REMOTE SENSING FOR SOIL SCIENCE

Harm Bartholomeus

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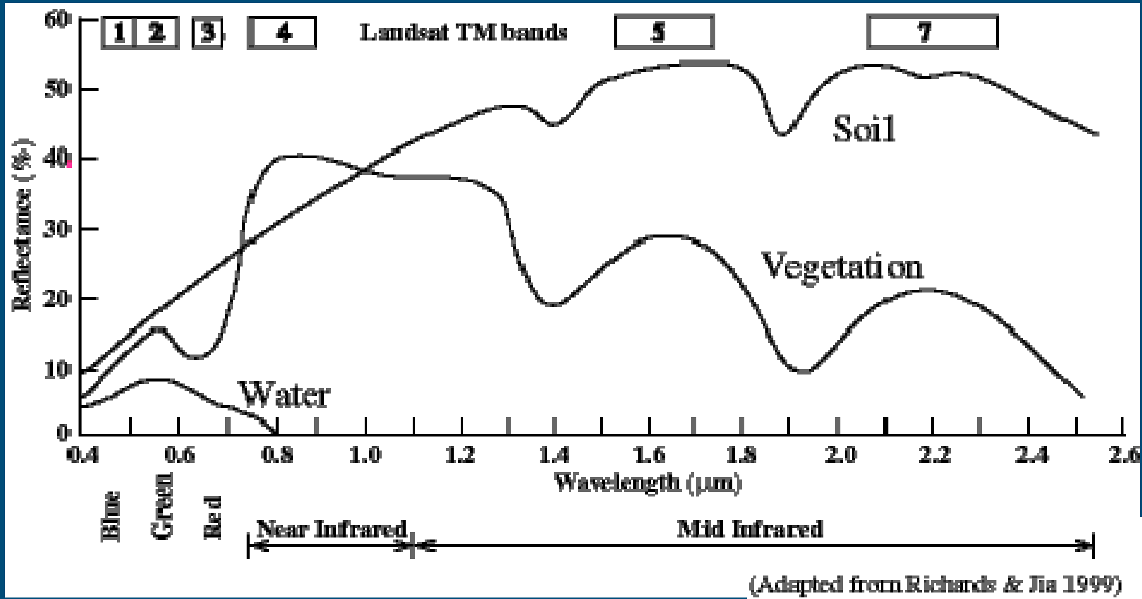
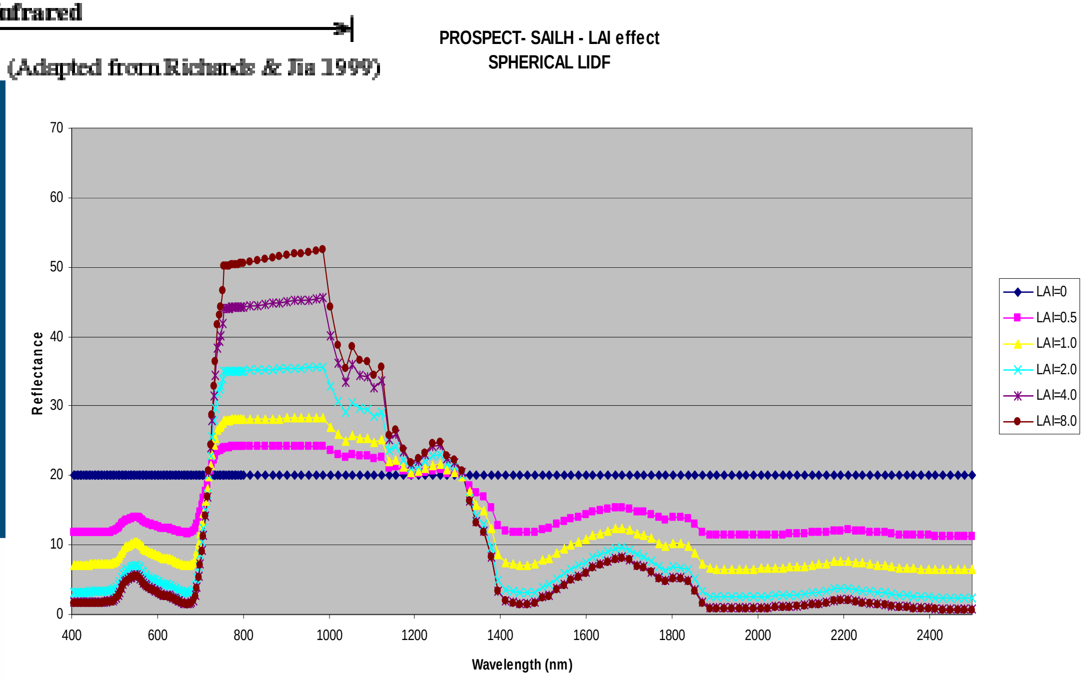
Introduction





Soil....

Soil Scientist

“Remote” Sensing

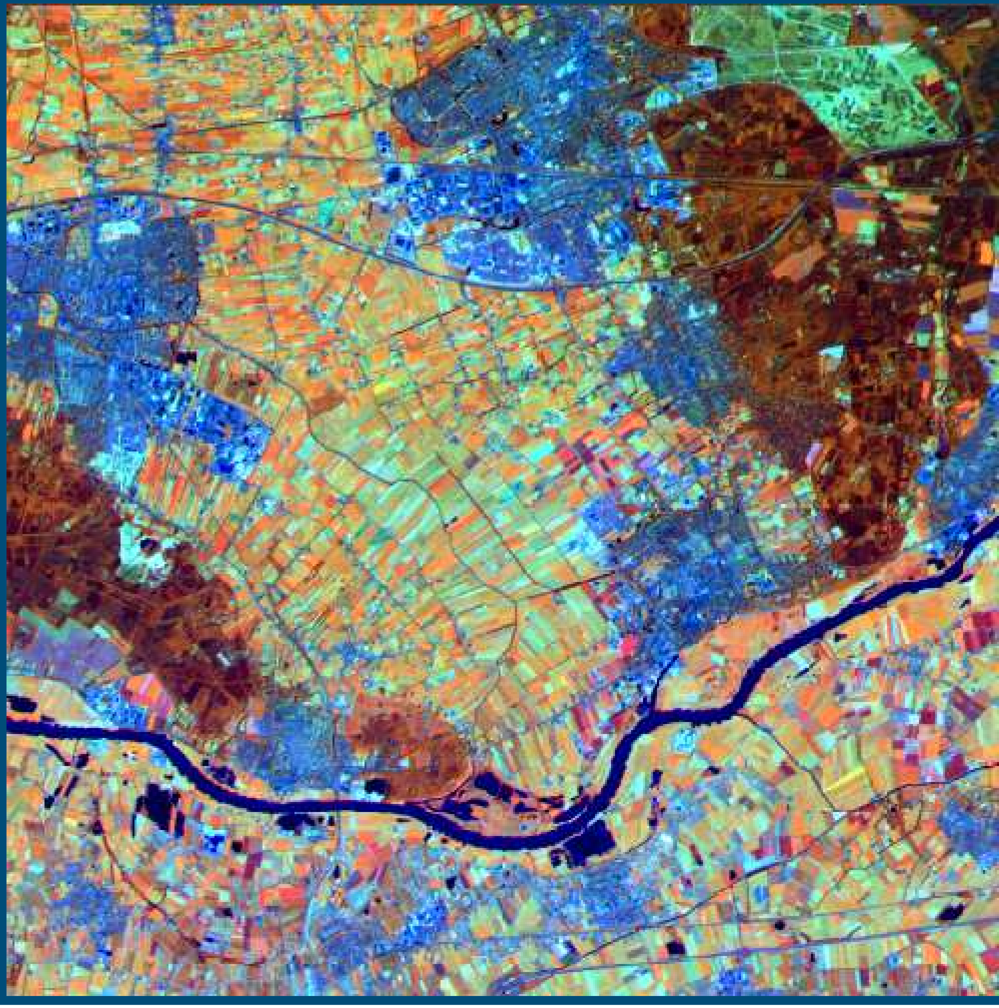
Info about soils from remote sensing 1/5

