

- 1 ☐ EMR Response: Soil & Snow
- 2 ☐ Soil & snow
 - Lower boundary condition of vegetation canopies
 - Important role in surface radiation budget – high albedo values
- 3 ☐ Soil
 - Physical & chemical properties
 - Soil carbon, nutrition, phosphorus, bulk density & particle size distribution
 - Needed in agricultural, ecological & hydrological models
- 4 ☐ Snow
 - Geophysical properties
 - Snow-covered area, water equivalent & grain size
 - Modeling soil & snow radiation – helps in developing the advanced algorithms to estimate their properties
- 5 ☐ Similarities of soils & snow
 - Model bidirectional reflectance distribution functions of soils & snow
 - Both characterizations of dense particulate media – densely packed
 - Models as spheroids
 - Surface roughness – order of mm to cm
 - Anisotropic diffuse & direct solar illumination irradiance
- 6 ☐ Single scattering properties of snow & soil
 - Single particle scattering & absorbing quantities required for calculating multiple scattering
 - Single scattering albedo, ω , which represents the probability that light incident on a particle will be scattered
 - Particle scattering phase function $P(\theta)$, where θ is the scattering angle
- 7 ☐ Mie theory
 - Mie scattering – large particles
 - Particle size is close to the length of the wavelength – $0.1 < \chi < 50$ – aerosol particles in the atmosphere
 - Assume snow & soil particles can be modeled as spheres
 - Know the size distribution & refractive indices of components comprising the particulate media
 - Use Mie theory to provide optical parameters of individual particles
- 8 ☐ Optical properties of snow
 - Model as layered particulate medium composed of ice spheres in air
 - Use refractive indices of ice and an optically equivalent ice sphere radius – Mie theory used to calculate single particle scattering & absorption
- 9 ☐ Mie theory
 - Snow grains behave as spheres (or optically equivalent spheres)
 - Snow grain radii – range in size from 50 μm for fresh, cold snow to 1000 μm representing wet snow or grain clusters
- 10 ☐ Optical property

- Spectral variation in the reflectance of snow in visible and near-infrared wavelengths – absorption coefficient (imaginary part of the refractive index) varies by 7 orders of magnitude at wavelengths 0.4-2.5 μm (Fig. 4.1)

11 ☐ Optical properties of soils

- Need to know mineral & organic components of the soil, relative fractions estimated
- Mie scattering theory – less successful for soils due to:
 - Particle size – much larger than the visible & near IR wavelengths ($\chi \sim 50$)
 - Particle shape – nonspherical shape of soil particles

12 ☐ Other approaches for soils

- Ray tracing approach
 - considers diffraction, reflection, refraction of a large particle
- Anomalous diffraction theory
- Method of complex angular momentum
- High-energy approximation

13 ☐ Multiple scattering solutions

- 3 categories of solutions
 - Approximate solutions
 - Numerical solutions
 - Geometric optical modeling
 - Can represent soil roughness effects

14 ☐ Approximate solutions

- Radiative transfer equations for snow – Warren & Wiscombe
 - 2-stream approximation – diffuse upwelling flux from either snow or soils

15 ☐ Snow

- Approximation characterizes the strong forward scattering of snow throughout the optical region
 - Physical depth & bulk density of snowpack affects scattering & absorbing properties via the optical depth, τ
 - Optical depth – dimensionless quantity
 - Snow – related to snowpack density, depth, snow grain size, and wavelength of observation

16 ☐ Snow: surface albedo depends

- Snow particle size
 - Increasing grain size affects albedo more in the NIR than visible
 - Albedo sensitive to grain size, 1.0-1.3 μm
- Water equivalence
 - Reflectance reduced as snow water equivalence (depth) decreases
- Solar zenith angle
 - Increased angles result in larger snow reflectance

17 ☐ Soil

- Hapke model of bidirectional reflectance
- Retrieve soil physical properties

18 ☐ Numerical solutions

- Use discrete ordinates & adding-doubling numerical methods – determine bidirectional reflectance quantities of snow & soil

19 ☐ Geometric optical modeling

- Mathematical expressions used to describe the geometry of the surface – soils
- Bidirectional reflectance calculated from parameterizations of reflectance & transmittance of the 3-D objects that make up the scattering medium

20 ☐ Soil surface

- Simulate soil aggregates by cuboids
- Monte Carlo method – soil surface height varies periodically with the cosine function in 1 or more directions
- Opaque spheres in a regularly spaced grid over an isotropically scattered horizontal surface

21 ☐ Inversion of snow parameters

- Estimate snow parameters from RS data – snow albedo, snow grain size, equivalent water content

22 ☐ Snow grain size

- Primary parameter controlling broadband albedo
- Rate of change of grain growth is exponentially proportional to snow temperature
- Changes in grain size
 - Useful indicators of thermodynamic processes in snowpack
 - Can help identify ice sheet surface features
 - Melt areas, snow dunes, blue ice regions, indicates changes in snow energy balance

23 ☐ Snow grain size

- Snow reflectance in NIR wavelengths is sensitive to grain size
- In visible wavelengths, insensitive to grain size
- Snow reflectance strongly affected by the texture of the uppermost layer of the snow surface

24 ☐ Practical issues

- Snow and soil surface roughness
- Soil inversion with ancillary information
- Soil moisture conditions