Outline

• Soils
  – Properties that are detectable from remote sensing using optical and radar sensors

• Geomorphology
  – Patterns as an indication of processes
Factors Influencing Soil Reflectance

- mineral composition
- soil moisture
- organic matter content
- texture and roughness
- salinity
Soils: Mineral Composition

- Affects the visible, NIR, and thermal portions of the reflectance spectrum
- Increasing reflectance from visible to NIR
- Iron and clays are detectable
  - oxidized iron appear red
  - reduced iron appear green-blue
  - clays affect water and OH+ absorption features
Key characteristic of soil spectrum: increasing reflectance with increasing wavelength through the visible, near and mid infrared portions of the spectrum
Iron oxide causes absorption in the UV, blue and green wavelengths as well as absorption in the NIR (850 to 900 nm). Also, scattering in the red is higher for soils with iron oxide, leading to a red color.
Iron Oxide

- Iron content in the Santa Monica mountains mapped using AVIRIS (Palacios-Orueta et al. 1999)
Soils: Organic Matter Content

- OM affects soil color, heat capacity, water holding capacity, nutrient exchange, structure, and erodability
- Dark color generally associated with high OM
- Landsat TM bands 5 and 6 have negative correlation with OM
Soil Organic Matter

- Organic matter is a strong absorber of EMR, so more organic matter leads to darker soils (lower reflectance curves)
Soil Organic Matter

- Organic matter content in the Santa Monica mountains mapped using AVIRIS (Palacios-Orueta et al. 1999)
Soils: Texture

- Texture
  - %sand, %silt, %clay (these are size classes)
Soil Texture

- Proportion of sand, silt and clay in a soil (or horizon), usually calculated as % weight for each type of particle
- These percentages are divided different soil texture classes
Key characteristic of soil spectrum: increasing reflectance with increasing wavelength through the visible, near and mid infrared portions of the spectrum
Soil Moisture

- Water is a strong absorber, so soils with more moisture will be darker over most of the VNIR and SWIR portions of the spectrum than drier soils.
- The depths of the water absorption bands at 1.4, 1.9 and 2.7 μm can be used to estimate soil moisture.
Soil Moisture and Texture

- Since clayey soil holds water more tightly than sandy soil, the water absorption features will be more prominent in clayey soils given the same amount of time since the last precipitation or watering.

- AVIRIS can be useful for quantifying these absorption features.
Soils: Moisture Content

• Theoretically, soil moisture is directly related to surface soil moisture content
• SAR estimates of soil moisture are also influenced by:
  – roughness
  – topography
  – vegetation density
Soil Moisture from RADAR

- Higher dielectric constants (more moisture) yields higher RADAR backscatter.

Melfort, Saskatchewan, Canada, ERS-1: Rainfall was incident on the lower half of the image but not on the upper half.
Surface Soil Moisture from Synthetic Aperture Radar

12 January 1997
Soil near saturation

23 March 1997
Soil dry

Percent Volumetric Soil Moisture

0 5 10 15 20 25 30 35
Soil Moisture from Thermal Sensors

- Water has a higher thermal capacity than soil and rock.
- Moist soils will change in temperature more slowly than dry soils.
- Apparent thermal inertia can be used to distinguish dry from moist soils.
Soil Moisture from Thermal Sensors

Daedalus thermal image (night time). If we had a daytime image to compare it to, we could see the amount of change in temperature and make inferences on the soil moisture content (less change = more moisture).
Soils: Salinity

- Saline soils are a major limiting factor for vegetation growth
  - drawdown of coastal aquifers allows saltwater intrusion into groundwater
  - increase in irrigation in regions of salt-bearing minerals will activate salts into the groundwater
  - evaporation of salt-bearing irrigation water will increase soil salinity over time
Figure 1. Salt crust covered soils in the delta relief type

Figure 2. Landsat TM colour – composite, with bands 7,3,2 displayed as red, green, blue.
Application: Remote Sensing of Swelling Clay Soils

- Smectite clays (e.g. bentonite) can absorb more than their weight in water, have >100% increases in volume
- Responsible for massive damage to structures throughout U.S.
Pierre shale contains high concentrations of bentonite clays

AVIRIS data acquired to try to use hyperspectral imagery for mapping bentonite (Chabrillat and Goetz, 1999)
Bentonite clay exposure near Denver, CO

Increasing swelling potential

Trench samples, Denver metropolitan area
Geomorphology

- Landforms: patterns and processes
  - eolian
  - igneous
  - tectonic
  - karstic
  - fluvial
  - shoreline
  - glacial
Landforms

• Typically identified by shape, not spectral properties
• Use shadowing to identify features
  – optical (VIS/NIR imagery)
  – synthetic aperture radar
    • useful in regions frequent cloud cover
Eolian landforms

crescentic dunes from SAR

crescentic dunes from ASTER
longitudinal dunes from ASTER
(w/clays between dunes)

star dunes from Landsat TM
Igneous landforms

Mount Rainier, Washington

stratovolcano
Western Australia granite-greenstone complex: Pilbara Block

granite batholiths intruded into metamorphosed basalt
Tectonic Landforms

Landsat TM image of Nevada basin and range region
Colorado Rocky Mountains from Landsat TM (band 4)

Canadian Rocky Mountains from Radarsat
Karstic Landforms

- Karst topography develops by chemical dissolution of limestone rocks
- Creates caves, sinkholes, solution valleys, towers, pitted landscapes

photo of karstic towers in Guangxi, province China
Landsat TM image of Guangxi province, China (karst areas are dark)
Fluvial Landforms

- dendritic networks are easily recognized

Radar image of dendritic river network in east-central Colombia
Flat floodplains have shifting river channels producing meanders and oxbows.

Edge of floodplain is marked by bluffs on which is mature vegetation.

Lower Mississippi River Floodplain
Shoreline Landforms

MISR image of Mississippi Delta (birdsfoot delta)
Quickbird image of Bora Bora island (atoll)

Landsat image of fjords on Iceland
Glacial Landforms

ASTER image of receding glaciers in Bhutan
(note lakes forming at glacier termini)
Landsat TM image of “fluting” caused by massive glacial erosion of bedrock on the Canadian shield during the last ice age