(between 0.400 µm and 2.500 µm)

By observations of:

- Crop cover and vegetation
  - Relation between crop or vegetation and soil
  - Relation between crop development and soil
- Bare soil surface
  - Relation between soil surface and soil
- Topography (relief differences)
  - Relation between topography and soil

Info about soils from remote sensing 2/5



Landsat 5 TM 1995: bands 4,5,3 -> R,G,B

Info about soils from remote sensing 3/5

Caesar 12-07-1994 Bemmelenhoeve

Info about soils from remote sensing 4/5

Bemmelenhoeve 2

Info about soils from remote sensing 5/5

Olive trees

Iron rich soil

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ROSIS: RGB = 60, 40, 20

Radiance of Exposed Soil

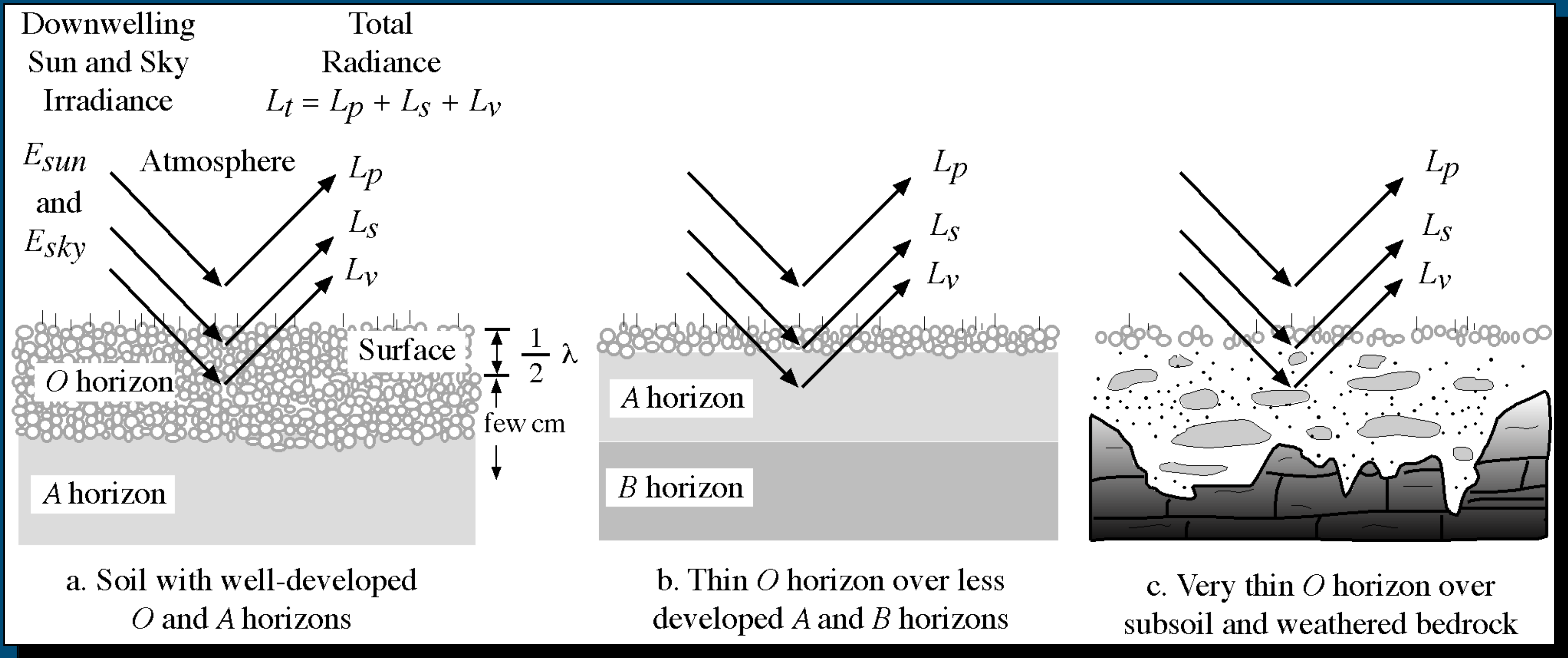
$$L_t = L_p + L_s + L_v$$

- L_t = at-sensor radiance of a pixel of exposed soil
- L_p = atmospheric path radiance, usually needs to be removed through atmospheric correction
- L_s = radiance reflected off the air-soil interface (boundary layer)
  - Soil organic matter and soil moisture content significantly impact L_s; typically characterize the O horizon, the A horizon (if no O), or lower levels if A and O are nonexistent.
- L_v = volume scattering, EMR which penetrates a few mm to cm.
  - penetrates approximate 1/2 the wavelength
  - Function of the wavelength (so RADAR may penetrate farther), type and amount of organic/inorganic constituents, shape and density of minerals, degree of mineral compaction, and the amount of soil moisture present.

