Lecture 10, Radiative Transfer through Vegetation, Observations, Part 3

- Sampling and measurement requirements
- Statistical tools for evaluating data
- Spatial Variation
  - Vertical profiles of total, direct, diffuse and complementary solar radiation
    - simple vegetation, crops, means, std deve
    - forests, broadleaved and conifer
    - spectral transmission, par, nir, ir
    - net radiation
  - Horizontal transcest
    - data in forests
    - probability distribution of sunlight within canopies
    - gap distribution functions
  - Light quality
- Temporal variation
  - spectra of light fluctuations
  - diurnal pattern of light transmission
  - seasonal pattern of light transmission

A statistical estimate of the number of sensors needed to define the light environment

CV, coefficient of variation (per cent)	n, number of samples (within 10% of the population mean)	n, number of samples (within 5% of the population mean)
150	609	865
100	270	382
50	68	96
25	17	24
10	3	4

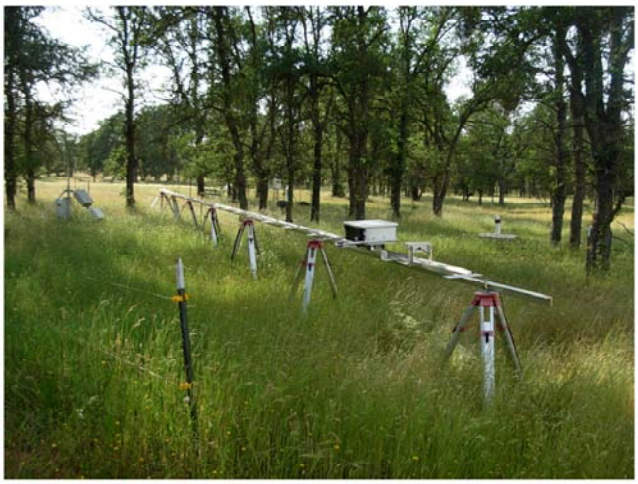
How Many Samples are Needed?

$$n = \frac{t^2 s^2}{d^2}$$

t is Student's t statistic
s is the standard deviation
d is the difference from the mean

Tram with radiation sensors traversing
in the understory of a savanna woodland

30 m Tram System, with Up and Down PAR and Rnet



Aerial View of Tram System

https://www.youtube.com/watch?v=rZNWxPoxYXg

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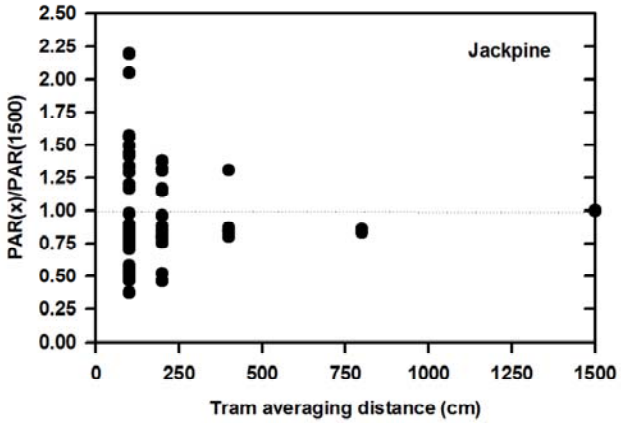
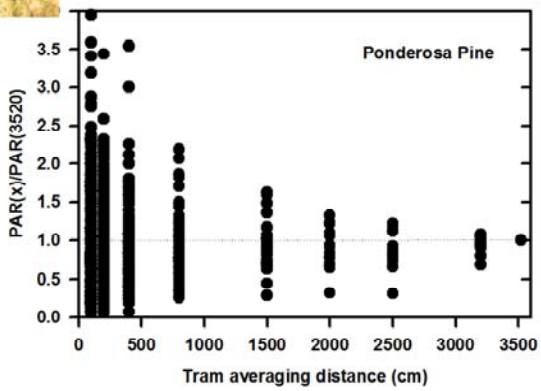
Simulation of light transmission through the canopy near the tram
https://www.youtube.com/watch?v=rZNWxPoxYXg
Plots are curtesy of Dr. Martin Beland

Tram with radiation sensors traversing
in the understory of a jack pine forest

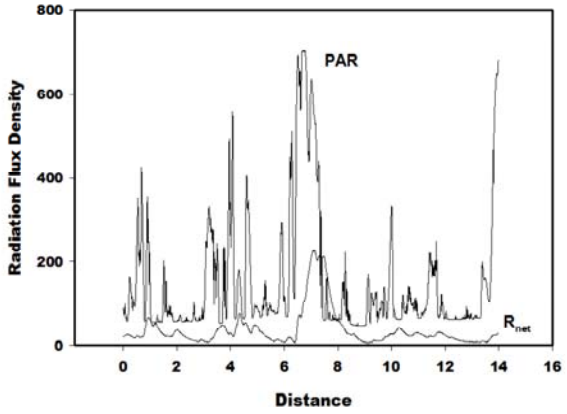
Averaging length needed for radiation measurements under two conifer forests differing in heterogeneity



