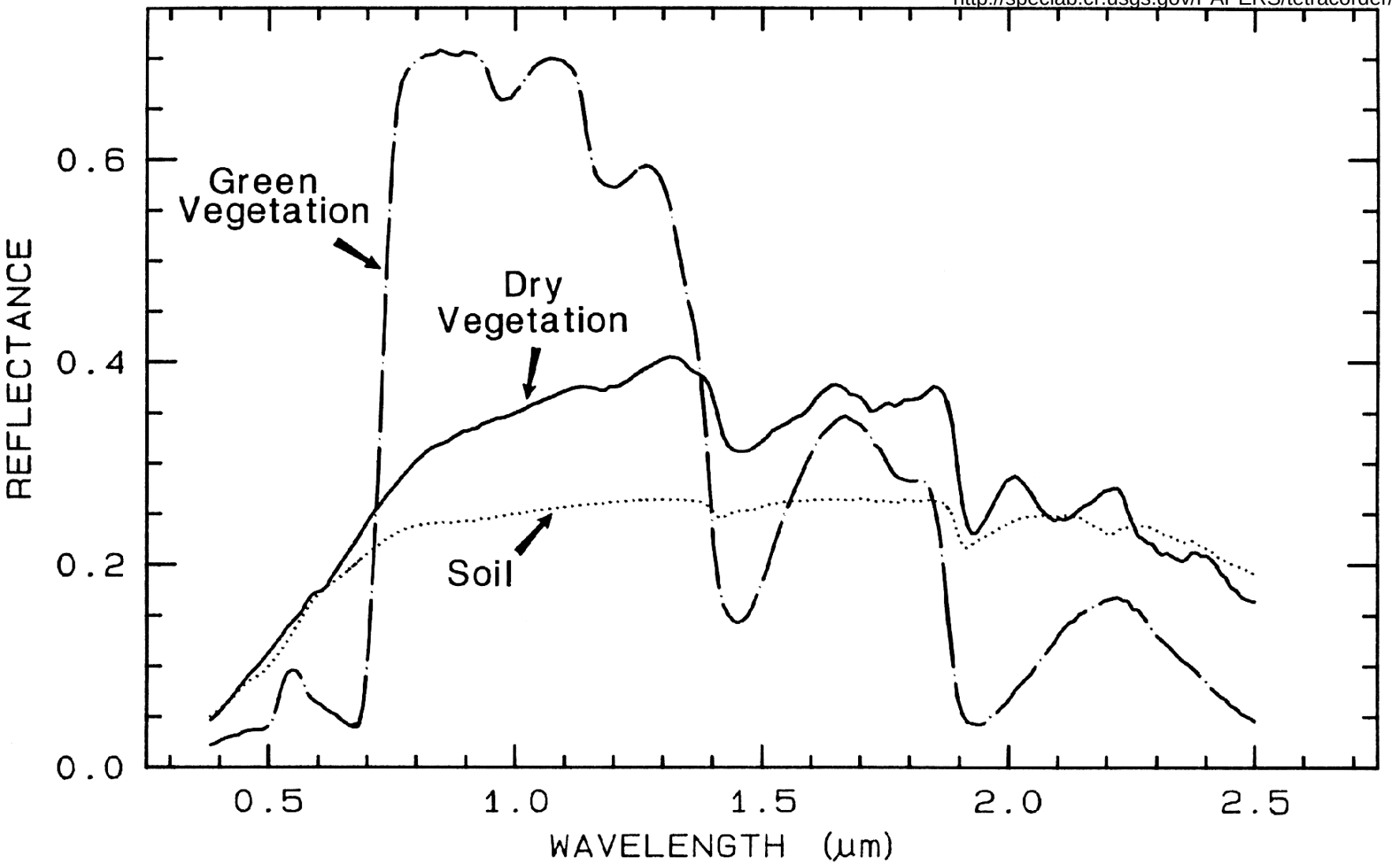
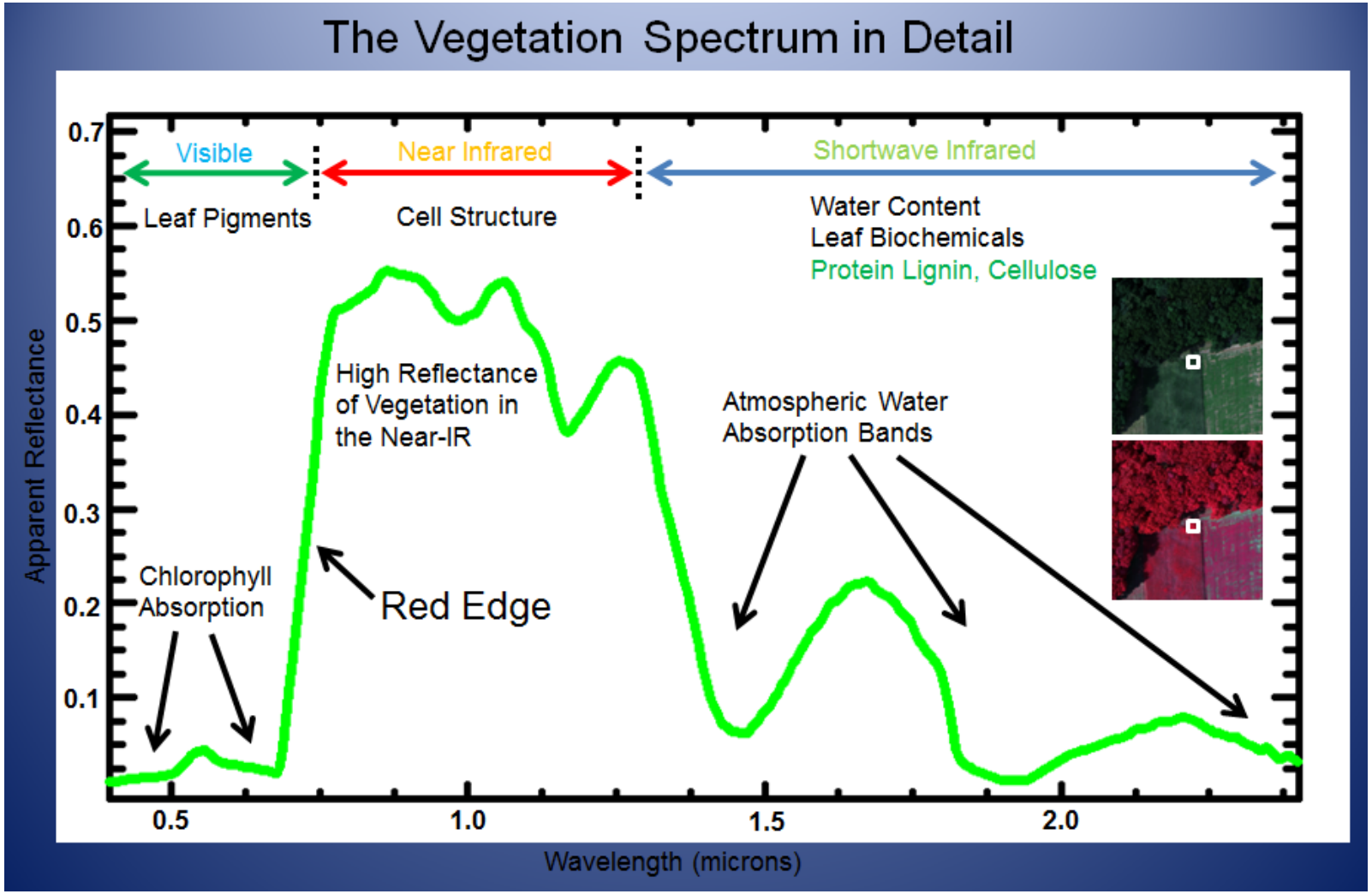
Fundamental Interactions with Earth Surface