Optical -> combined

Source: ERS 186 Environmental Remote Sensing; S. Ustin

Radiance of Exposed Soil



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Source: ERS 186 Environmental Remote Sensing; S. Ustin

Main factors influencing soil reflectance

- For bare soils:
  - Roughness and texture
  - Organic matter content
  - Moisture condition (re-reflecting, OH^-)
  - Mineralogical composition (OH^-, CO_3^{2-}, Fe^{2+}, Fe^{3+}, …)
- Causes of specific absorption bands:
  - Electronic processes: short wavelength; absorption bands
    - Fe: UV, 0.400 µm – 1.000 µm
  - Vibrational processes: long wavelength, (relatively) narrow bands.
    - OH: 1.450 µm, 1.950 µm
    - OH: >1.000 µm (minerals containing OH, H_2O)

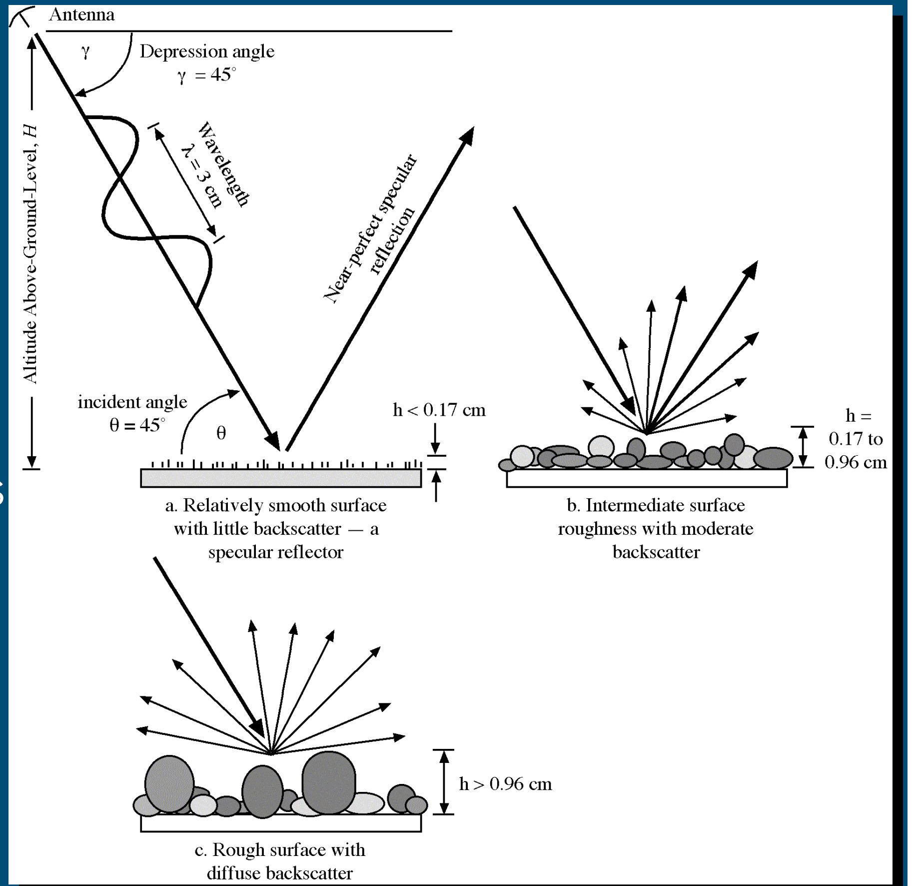
Surface Roughness

Opt.

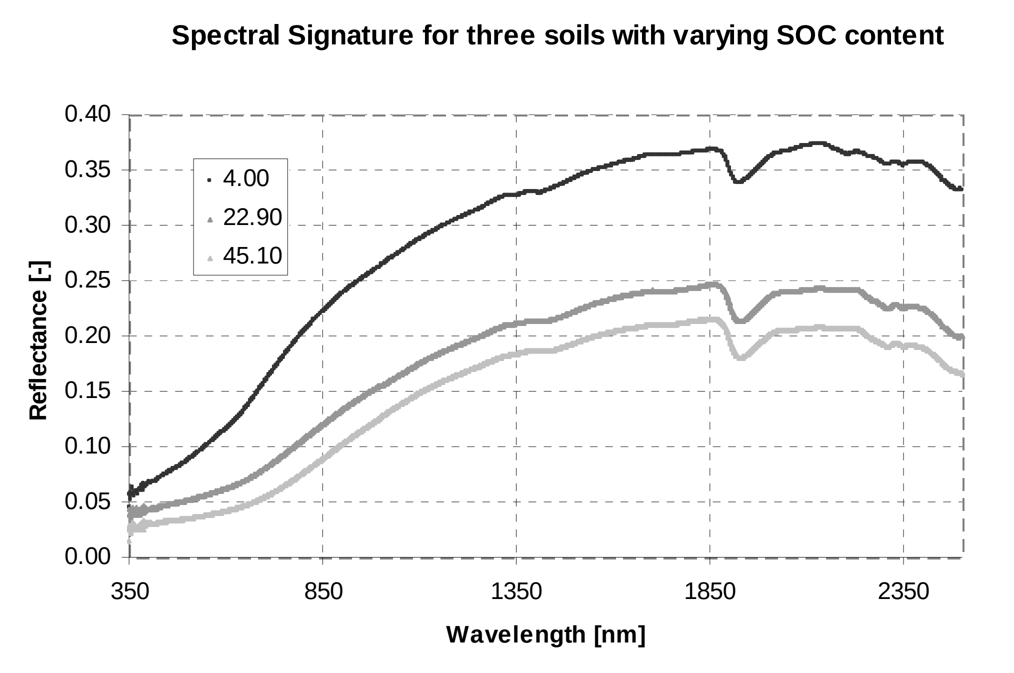
- A rough surface generally reflects less, due to self-shadowing effects and multiple scattering