Sample Length for a Heterogeneous Ponderosa pine stand

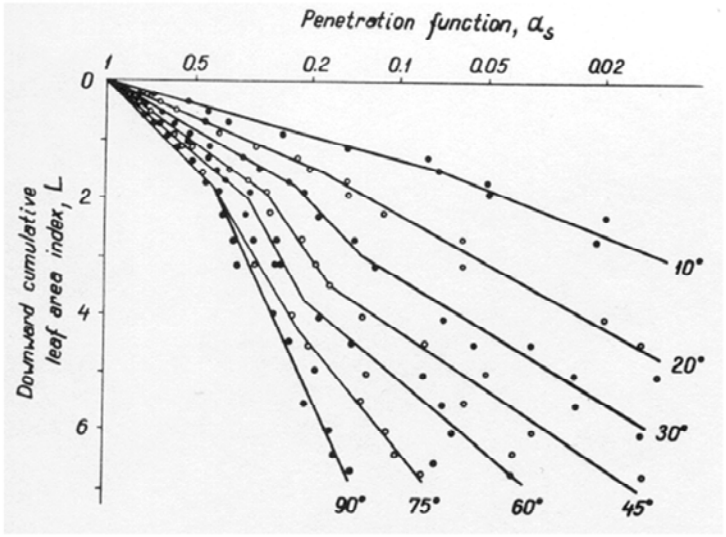


Transects of PAR under a forest canopy



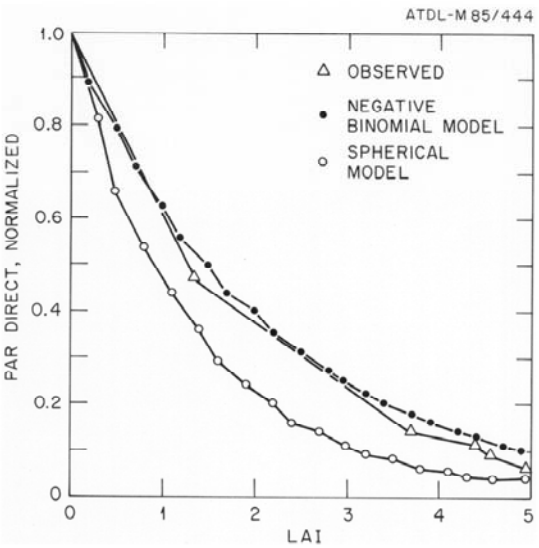
Note the smearing of light with a slow responding net radiometer, as compared with a faster quantum sensor.