http://speclab.cr.usgs.gov/PAPERS/tetracorder/

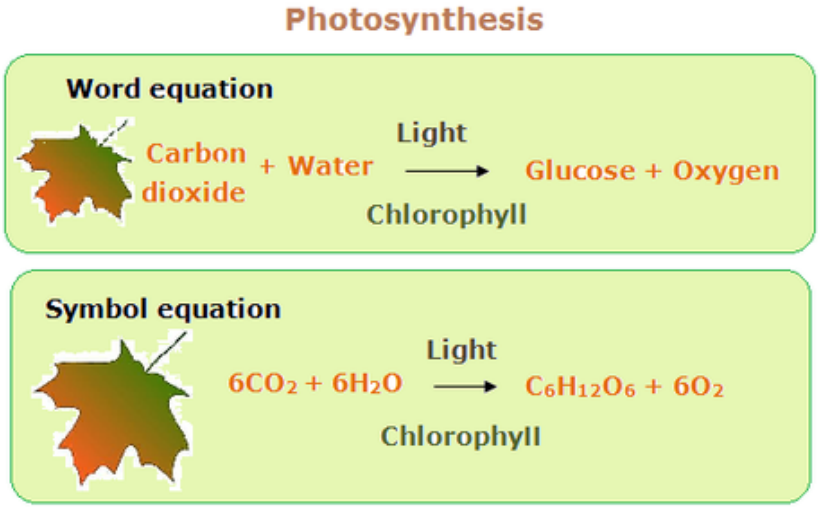


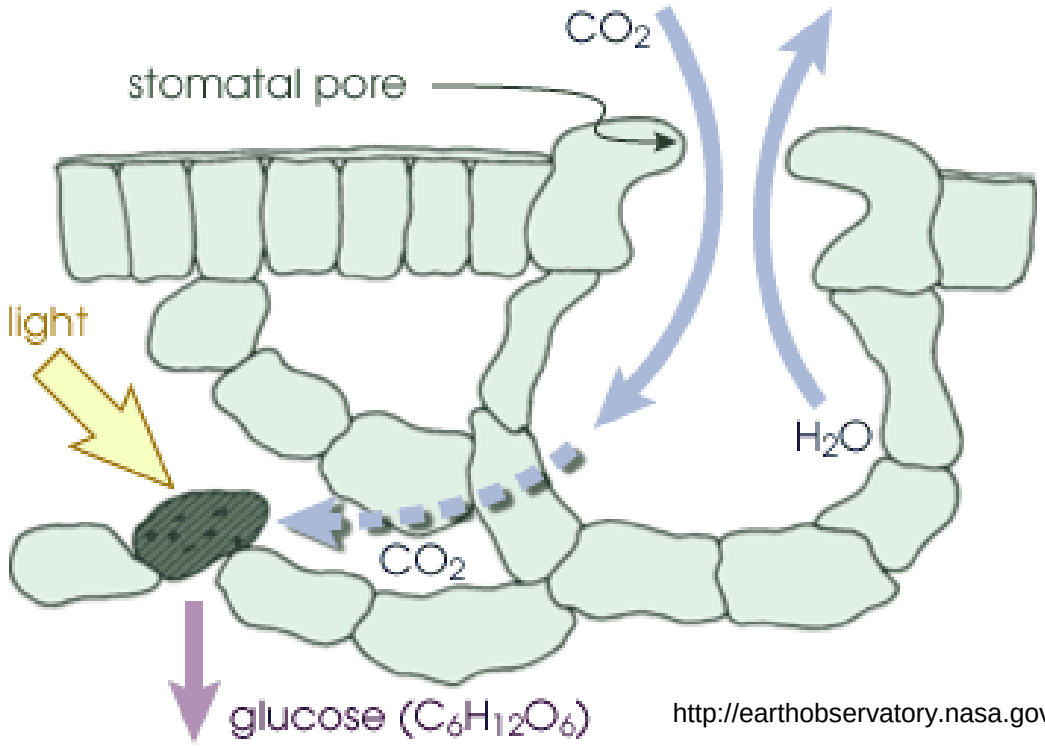

The Vegetation Spectrum in Detail
Visible
Near Infrared
Shortwave Infrared
Leaf Pigments
Cell Structure
Water Content
Leaf Biochemicals
Protein Lignin, Cellulose
High Reflectance of Vegetation in the Near-IR
Atmospheric Water Absorption Bands
Chlorophyll Absorption
Red Edge
Apparent Reflectance
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.5
1.0
1.5
2.0
Wavelength (microns)