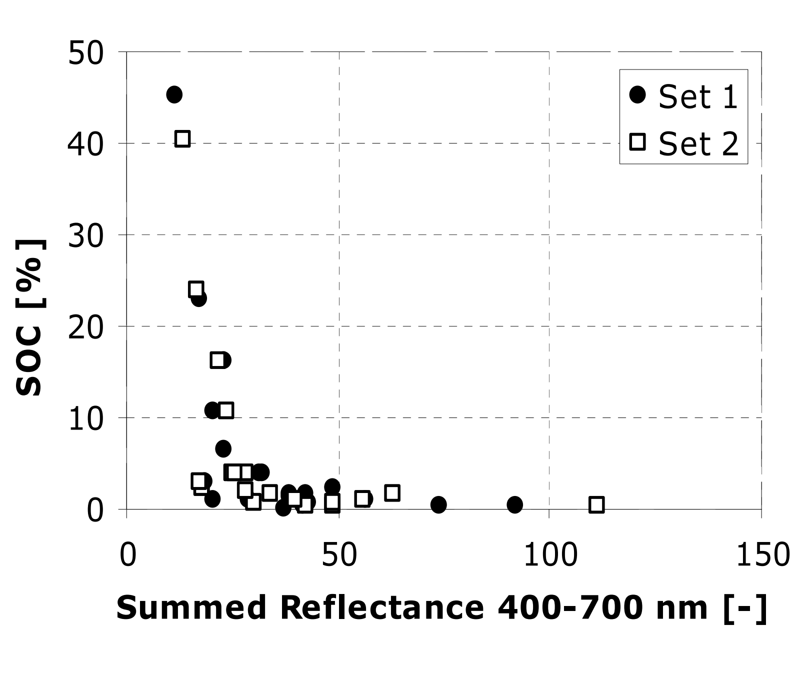
Microwave

- If a surface is smooth (particles smaller than wavelength), specular reflection is important.
  - No return – surface dark – unless sensor correctly positioned and pointed in specular direction.
  - Smooth soil surfaces tend to be clayey or silty, often are moist and may contain strong absorbers such as organic content and iron oxide.
- Conversely, a rough surface scatters EMR and thus appears bright.
  - But paradoxically, microwave data of well drained sands are often very bright, while clay-soils are dark, regardless of angle. Why?



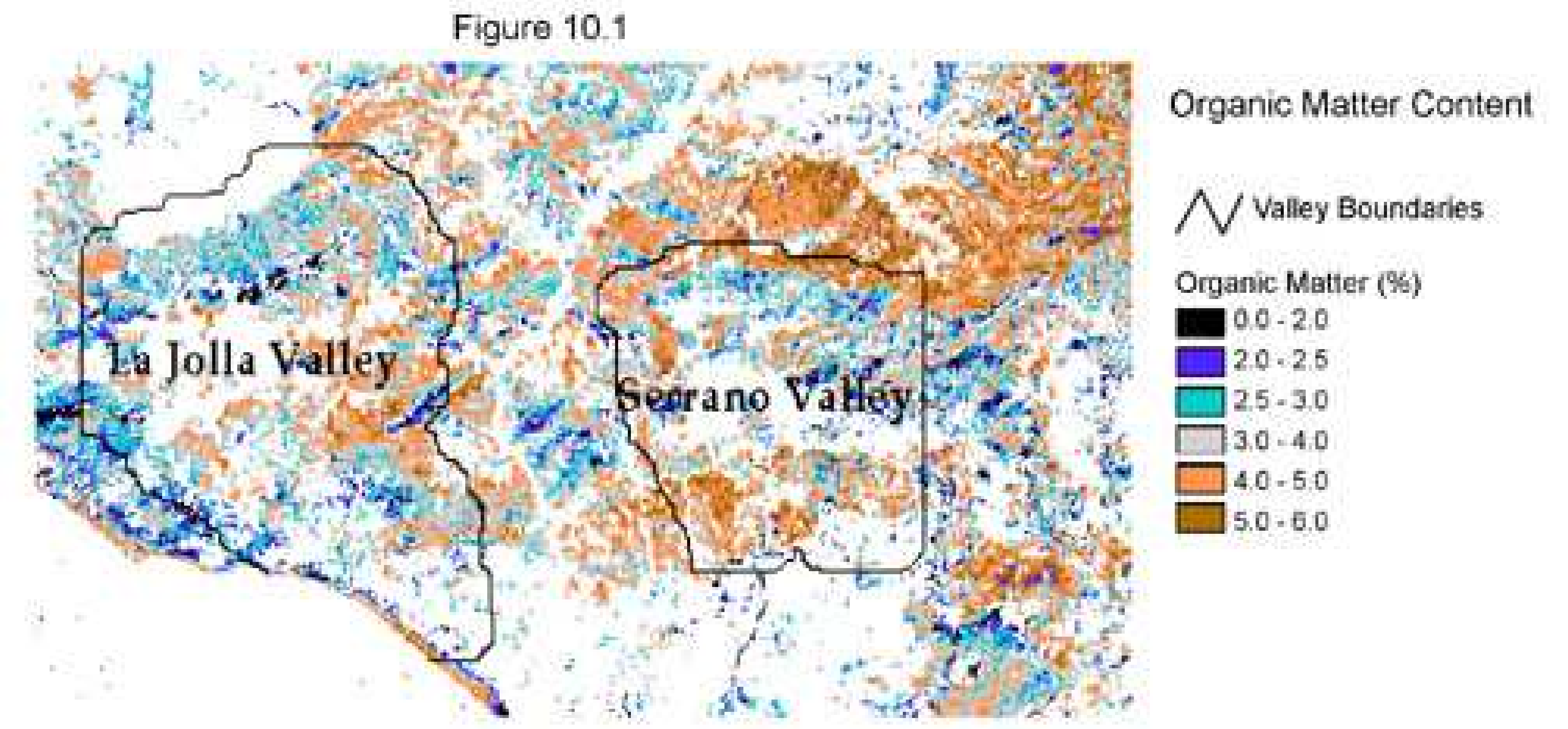
Organic Matter





- OM -> decrease in R
- Above 2% masking of other absorption features
- No distinct absorption features

