What's needed to improve canopy-radiation interactions in CLM?

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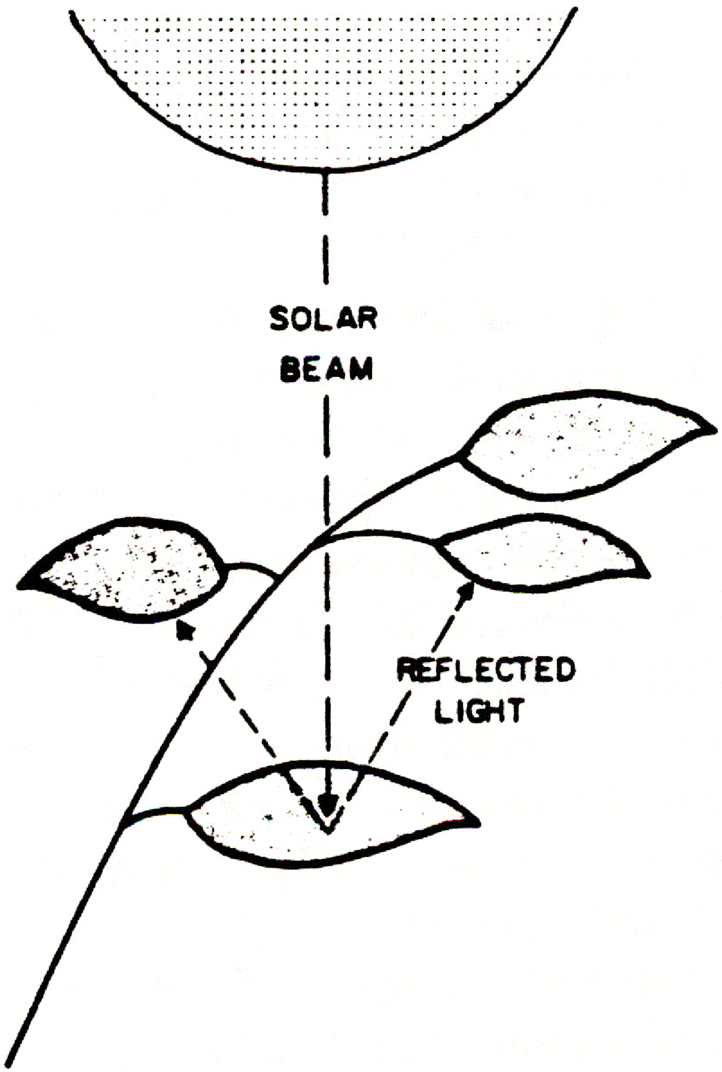
- Define issue
- Summarize recent papers.

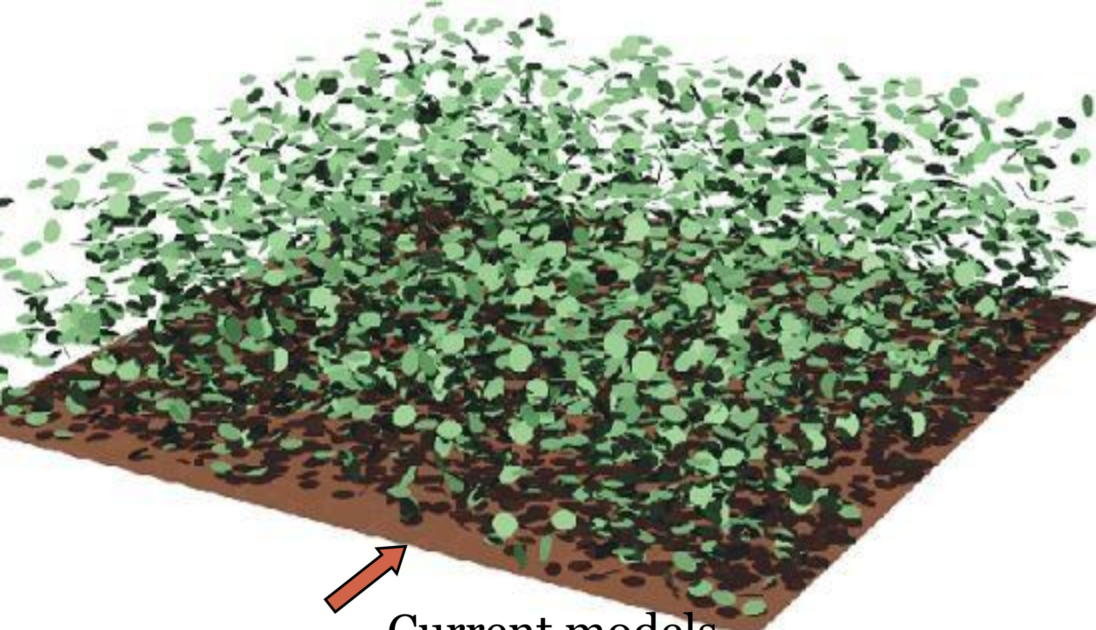
What's wrong with that currently in CLM?