Physical Basis of Remote Sensing

- Photosynthesis is the main process by which free energy in the environment is made available to the living world.
  - Photosynthesis is carried out by many organisms, including plants, algae and some bacteria. These life-forms "capture" light energy and use it to initiate a series of chemical reactions.
  - Atmospheric CO_2 is combined with an organic material already present in the cell (a 5-carbon compound, ribulose bisphosphate), leading to the production of simple carbohydrate molecules, thus storing the sun's energy in the bonds of simple sugars.
  - In this process, oxygen is produced and released as a byproduct.
  - In plants, photosynthesis is carried out in the leaves.

http://biology-igcse.weebly.com/the-equation-for-photosynthesis.html





http://earthobservatory.nasa.gov/Features/LAI/LAI2.php

Physical Basis of Remote Sensing

- There are two main groups of plants.
  - ***Monocotyledonae*** have
    - ✓ one cotyledon (seed leaf)
    - ✓ parallel veins in leaves
    - ✓ flower parts in multiples of three
    - ✓ a fibrous root system
    - ✓ scattered vascular bundles

  - ***Dicotyledonae*** have
    - ✓ two cotyledons
    - ✓ netlike veins
    - ✓ flower parts in fours or fives
    - ✓ a taproot system
    - ✓ vascular bundles arranged in rings.

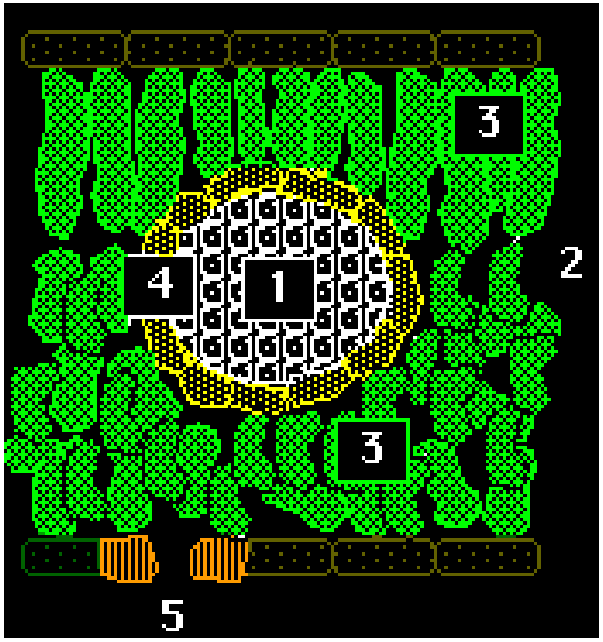
Physical Basis of Remote Sensing

❑ *Dicotyledonae*

- **C3** type of photosynthesis in which 3-phosphoglycerate is the first stable product, and ribulose bisphosphate is the CO_2 receptor.
- This photosynthetic pathway is also known as the Calvin Cycle.
- In the leaves of C3 plants, air spaces (containing carbon dioxide and oxygen) are in contact with the mesophyll cells, thus permitting photorespiration.

Leaf structures include:

- vein (1:white)
- air space (2:black)
- mesophyll cells (3:green)
- bundle sheath cells (4:yellow)
- stoma (5: orange)