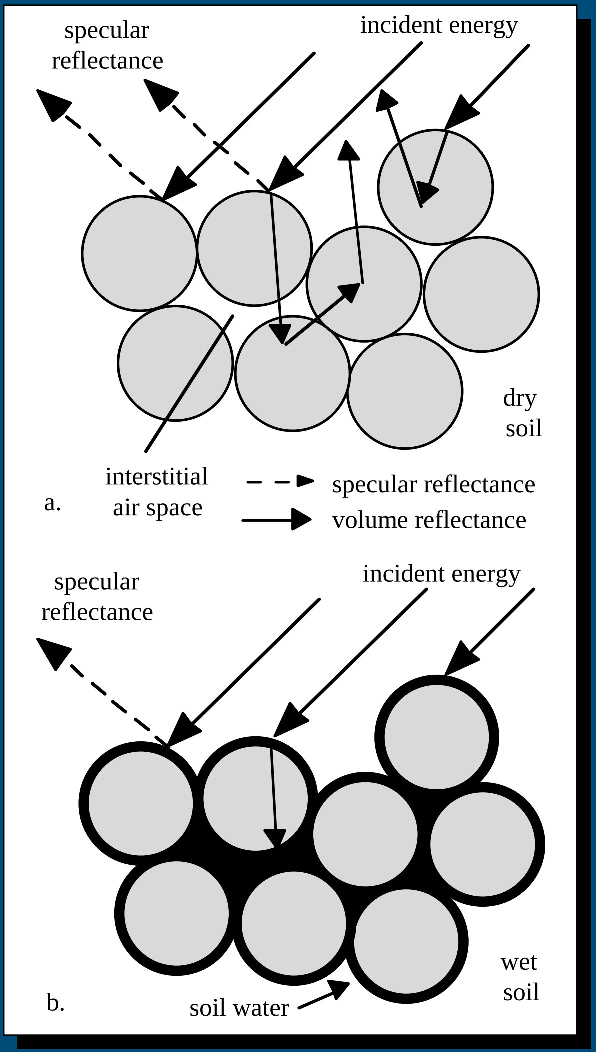
Organic Matter 2/2



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

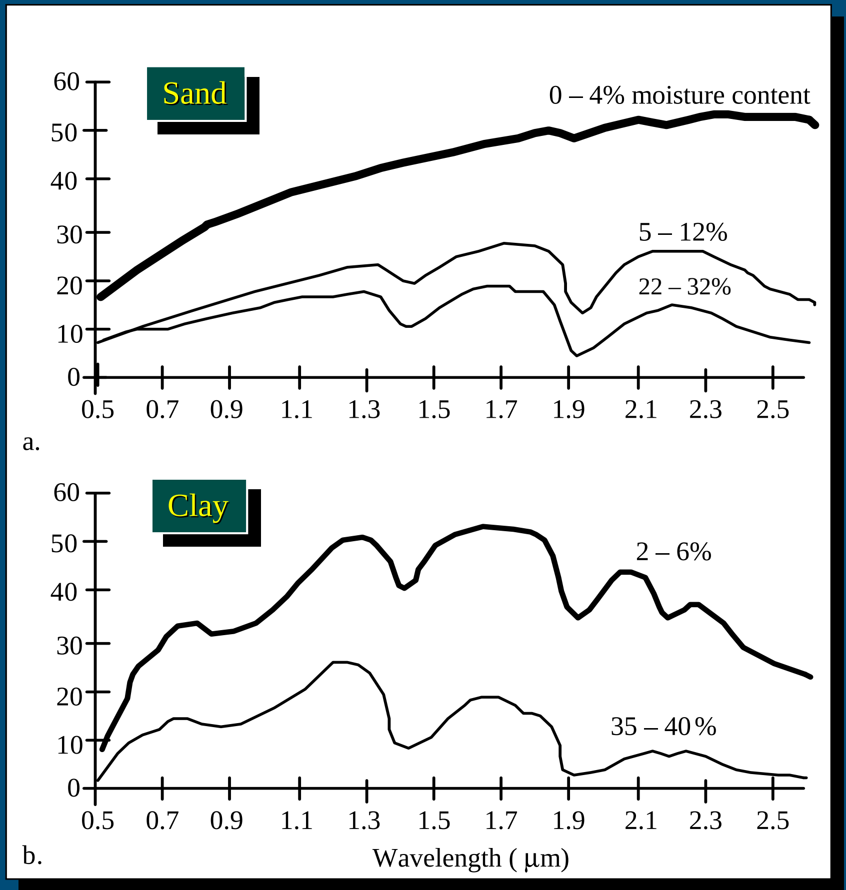
Soil Moisture

- Water ‘coats’ particles, filling air spaces and reducing the amount of multiply scattered light, so soils with more moisture will be darker in the VNIR and SWIR than drier soils.
- Moist soils will also be darker in the SWIR region where water absorption increases significantly with increasing wavelength.
- The depths of the water absorption bands at 1.4, 1.9 and 2.7 μm can be used to determine soil moisture.
  - (But why is this often not possible??)