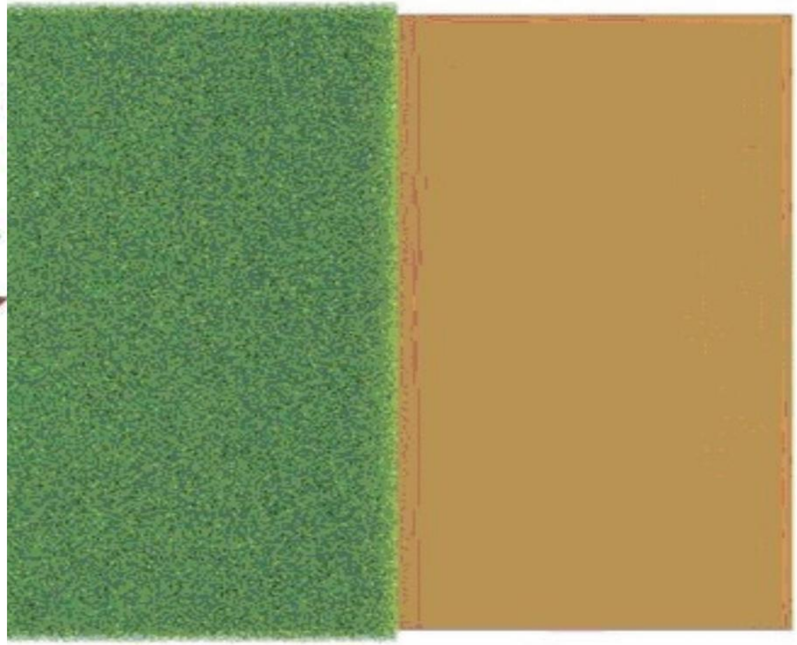
- Radiation designed for treatment of a homogeneous canopy but
- Many if not most canopies are heterogeneous.
- Homogeneous means we need only consider the geometry of leaves, e.g. orientation and LAI
- Heterogeneous means the geometry enters in to determining the radiation.



Sketch of the partial trapping of light reflected from a canopy leaf by overlying leaves.