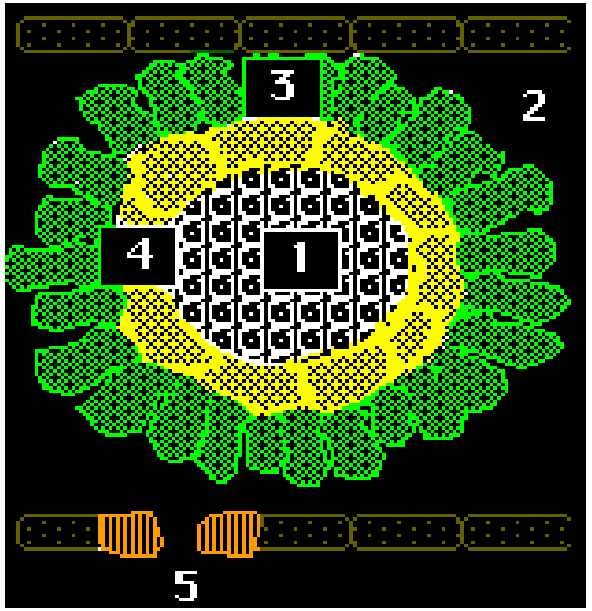
Physical Basis of Remote Sensing

❑ *Monocotyledonae*

- **C4** type of photosynthesis in which oxaloacetate is the first stable product, and phosphoenolpyruvate is the CO_2 receptor.
- Another name for this photosynthetic pathway is the Hatch-Slack pathway.
- In the leaves of C4 plants, the Calvin cycle occurs in the bundle sheath cells (yellow), which are not in contact with the air spaces.

Leaf structures include:

- vein (1:white)
- air space (2:black)
- mesophyll cells (3:green)
- bundle sheath cells (4:yellow)
- stoma (5: orange)



Physical Basis of Remote Sensing

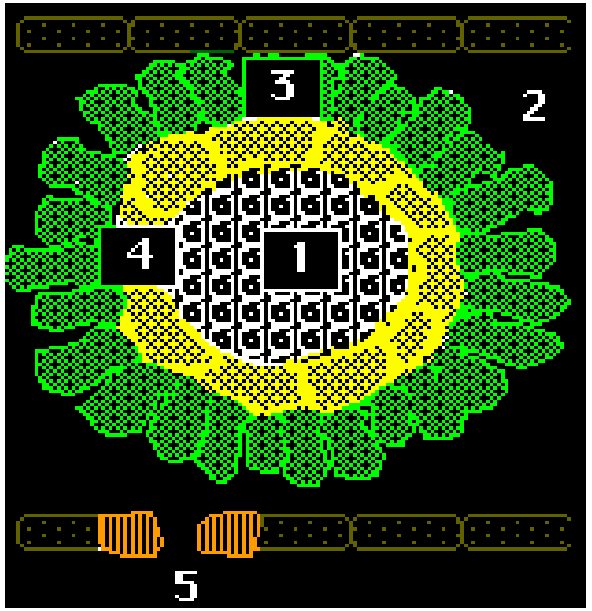
❑ *Monocotyledonae*

➢ Plants exhibiting this phenomenon (called C4 plants) include many important agricultural types like sugar cane, corn, millet, sorghum, and many light-adapted tropical species.

➢ The C4 pathway requires more energy, hence C4 plants tend to live in well-illuminated environments.