Source: ERS 186 Environmental Remote Sensing; S. Ustin

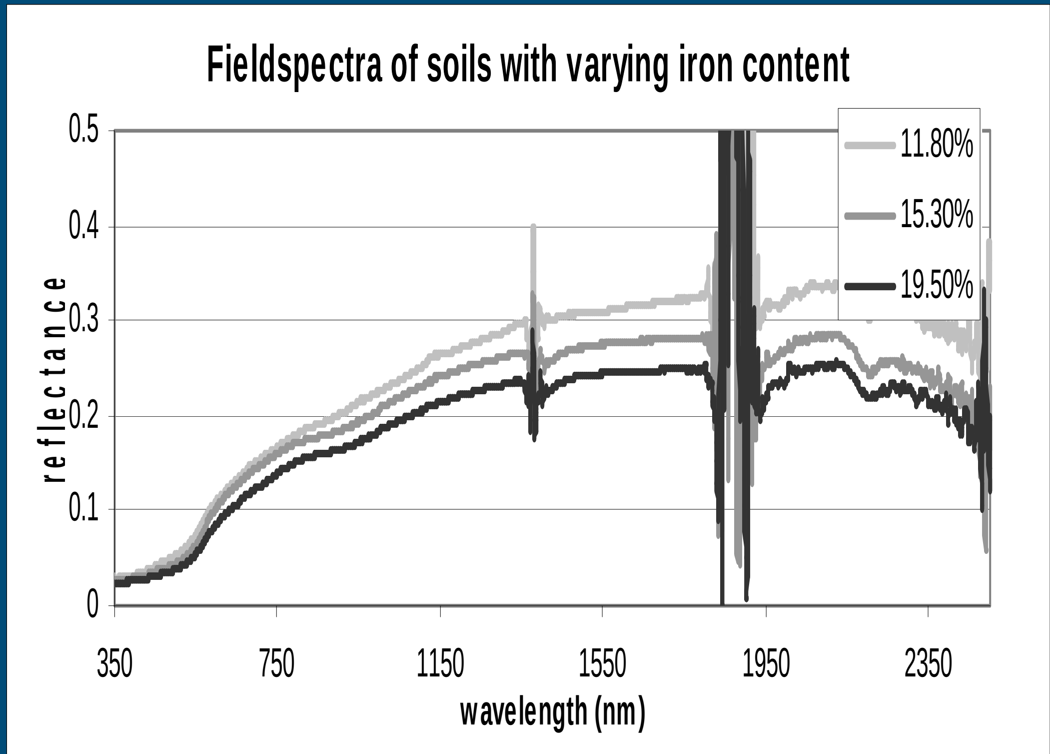
Soil Moisture and Texture 2/2



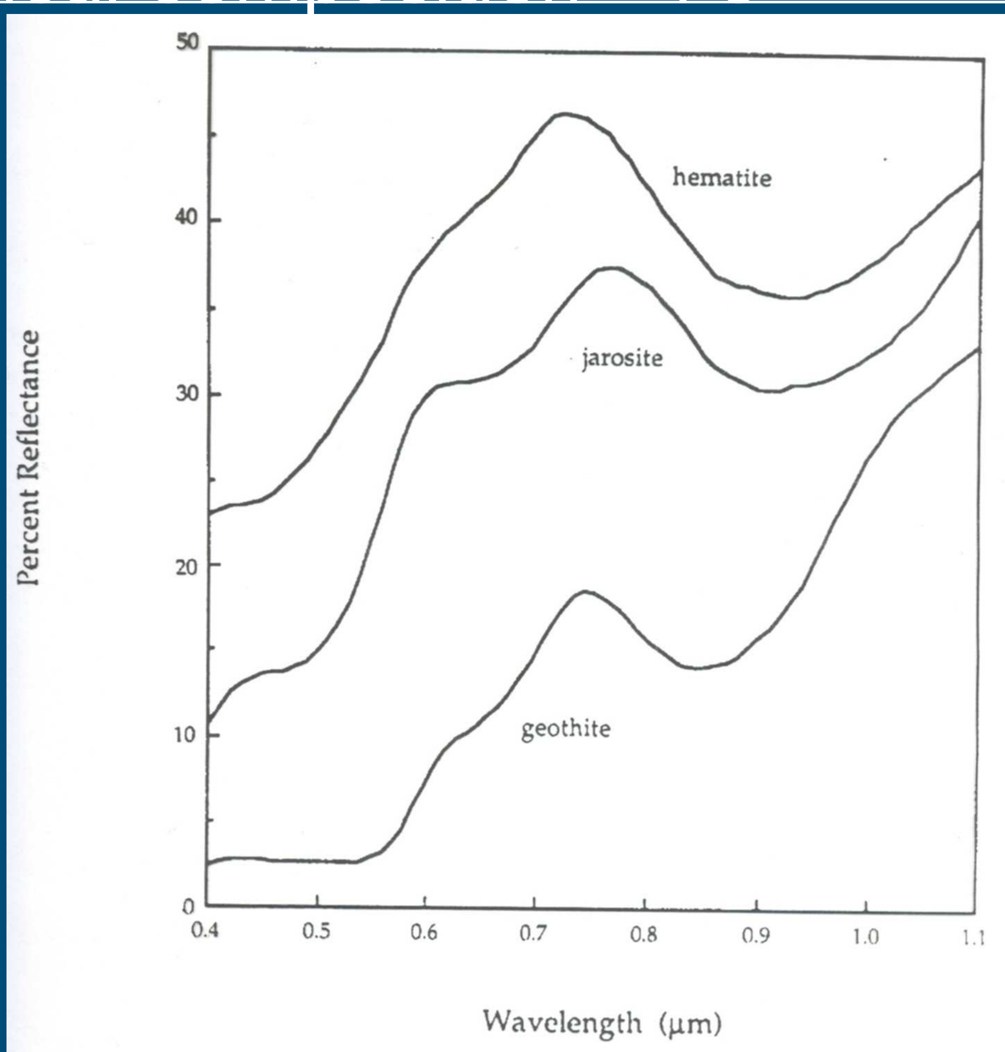
- Clays hold more water more ‘tightly’ than sand.
- Thus, clay spectra display more prominent water absorption bands than sand spectra.
- AVIRIS can be useful for quantifying these absorption features.