Beam radiation penetration through sorghum



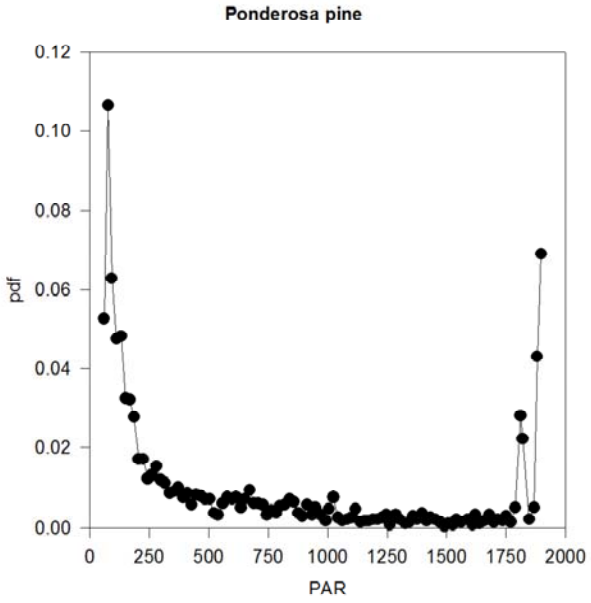
Data of Laisk

Test of beam radiation transmission through a deciduous forest

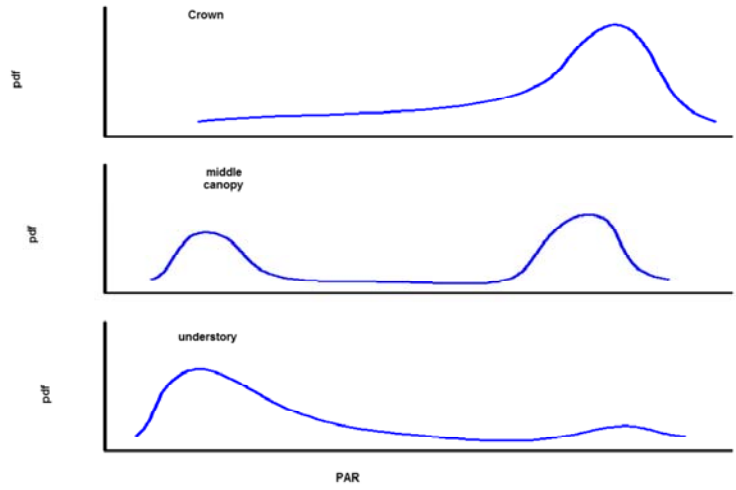


Note how the clumping of foliage enhances the probability of beam penetration as compared to conditions assumed for a forest with randomly distributed foliage

Probability of PAR Transmission across the floor of a ponderosa pine stand



Pdfs of solar radiation



adapted from Ross et al. 1998; Baldocchi et al., 1985

Statistical Moments

Expected Value

$$E[f(x)] = \int_{-\infty}^{\infty} p(x) f(x) dx$$

$$sk = \frac{\overline{x'^3}}{\sigma^3}$$

skewness

$$kr = \frac{\overline{x'^4}}{\sigma^4}$$

kurtosis

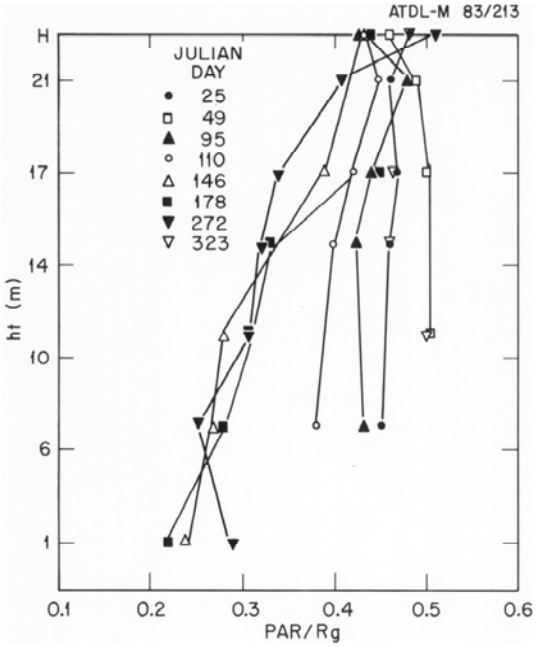
Light Quality

$$E = hc \frac{\int_{400}^{700} E(\lambda) d\lambda}{\int_{400}^{700} \lambda \cdot E(\lambda) d\lambda}$$

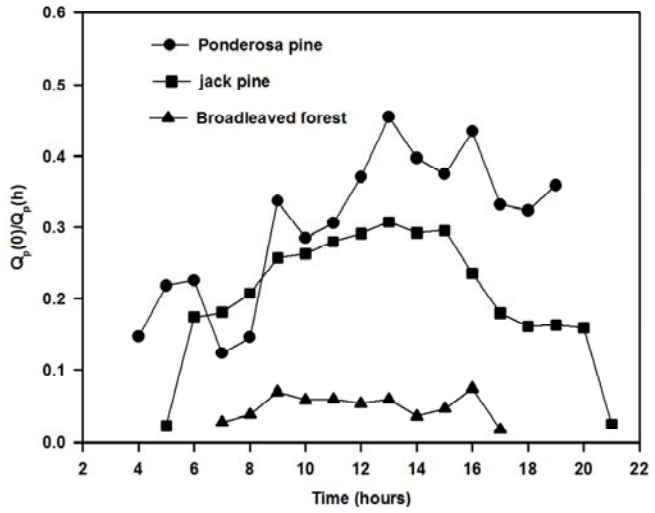
E (μW cm^{-2})	wavelength (nm)
1.3	400
1.7	450
1.6	500
2.85	550
1.85	600
1.4	650
2	700

: 1 W m^{-2} equals 4.329 μmol m^{-2} s^{-1}

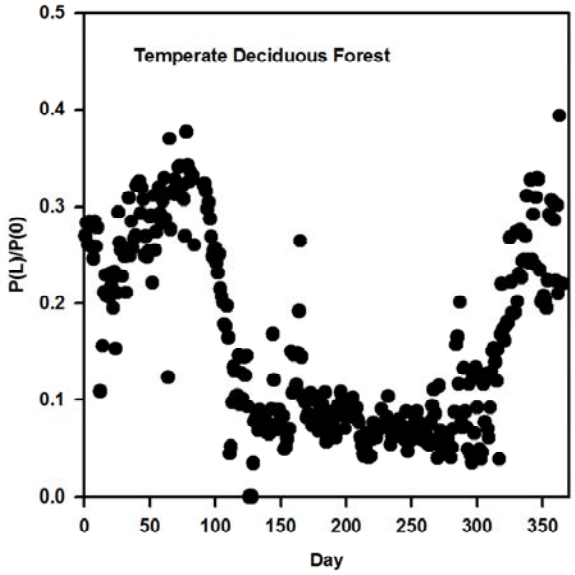
Profile of PAR vs shortwave radiation in a deciduous forest during various seasons