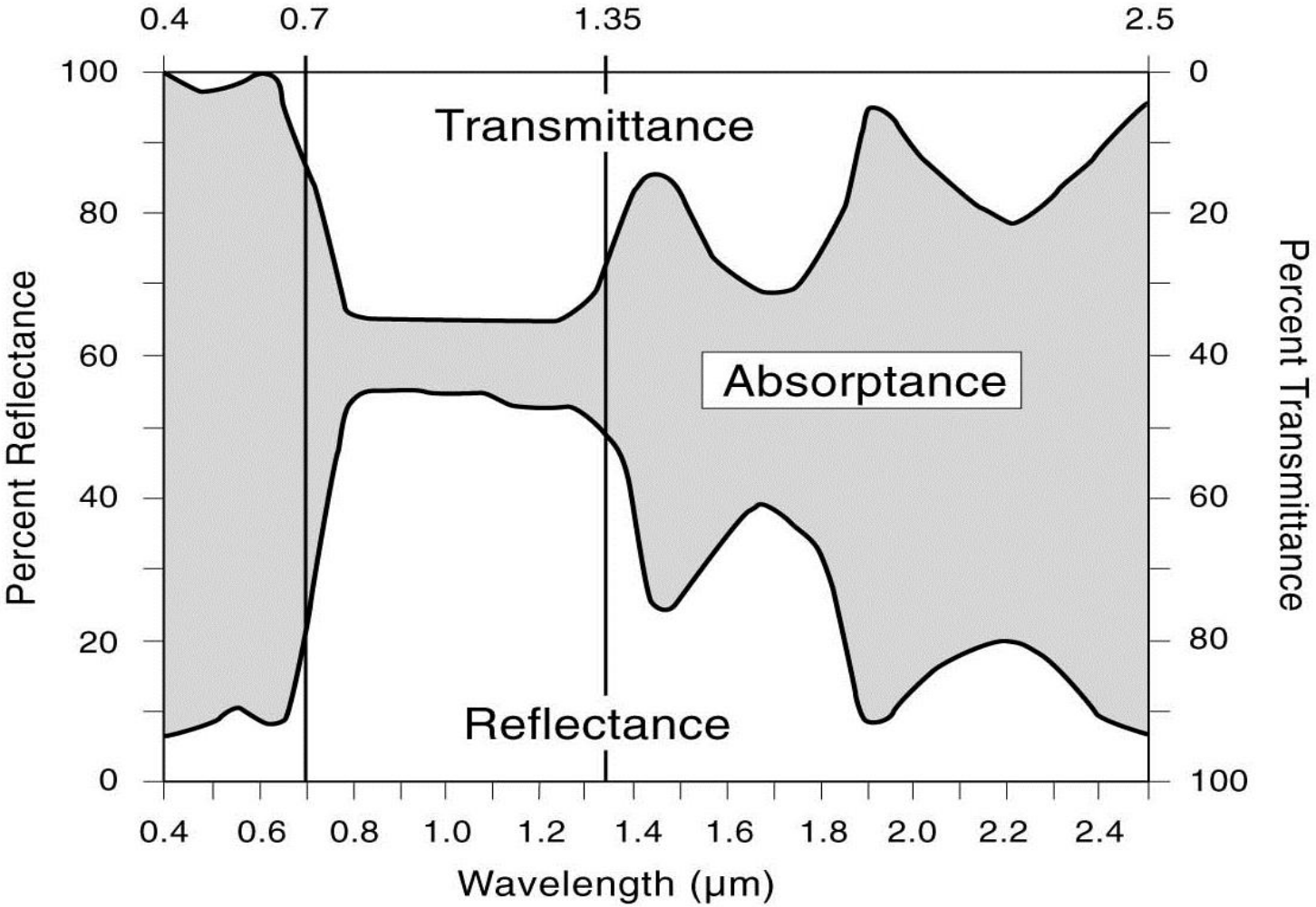
Leaf structures include:

- vein (1:white)
- air space (2:black)
- mesophyll cells (3:green)
- bundle sheath cells (4:yellow)
- stoma (5: orange)