Source: ERS 186 Environmental Remote Sensing; S. Ustin

Mineralogical composition – Fe

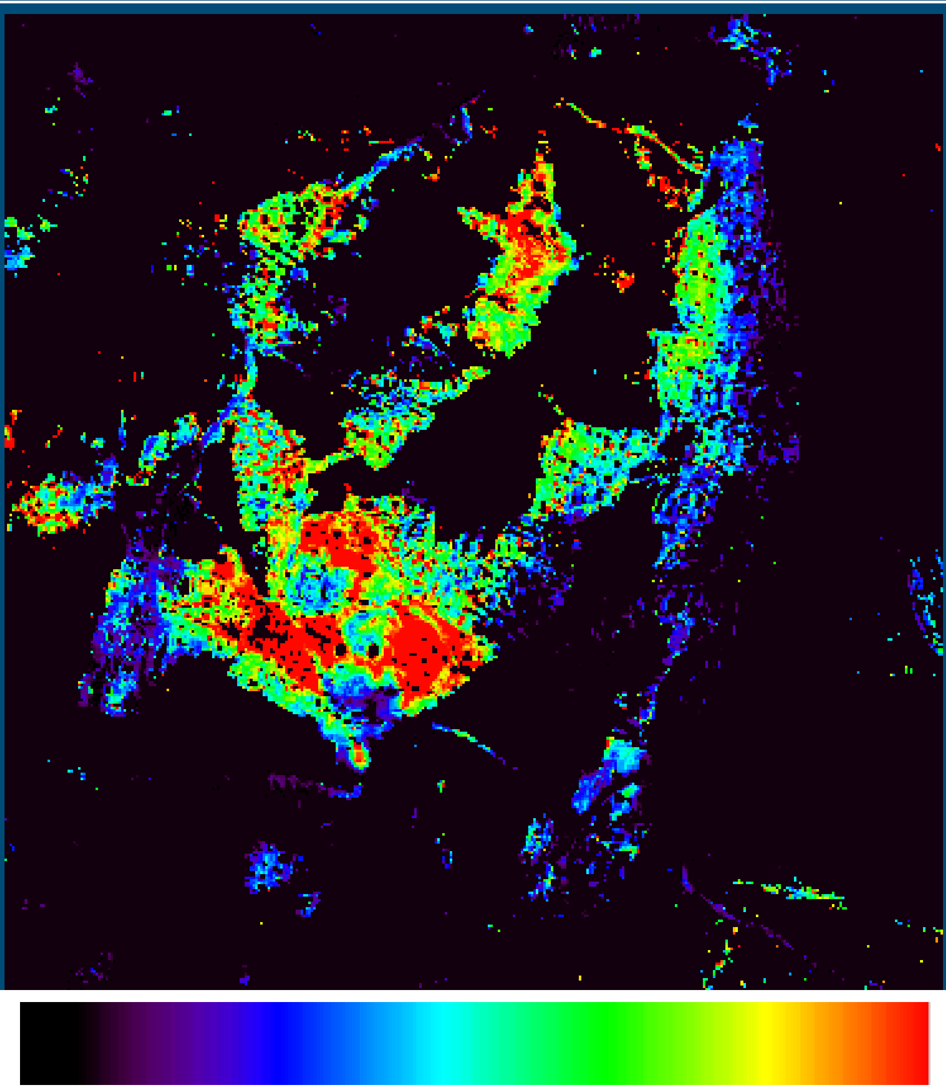


Mineralogical composition – Fe 2/4

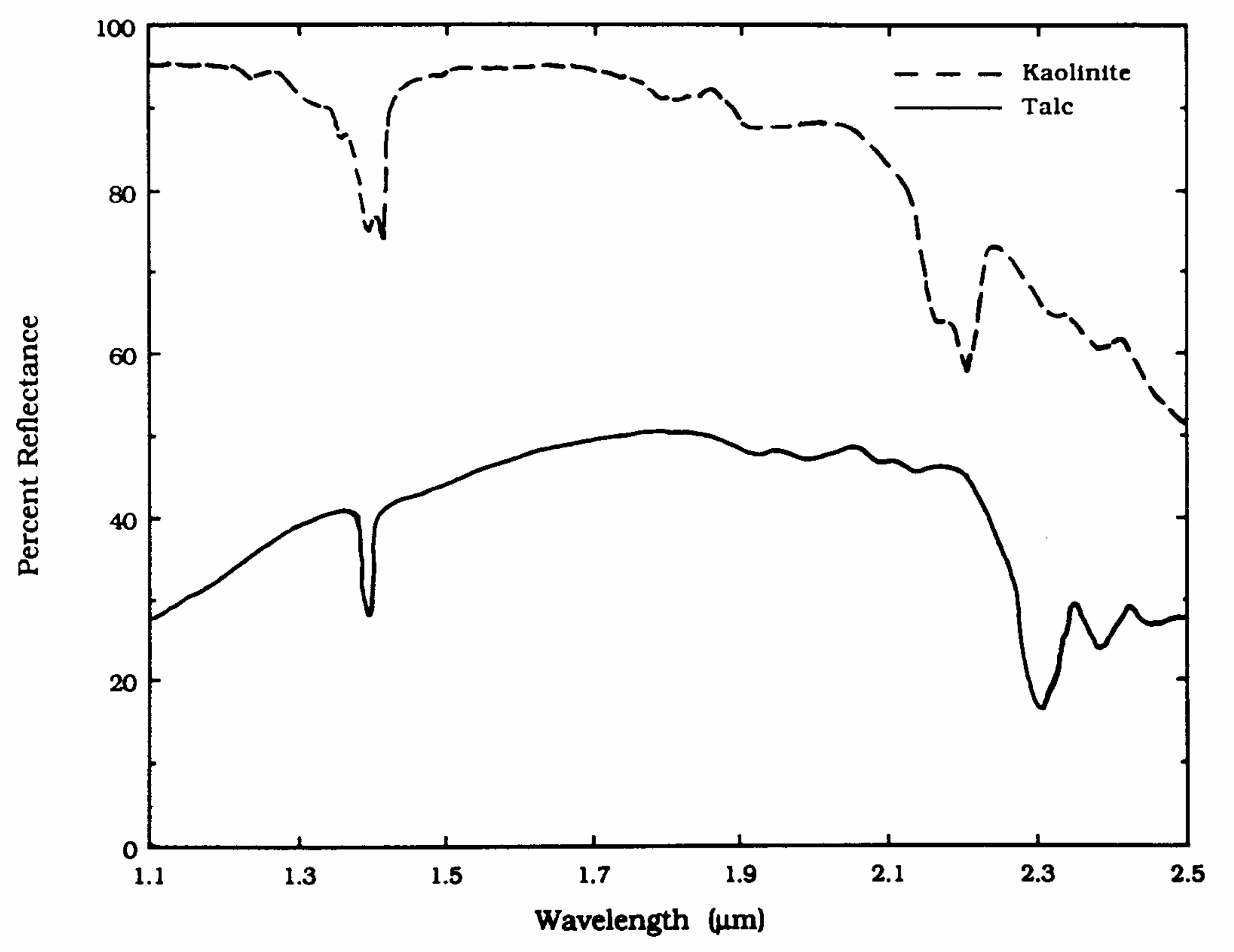


Reflectance spectra of iron bearing minerals (Goetz, 1989)

Mineralogical composition – Fe

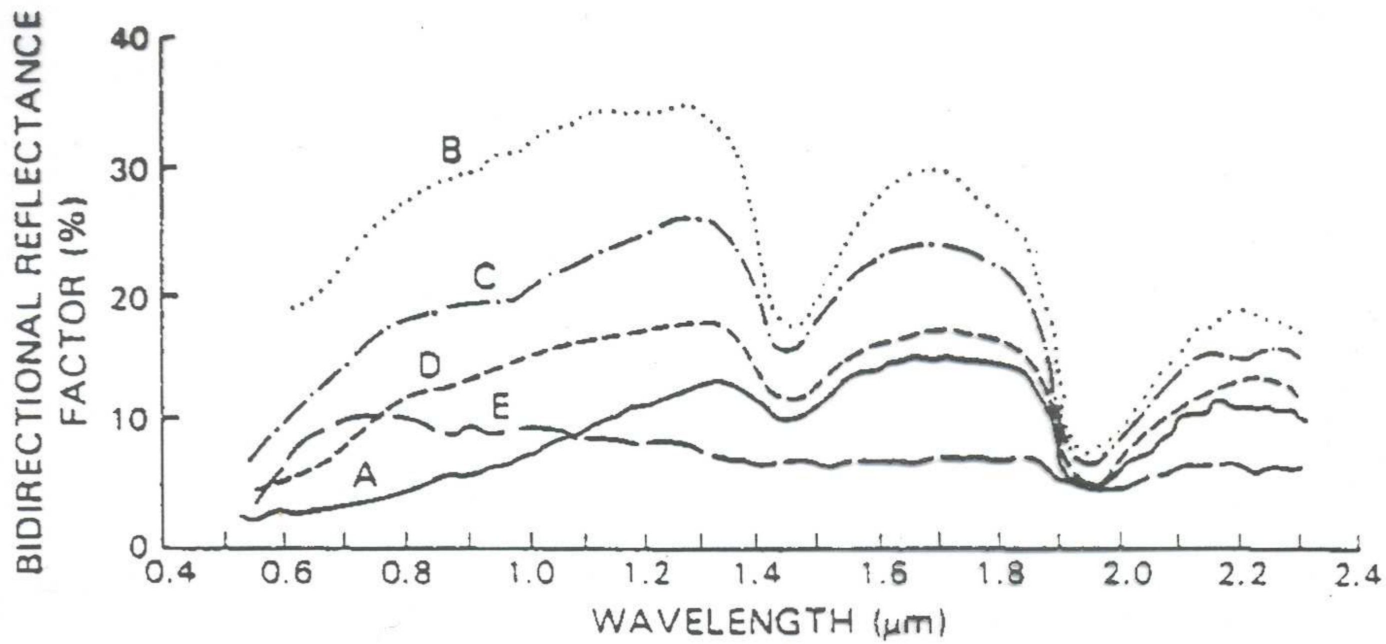


Mineralogical composition – OH



Reflection spectra of OH bearing minerals (Goetz, 1989)

Characteristic bare soil curves



The characteristic soil bidirectional reflectance spectra of Stoner and Baumgardner (1981).
Curve A: soils having high (>2%) organic-matter content and fine texture.
Curve B: soils having low (<2%) organic-matter content and low (<1%) iron-oxide content.
Curve C: soils having low (<2%) organic-matter content and medium (1 to 4%) iron-oxide content.
Curve D: soils having high (>2%) organic-matter content, low (<1%) iron-oxide content, and moderately coarse texture.
Curve E: soils having high (>4%) iron-oxide content and fine texture.
(Reproduced from "Characteristic Variations in Reflectance of Surface Soils" by E.R.Stoner and M.F.Baumgardner, Fig. 1, Soil Science Society of America Journal, Volume 45, No. 6. Pages 1161-1165 by permission of the Soil Science Society of America, Inc.)

