CE806 – Introduction

Background

- Optical remote sensing – 0.4-14 μm
- Radiometric variables
- Physical concepts
- Major components of a remote sensing modeling system
  - Link remote sensing with land surface variables
    - Continuous variables – leaf area index, albedo
    - Categorical variables – land cover

Quantitative models to estimate land surface variables

- Categories of quantitative models:
  - Statistical
  - Physically-based
  - Hybrid – combine both statistical & physical models
- These models use the following signatures:
  - Spectral
  - Spatial
  - Temporal
  - Angular
  - Polarization – beyond scope of this course

Statistical models

- Based on correlation relationships of land surface variables & remotely sensed data
- Easy to develop; effective to summarize local data
- Usually site-specific
- Cannot account for cause-effect relationships

Physically-based models

- Follow the physical laws of the remote sensing system
- Establish cause-effect relationships
- If model doesn't perform well, can improve by incorporating latest knowledge & info
- Takes a long time to develop & learn
- Model is an abstract of reality – can be complex with large number of variables

Basic concepts

- Digital numbers
- Radiance
- Solid angle
- Irradiance
- Bidirectional reflectance and albedo
- Extraterrestrial solar irradiance

Digital numbers – DNs

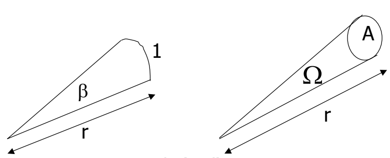
- Early statistical models used DNs to estimate surface characteristics directly
- Raw data from data providers
- Scaled integers from quantization
- Linear quantization systems – 6-12 bits
- DN $\in$ [1, 2^Q]
  - Higher Q leads to higher radiometric precision

Radiance

- DNs – convert to physical quantities to estimate land surface variables, such as radiance (intensity)
- Spectral (monochromatic) radiance – energy per area per solid angle per unit wavelength – W cm^{-2} Sr^{-1} μm^{-1}
- DNs linearly related to radiance
  - Remote sensing data providers give conversion coefficients – sensor calibration

Solid angle

- Using the solid angle (Ω) takes into account the directional dependence of radiance – Fig 1.1



β = 1/r (rad)

Solid angle

- Arc length of full circle is $2\pi r$ – angular measure is 2π rad
- Solid angle $\Omega = A / r^2$ (sr)
- For a sphere whose surface area is $4\pi r^2$ – its solid angle is 4π sr
- Solid angle of upper or lower hemisphere is 2π sr

Solid angle

- Solid angle often represented by zenith & azimuth angles in polar coordinates (Fig. 1.2)
- Zenith angle ranges from 0 to 180°
  - 0-90° upwelling hemisphere: $0 \le \mu \le 1$
  - 90-180° downwelling hemisphere: $-1 \le \mu \le 0$
- Azimuth angle ranges from 0 to 360°
  - $0 \le \phi \le 2\pi$
- Viewing zenith angle not equivalent to the sensor scan angle (Fig. 1.3)

Irradiance

- Flux density or flux
- Irradiance, E – integration of radiance (L) over the entire solid angle of a hemisphere consisting of the zenith angle (θ) and the azimuth angle (ϕ)

Bidirectional reflectance & albedo

- Upwelling radiance depends on the incoming solar radiation
- To normalize the variation of the incoming solar radiation, the top-of-atmosphere (TOA) radiance $I(\theta_v,\phi_v)$ converted from DN at the specific viewing direction is further converted to reflectance

Bidirectional reflectance & albedo

- Spectral bidirectional reflectance distribution function – BRDF
- In practice, use the dimensionless bidirectional reflectance factor – BRF
- Surface directional hemispherical reflectance – DHR – local or planar albedo (black-sky albedo)
- Bihemispherical reflectance – BHR – is a further integration of DHR over all illumination directions – global or spherical albedo (bright-sky albedo)

Extraterrestrial solar irradiance

- Incoming TOA irradiance depends on the astronomical distance between the Sun & Earth
- Total irradiance integrated over all wavelengths is called the solar constant
- Need to select the right data source of TOA solar irradiance

Remote sensing modeling system

- Model an optical remote sensing system
  - Scene generation
  - Scene radiation modeling
  - Atmospheric radiative transfer modeling
  - Navigation modeling
  - Sensor modeling
  - Mapping and binning

Scene generation

- Quantitative description of our understanding of the land surface
  - Quantifies the relationships among the type, number and spatial distribution of objects & the background in the scene of a land surface
- H- (high) and L- (low) resolution models
  - Fractals and Lindenmayer (L) systems

Scene radiation modeling

- Use 3 types of models to characterize the radiation field of the scene:
  - Geometric optical models
  - Turbid-medium radiative transfer models
  - Computer simulation models

Atmosphere radiative transfer modeling

- Earth's atmosphere affects remote sensing imagery significantly
- Atmospheric gases, aerosols, and clouds scatter and absorb the incoming solar radiation & the reflected and/or emitted radiation from the surface
- Modulates the spectral dependence & spatial distribution of the surface radiation

Navigation modeling

- We need to calculate the position of the satellite in space, track it from earth, and know where the instruments are pointing – concern of the engineer

Sensor modeling

- Spectral response functions
  - L_b – effective (average) spectral radiance of a specific band
- Spatial response, characterized by MTF (modulation transfer function), precise measurement of details & contrast made in the frequency domain
  - Fourier transform of the MTF, is called the point spread function (PSF)
  - Define the effective instantaneous field of view (EIFOV)

Mapping & binning

- Geolocation of the central point & other parameters of each measurement need to be determined
- Important process in image generation is to bin these measurements into a 2-D array with one particular map projection
  - Equal-area map projections (SOM, UTM)
- Forward binning & inverse binning methods

Remote sensing modeling system

- Forward modeling scheme predicts what remotely sensed data will be under a set of environmental and sensing conditions
- Physically-based inversion scheme determines various land surface geophysical & biophysical variables from remotely sensed data
- Need a good physical understanding of the different components in a remote sensing system

Summary

- Radiometric variables introduced
- Major components of a remote sensing modeling system described