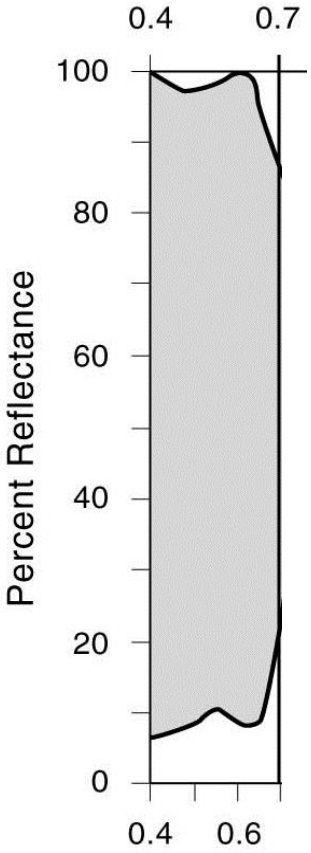
Physical Basis of Remote Sensing

- Vegetation reflectance



Physical Basis of Remote Sensing

- Vegetation reflectance in the visible

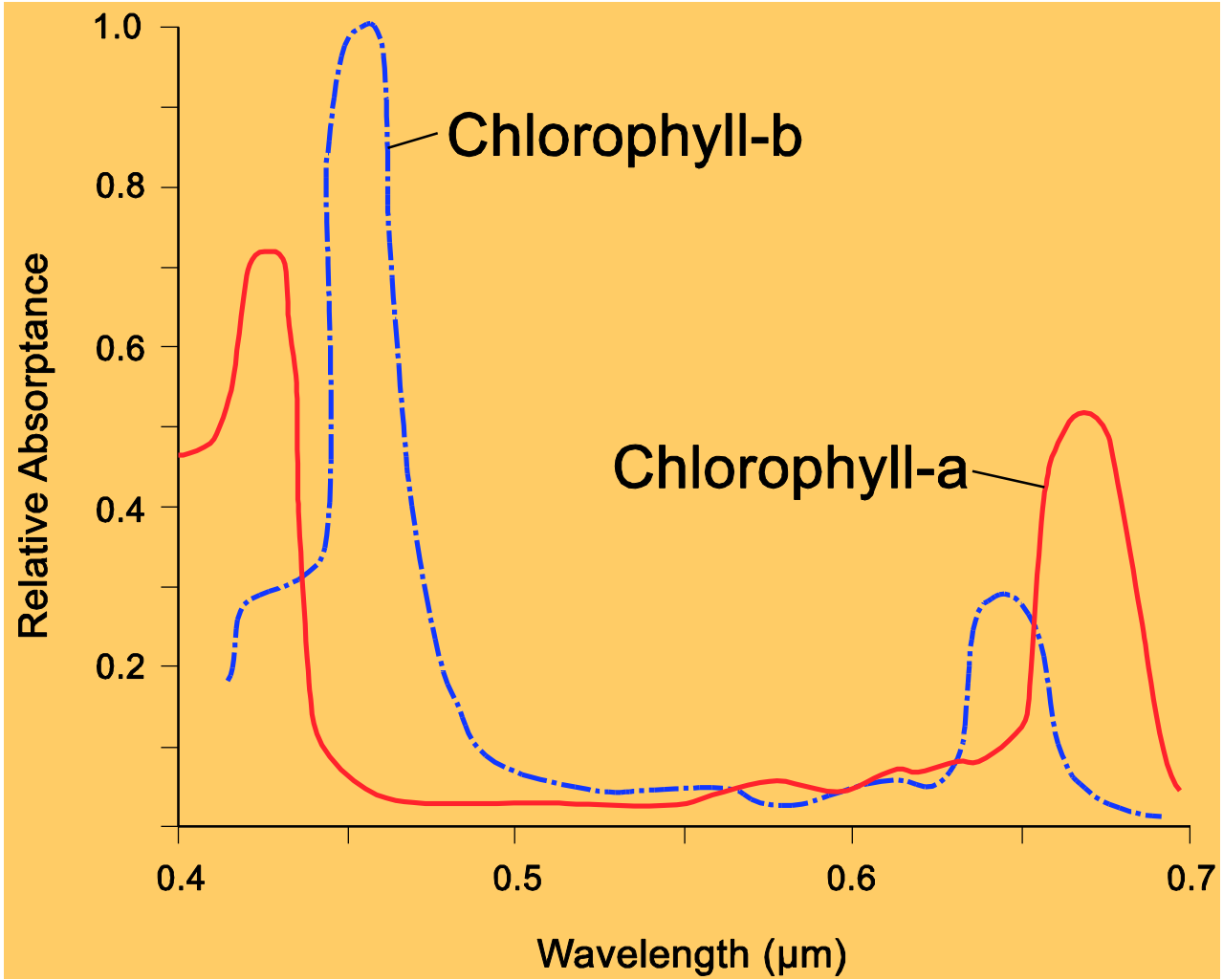


- Primary biophysical control of reflectance
  - ✓ Plant pigments
    - Chlorophyll-a and -b
    - Anthocyanin
    - α-Carotene
    - Lutein