(Stoner and Baumgardner, 1981)

Conclusions / Remarks

- For general information about soil types Landsat-type data can be used
- For *quantitative* retrieval of soil parameters (organic matter, iron, moisture) detailed spectral measurements are needed

  -> imaging spectrometry
- Analysis within one soil-type is usually straightforward, models are not always (seldom??) applicable on several soil types.
- Vegetation is annoying (Tell this to Dr. Clevers!! ☺)
- But it is also the big challenge to unravel the vegetation-soil interaction (e.g. for monitoring of carbon-sequestration)

Questions so far?

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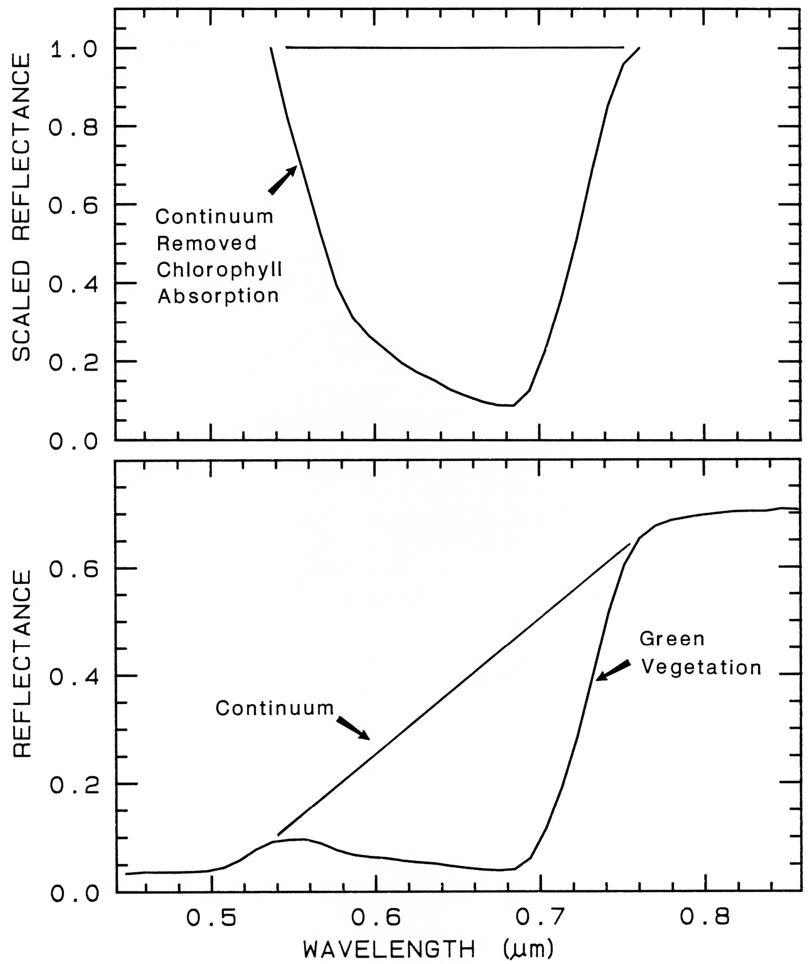
For the Exercises: Continuum removal

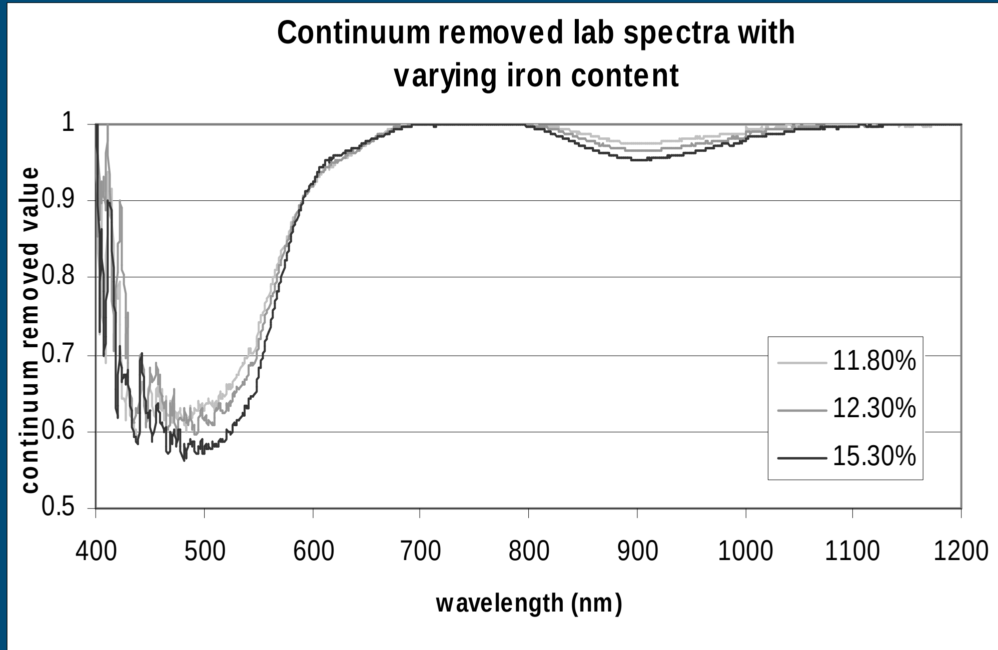
- Continuum Removal is used to normalize reflectance spectra to allow comparison of individual absorption features from a common baseline.
- The continuum is a convex hull fit over the top of a spectrum utilizing straight line segments that connect local spectra maxima.
- The first and last spectral data values are on the hull and therefore the first and last bands in the output continuum-removed data file are equal to 1.0.

(Source: ENVI online help)

Convex hull

For the Exercises: Continuum removal





Answers: influence of roughness and water