Ref. Dickinson 1983

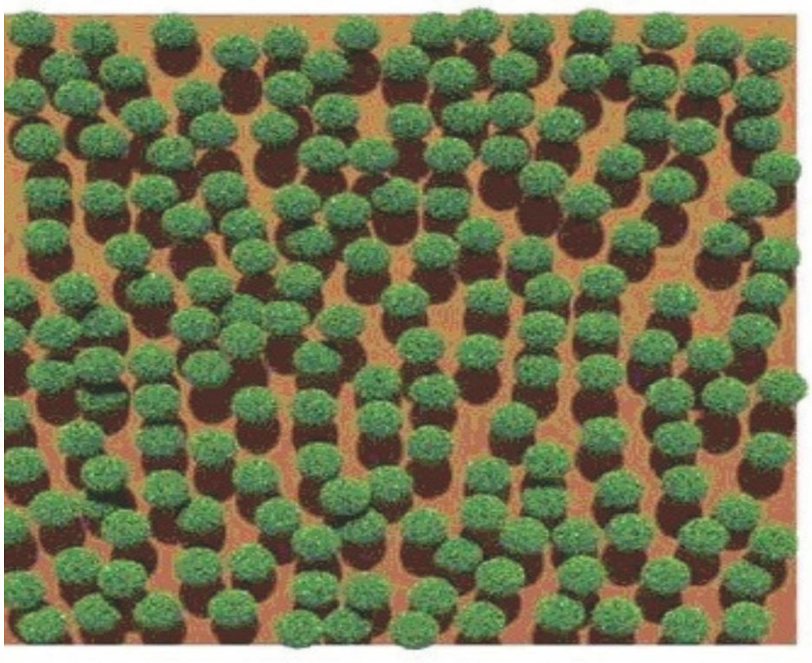




Current models

Thanks to B. Pinty for fig.

Reality



What's the difference?

- Quantitative differences – changes somewhat canopy albedo, changes a lot how much of radiation reflected by underlying soil is absorbed by canopy.
- Major qualitative difference – the surface covered radiatively by the vegetation is that on which shadow is cast, not simply that which lies underneath. Changes a lot the partitioning of radiative heating between soil and canopy
  - Diurnal varying – current definition of pfts applies only for overhead sun

How has sparse vegetation been represented in CLM?

- Earliest Dai et al. version of CLM included fractional vegetation, concept was thrown out as NCAR wanted to separate the bare soil from the pfts as done in LSM.
- CLM 3.0 data from AVHRR apparently largely implemented by uniformly covering bare soil with small LAI vegetation
- CLM 3.5 with Lawrence MODIS data appears to assume small areas of pfts and large areas of bare soil.
- In both cases, the bare and pft fractions interact with the same soil column as if close together.

How do we need vegetation to be represented?

- Where heterogeneity is at the small scale of shadow areas, need to include the bare element as part of the vegetation.
- Suggest new pfts – e.g. for evergreen shrub add a pft called sparse evergreen shrub – associate with it a fractional cover of vegetation, fc as obtained from MODIS continuous fields data set.

What else needs to be changed in model code?

- Refer to Oleson et al, 2004 documentation.
- P 37 need Sv and Sg – solar absorbed by vegetation and ground (similar considerations needed for long-wave but we limit discussion here to solar).
- In current code ground under pft ground only absorbs sun that has been transmitted or scattered as diffuse light through the canopy.
- A sparse pft has a sun angle dependent fractional area of shadow under which logic same as above.
- Area not covered by shadow gets direct sun.

