Spectral Signatures and Their Interpretation

- EMR and earth materials interaction
- Spectra of earth materials
- Multispectral images and their interpretation
EMR and earth materials interaction

- When EMR from the sun reaches the earth surface, it is
  - transmitted - transmittance
  - absorbed - absorbance
  - reflected - reflectance
- The nature of how the earth materials transmit, absorb or reflect the solar EMR is called spectral signature of an object.

Spectra of earth materials

- Vegetation
- Soil and rocks
- Water, ice and snow
- Cloud, fire and smoke
Vegetation

- Contains water, cellulose (tissues and fibres), lignin (non-carbohydrate constituent of wood), nitrogen, chlorophyll (“green” pigments) and anthocyanin (water-soluble pigments).
- Depending on how ‘active’ (i.e. kinds of chlorophyll) a green vegetation is, the combination of transmittance, absorbance and reflectance vary in different bands of the spectrum.

Physiological factors

- Leaf structure
- Reflectance, transmittance, and absorptance spectra
- Leaf maturation
- Mesophyll arrangements (internal structural differences)
Leaf structure

A leaf’s structure and its reflectance characteristics at visible and near IR wavelengths.

Transmittance, absorbance and reflectance

Fractions of the total light incident on the upper surface of a mature orange leaf that is reflected, absorbed and transmitted.
Absorption spectra

Absorption spectra of chlorophyll \( a \) (blue-green) and chlorophyll \( b \) (yellow-green).

Spectral reflectance

Average spectral-response curves for six materials.
Spectral reflectance (cont.)

Below: Average spectral-response curves for four types of vegetation

Right: Average spectral-response curves for a plant leaf as it progresses from a healthy state through different stages of damage.

Other factors

- Leaf damage;
- Sun and shaded leaves;
- Leaf water content;
- Leaf air spaces; and
- Salinity and nutrient levels.
Vegetation canopy

- Transmittance of leaves;
- Amount and arrangement of leaves;
- Characteristics of, e.g., stalks, trunks, limbs, etc.;
- Background (soil, leave litter, etc.);
- Solar zenith angle;
- Look angle; and
- Azimuth angle.

Soil and rocks

- The reflectance from soil and rocks is influenced by:
  - colour
  - mineral contents (chemical composition or crystalline structure)
  - structure
  - and others
- We use soil for discussion
Field reflectance spectra of green grass, dead grass, Virginia Pine, Scarlet Oak, packed bare soil and ploughed soil with cobbles.

Factors influencing interpretation of soils

- Soil colour
- Mineral content - depends upon the intermolecular vibration of the molecules
- Organic matter - influences soil colour and moisture
- Particle size - reflectance and thermal diffusivity, and moisture.
Reflectance of minerals

Directional hemispherical reflectance spectra in the 0.4-2.5\( \mu \)m wavelength region and biconical reflectance spectra in the 2-25\( \mu \)m wavelength region of two clay minerals: kaolinite and montmorillonite.

Factors influencing interpretation of soils (cont.)

- Soil texture - mainly indirect effects on, e.g., soil moisture.
- Structure and surface roughness (soil aggregation) - "smoothness" of soil - have significant effects on RADAR response.
- Soil emissivity - thermal emissivity: ratio of energy radiated at the surface / black body.
- Soil temperature - influences the interpretation of thermal imagery and time of sensing.
Reflectance from soils

- O₂ and CO₂ and water vapour absorption;
- Sun illumination varies with atmospheric conditions and solar radiation
- Effects of soil structure, surface roughness, etc.
- The intensity of the sun peaks at about 0.5µm falling off rapidly at shorter and longer wavelengths.

Water, ice and snow

- Water
  - visible transmittance is high
  - high absorptance in NIR
  - influenced by the cleanliness
- Snow
  - high reflectance in < 1.5µm
  - low at 1.5 and 2µm
  - very low in the thermal IR
Reflectance of ocean water

Calculated change in bulk reflectance of ocean water with increasing concentration of phytoplankton.

Reflectance of snow

Computed reflectance spectra of three different textures of snow (coarse, fine, and frost) for (a) the 0.3-3.0µm wavelength region, (b) the 3-14µm wavelength region.
Cloud, fire and smoke

- **Cloud**
  - strong reflectance in visible and NIR
  - associated with shadow
  - can be penetrated by radar
- **Fire**
  - high temperature
  - Wien's displacement law
- **Smoke**
  - highly visible (black or white) in visible
  - can be penetrated by TM5 and TM7 as their wavelength is larger than the most smoke particles.

\[ \lambda_{\text{max}} = \frac{W}{T} \]

\[ W = 2.897 \mu m \ K \]

Multispectral images and their interpretation

- Single image band interpretation
  - similar to airphoto interpretation
  - beware of the spectral wavelength of the band and the spectral signatures of the objects
- Colour composites
- Multispectral band statistics
- Multispectral classifications
Single band interpretation

Colour composites

- Number of composites
  \[ N = \frac{n!}{3!(n-3)!} \]

- Example: TM 6 non-thermal bands
  \[ N = \frac{6!}{3!(6-3)!} = 20 \]
### Colour composites (cont.)

<table>
<thead>
<tr>
<th>RED</th>
<th>GREEN</th>
<th>BLUE</th>
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<tbody>
<tr>
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<tr>
<td>CZCS6</td>
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</tbody>
</table>

#### Colour composites (cont.)

- **Nature colour**: TM3, TM2, TM1
- **Colour IR**: TM4, TM3, TM2, MSS7, MSS5, MSS4, HRV3, HRV2, HRV1, AVHRR4, AVHRR3, AVHRR1, TM7, TM2, TM1
- **Mapping bushfire**: AVHRR4, AVHRR3, AVHRR1, TM7, TM2, TM1
- **Study El Niño**: CZCS6, CZCS2, CZCS1
Multispectral band statistics

Histogram

Multispectral band statistics (cont.)

Scattergram