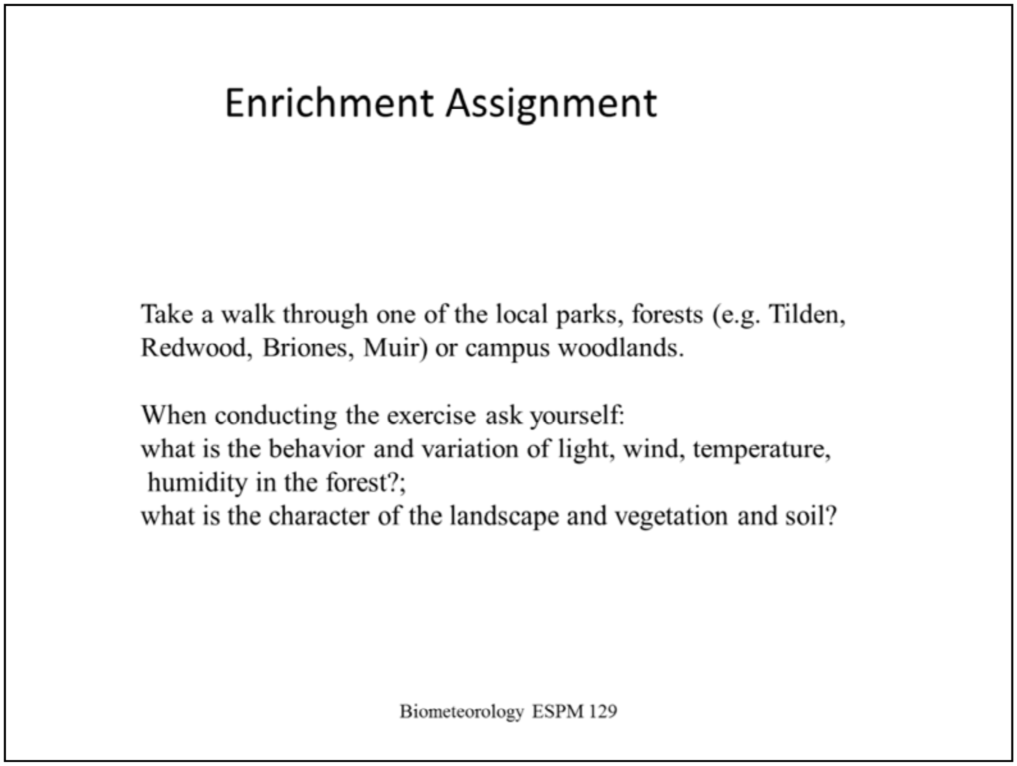
This spring my colleague, Russ Monson and I, published a textbook. Much of it is distilled from the lecture notes Russ and I have developed over the years. Though I will not teach directly from the book, as it is more detailed than this class and the order of material is orthogonal to how I teach this class. But if you like this topic and want a reference, I think it is a good resource. A free version is available as an e book version through the campus library, http://ebooks.cambridge.org/ebook.jsf?bid=CBO9781139629218



I got introduced to this field by Monteith's Principles of Environmental Physics when I took Biometeorology at UC Davis. As a grad student at Nebraska, my Professors wrote and taught from Microclimate, the Biological Environment. Later, another professor on my PhD committee, John Norman, co-wrote Introduction to Environmental Biophysics. In developing my class notes over the years I also drew a lot from Jones' Plants and Microclimates. For the boundary layer meteorological components, Stull's Introduction remains a classic.

Some of these books are available on line from the Berkeley Library. Stull's book is at http://link.springer.com/book/10.1007%2F978-94-009-3027-8

As one grows a personal library these other books are classics and members of the 'must have'/ 'should have'



This week end is Labor Day. I always like to challenge students with a walk in the woods. Take a hike and explore and be conscious of the microclimate about you. Try and use the chat portion of the site to communicate the unique experience you felt and observations you made. What new things did you see as a budding biometeorologists that you may not have thought about in the past?