1 ❑ EMR response: vegetation

2 ❑ Vegetation properties from RS

- Critical inputs to land surface process models, driving biochemical models, & other biospheric functions
  - Albedo
  - Leaf area index (LAI)
  - Fractional photosynthetically active radiation (FPAR) absorbed by canopy
  - Surface roughness
  - Phenology

3 ❑ Vegetation models

- Physically-based canopy reflectance models that link canopy properties with sensor-measured radiance
  - Radiative transfer models
  - Geometric optical models
  - Computer simulation models

4 ❑ Canopy radiative transfer formulation

- Canopy configuration
  - 1-D turbid medium (atmosphere & water) with canopy elements randomly distributed
  - Canopy field with leaves – fig. 3.1
- Canopy architecture
  - Leaf area index (LAI)
  - Leaf angle distribution (LAD)
  - Leaf dimension
- Suitable for dense vegetation canopies

5 ❑ One-dimensional radiative transfer equation

- Early modeling work
  - Suits (1972) model
    - Vertical & horizontal leaves
    - Canopy structure & solar/viewing geometry
  - Verhoef (1984) model – SAIL (light *s*cattering by *a*rbitrarily *i*nclined *l*eaves) canopy model
  - Gastellu-Etchegorry et al. (1996) improved SAIL by considering anisotropic behavior of soil background

6 ❑ One-dimensional radiative transfer equation

- Use a flat homogeneous canopy
- Diffuse scattering of the leaves
  - Bi-Lambertian scattering model
- Interactions of photons with leaves
  - Specular reflectance
  - Lambertian diffuse reflectance
  - Lambertian diffuse transmittance
  - Controlled by canopy configures & its optical properties

7 ❑ Boundary conditions

- Need to specify upper (bottom of atmosphere) & lower boundary conditions

- Determine sky radiance distribution
  - Depends on reflectance from canopy
  - Iterative process

8 ❑ Hotspot effects

- Hotspot – a reflectance peak around a viewing direction that is exactly opposite the solar illumination direction
- Based on shadow hiding theory
  - Viewing direction coincides with the solar viewing direction – no shadows are seen & observed radiance reaches a local maximum

9 ❑ Hotspot effects

- Hotspots one of most information-rich subregions in a BRDF space
- Retrieve canopy structural parameters
  - Leaf size & shape
  - Tree crown size
  - Canopy height for low-LAI stands

10 ❑ Formulations for heterogeneous canopies

- Canopy heterogeneity – row crops or orchards with isolated tree crowns
- DART (discrete anisotropic radiative transfer) model
  - 3D Cartesian geometry

11 ❑ Leaf optical models

- Leaf reflectance – Fig. 3.8 – typical response characteristics of green vegetation
- Optical properties of scattering elements – leaves (microstructure & material property of leaves) – are needed in a canopy model
- Want to retrieve biochemistry from canopy reflectance observations
- Suitable for handing sparse vegetation canopies with regular shaped crowns

12 ❑ "Plate" models

- PROSPECT (Allen et al. 1969) model simulates leaf reflectance & transmittance – broadleaf canopies
  - Uses geometric optical principles
  - Index of refraction & absorption coefficient

13 ❑ Needleleaf models

- LIBERTY (leaf incorporating biochemistry exhibiting reflectance & transmittance yields)
- Linear summation of individual absorption coefficients of major constituent leaf chemicals, according to their content per unit area of leaf

14 ❑ Ray tracing models

- Detailed description of individual cells & their unique arrangement inside tissues
- Optical constants of leaf materials defined

15 ❑ Stochastic models

- Stochastic leaf optical models based on Markov chain theory
- Probability of occurrence of leaf states – Fig. 3.12 – described by the elements of

a vector – state vector

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17 ## Turbid medium models

- Use Kubelka-Munk theory – consider leaf as a slab of diffusing & absorbing material

18 ## Solving radiative transfer eqs.

- Numerical & approximate solutions
- Several examples described in text

19 ## Geometric optical (GO) models

- Canopy consists of a series of regular geometric shapes placed on the ground
- Li & Strahler (1985) model

20 ## Computer simulation models

- Use for accurate computation of the radiation distribution over a complex canopy configuration
- Want to understand the radiation regime & validate some simplified models
- Retrieve biophysical parameters

21 ## Computer simulation models

- Typical methods:
  - Monte Carlo ray tracing (MCRT)
    - Forward & reverse ray tracing
    - Combination – bidirectional ray tracing
  - Radiosity (radiant existence) method
  - Based on light transport (or rendering) eq. – computer graphics applications, realistic scene rendering