light transmission through contrasting forests



Seasonality of light transmission through a deciduous forest



Schematic of light environment in a deciduous forest

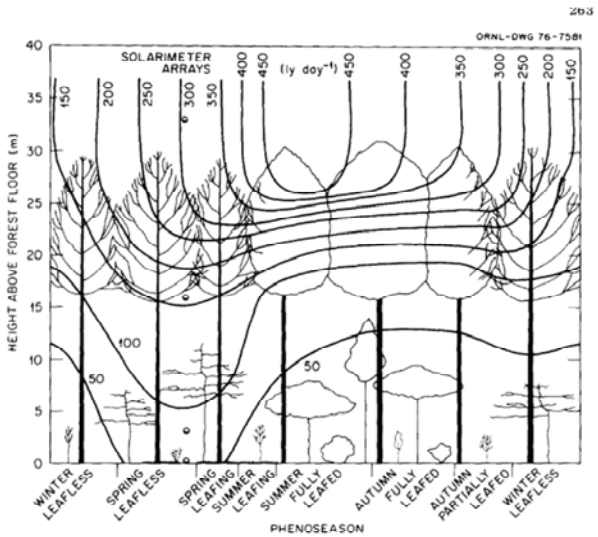
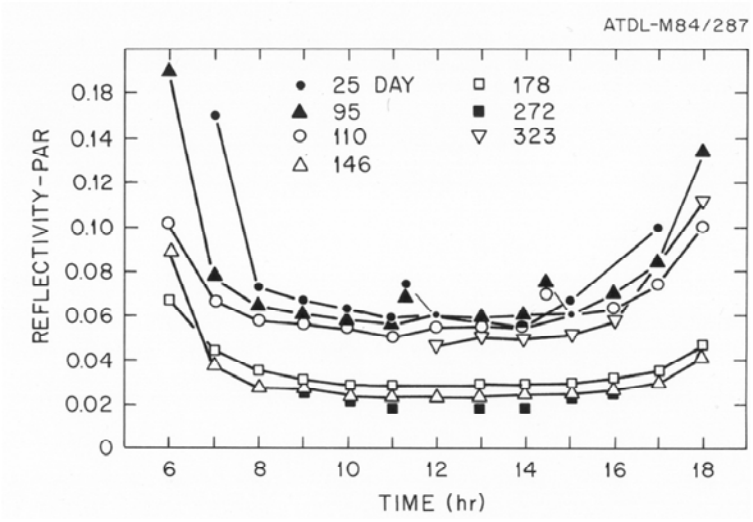


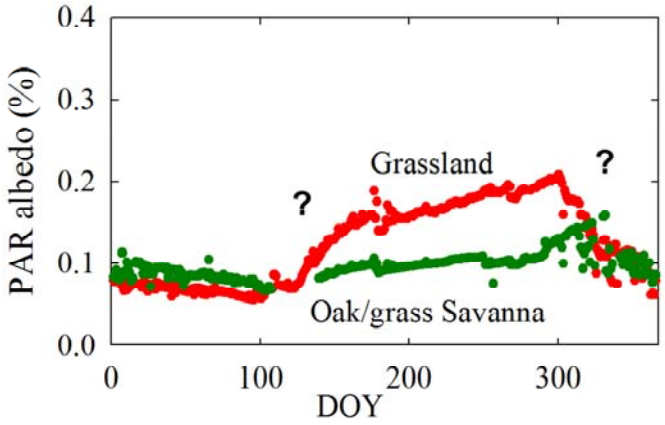
Fig. 4. Synthesized annual course of average daily total solar radiation received above and within the *Liriodendron* forest. ORNL DWG. 76—7581.

(Hutchison and Matt, 1977)

Seasonality of albedo over a deciduous forest



PAR albedo of a grassland and oak savanna, near Ione CA



Midday 4 hr mean data.

Data of Xu and Baldocchi

Summary

- Solar radiation in a plant canopy has much spatial variability.
  - Appropriate sensors and sampling systems need to be employed, such as line sampling or multiple sensors, is needed in the short term.
- Fewer sensors can be used to measure daily integrated radiation.
- Light transmission experience much seasonality due to changes in sun angle and leaf area index