1 ❑ Atmospheric correction of optical imagery

2 ❑ Introduction

- Various practical algorithms are available to remove atmospheric effects from remotely sensed data – want to recover surface reflectance
- Preprocessing step – introductory remote sensing
- Critical step – quantitative remote sensing – most inversion algorithms are based on surface reflectance that are retrieved from atmospheric correction

3 ❑ Introduction

- Large portion of optical RS imagery is contaminated by aerosols, clouds & shadows
  - Want to remove these atmospheric effects from imagery – beneficial for land surface characterization
- As use RS data more quantitatively
  - Want accurate retrieval of surface reflectance
  - All canopy models used for inverting canopy biophysical parameters are based on surface reflectance

4 ❑ Atmospheric correction

- To retrieve surface reflectance from RS imagery is called *atmospheric correction*
  - Process that converts the top-of-atmosphere (TOA) radiance to surface reflectance
  - Difficulties – variations of concentrations in time & space: aerosols & water vapor
    - Aerosols – shortwave bands
    - Water vapor – affects the near IR bands

5 ❑ Atmospheric correction

- Two major steps:
  - Atmospheric parameter estimation
  - Surface reflectance retrieval
    - Straightforward, as long as all atmospheric parameters are known
    - Look-up table method – radiative transfer codes are used offline (tables are created before running atmospheric correction code) to compute tables for online corrections
- To estimate atmospheric parameters from imagery itself – more difficult & challenging

6 ❑ Atmospheric effects

- Molecular & aerosol scattering & absorption by gases (water vapor, ozone, oxygen, & aerosols)
  - Easy to correct for molecular scattering & absorption by O_3, O_2 & aerosols because of stable concentrations of these elements over time & space
  - Most difficult task to estimate spatial distributions of aerosols & water vapor directly from imagery

7 ❑ To correct single-viewing-angle imagery – invariant-object method

- Assume some pixel reflectances in a scene are quite stable through time
- Linear relationship – based on reflectance of these invariant objects – used to normalize imagery acquired at different times
- Relative normalization procedure – used in FIFE
- If simultaneous ground reflectance measurements available or some assumptions about surfaces can be made – can be an absolute correction procedure

8 ❑ To correct single-viewing-angle imagery – invariant-object method

- Fig. 6.1 – linear regression analysis
- Ideally need to identify "invariant" pixels with variable brightness from dark to bright in each band (not very bright, very dark pixels)
- Normalizing top-of-atmosphere (TOA) radiance not equivalent to normalization of surface

reflectance because of nonlinear relationship between TOA radiance & surface reflectance

9 To correct single-viewing-angle imagery – look-up table method

- Step 1: Create tables of variables [L_p, *s*, $E_0\ \gamma(\mu_v)\ \gamma(-\mu_0)$] for each image using a radiative transfer pkg (MODTRAN or 6S) with 2 free variables (aerosol optical depth & water vapor)
- Step 2: Determine the spectral reflectance of "invariant" pixels of reference image *J* by assuming values of aerosol optical depth & water vapor

10 To correct single-viewing-angle imagery – look-up table method

- Step 3: Determine aerosol optical depth and/or water vapor of other images – searching tables created from step 1 & match the TOA radiance of these "invariant" pixels
  - Surface reflectance of these "invariant" pixels are the same as those in image *J*
  - Linear interpolation is needed
  - Retrieve surface reflectance of all pixels of all other images, as soon as atmospheric variables are known
- Simple, physically-based atmospheric correction method

11 Histogram matching methods

- Based on assumption that surface reflectance histograms of clear & hazy regions are the same
- After identifying clear & hazy regions – histograms of hazy regions are shifted to match the histogram of their reflectance of the clear regions
- Steps outlined in Section 6.2.2

12 Dark object methods

- One of oldest & simplest methods
  - An image has pixels whose surface reflectance is negligible (complete shadow)
  - Image pixel values of each band are subtracted by its minimum value
- Improved by incorporating a physically-based procedure
  - Use middle IR band around 2.1 μm – identify dense vegetation pixels
  - Reflectances highly correlated with blue & red bands
- See procedure – Section 6.2.3

13 Contract reduction methods

- For regions where surface reflectance is stable – variations of satellite signal acquired at different times attributed to variations of atmospheric optical properties
  - Aerosol scattering reduces variance of local reflectance
  - Larger the aerosol loading, smaller the local variance
- If know actual surface variance, TOA radiance from satellite observations can be used to estimate the transmittance terms, depends mainly on aerosol optical depth τ

14 Cluster matching method

- Key component – to estimate the spatial distribution of aerosol loadings under general conditions
- Need to estimate:
  - Aerosol optical depth
  - Single scattering albedo, phase function – from aerosol climatologic data
  - Surface adjacency effects

15 Estimating aerosol optical depth

- Assume average reflectance of each cover type is the sme under different atmospheric conditions (clear to hazy)
- Use near-IR bands 4 & 5 and mid-IR band 7 – bands least contaminated by most

aerosols – 3 bands used to classify pixels into cover types
- Figure 6.3 – flow chart

16 ❑ Surface adjacency effects

- Caused by complicated multiple scattering in the atmosphere-land surface system
- Pixel values of high-resolution imagery over a heterogeneous landscape are affected by neighboring pixels
  - Dark pixels appear brighter, bright pixels appear darker
  - Imagery seems hazy & lacks contrast
- Details in Section 6.2.5.2 – example corrections in Fig. 6.6