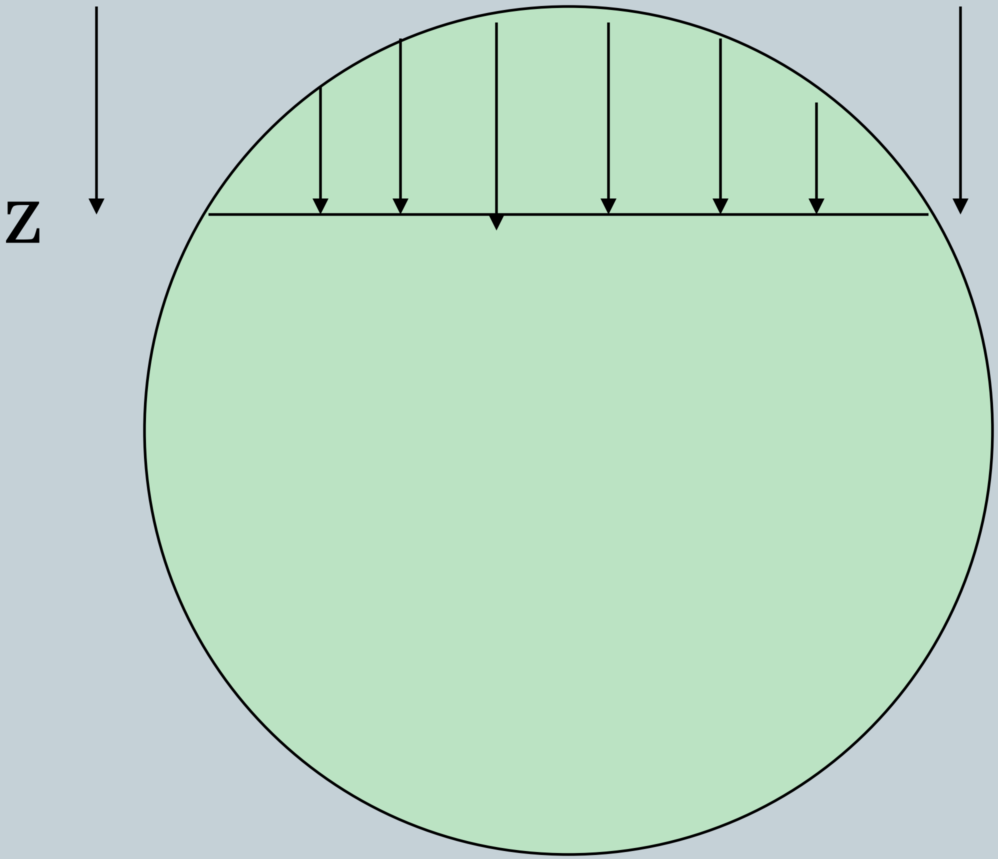
How is canopy heating modified?

- Applies over shadowed fraction of area.
- How such direct beam radiation transmitted or scattered up and down is changed following Dickinson et al (2008), Dickinson (2008) for a single shrub corrected for details left out.
- Details:
  - how to reduce shadowed area for overlapping shadows? And how to compensate for the overlap by adding extra leaves to the single shrub.
  - Solutions are for spherical shrub. Easy to make prolate spheroids but need aspect ratio data for the vegetation to do so

Treatment of shadow overlap

- Fractional area of shadow should approach 1 as shadows fc S large (S the relative area of a single shadow- for sphere is 1./ cosine of sun angle).
- Should approach fc S when this is small.
- Many possible ways to do this – can associate with such ways statistical models of the bush distribution.
- Simplest statistical model is the same as used for leaves, i.e use for fractional area of shadow:

$$[1. - \exp(- fcS)]$$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Add extra leaves to represent shadow overlap

- Because of overlapping shadows , shadowed area reduced by f = (1. – fcS) / fcS
- Easiest, but perhaps least realistic (suggested by Xiowen Li). Use an LAI equivalent of LAI/f
- Put the extra leaves as homogeneous layer above canopy – has benefit of approaching homogeneous canopy description with large enough LAI
- Confine bush to a cylinder with radius smaller than that of the initial sphere and representing an average of what remains sunlight after shadow overlap

Vegetation Fractional Cover for Radiation Computation

- **Starting Point**: MODIS/Terra Dataset for Vegetation Continuous Fields at Global 500m : Percent of Canopy cover for *Broadleaf, Needleleaf, Evergreen, Deciduous, Shrubs, Crops, Other Herbaceous, Ice and Bare Ground.*
- *Bare Ground fraction below a threshold value (say 40%) can be distributed evenly by increasing the vegetation coverage and defining fractional cover parameter. Canopy cover goes to crown cover by divide by 0.8*
- ***Example****: A 500m patch with:*

Canopy Cover Fraction	
Evergreen tree	**37%**
Shrubs	**25%**
Bare Ground	**38%**

Adjusted to Crown Cover	
Evergreen tree	**46%**
Shrubs	**31%**
Bare Ground	**23%**

Adjusted for Fraction Cover	
Evergreen Broadleaf	**60%**
Shrubs	**40%**

with fractional coverage 0.77 for both land covers.

- *Bare ground tile contribution computed only when less than 5% vegetation in a pixel. Assuming pixels are of equal area, above logic applies equally well to fractions obtained by aggregating over the gridsquare -bare pixels left out*