Physical Basis of Remote Sensing

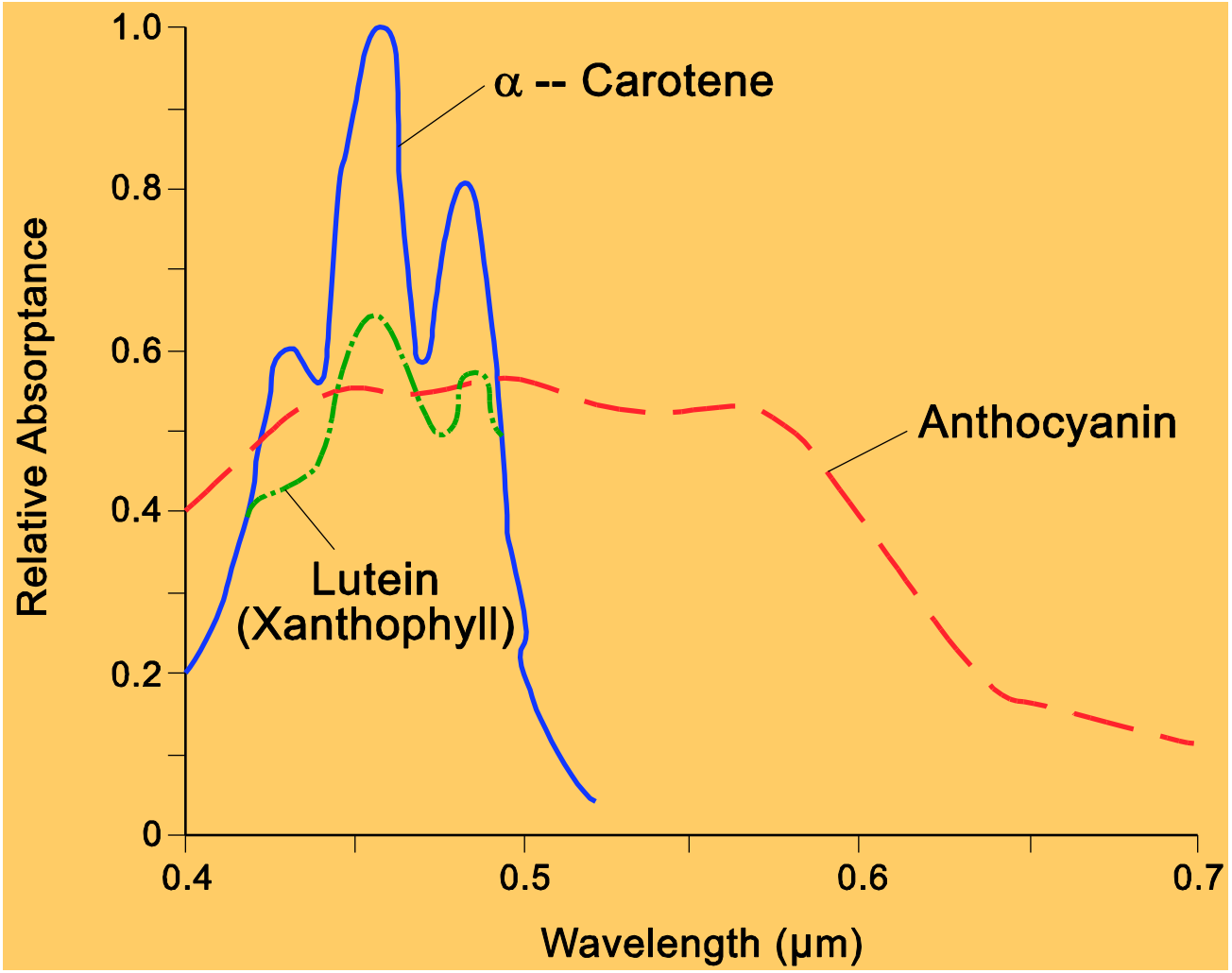
❑ Chlorophyll absorption in the visible

- **Chlorophyll-a is found in almost all photosynthetic systems.**
- **Chlorophyll-b, an accessory pigment, is only found in plants, green algae, and green bacteria.**



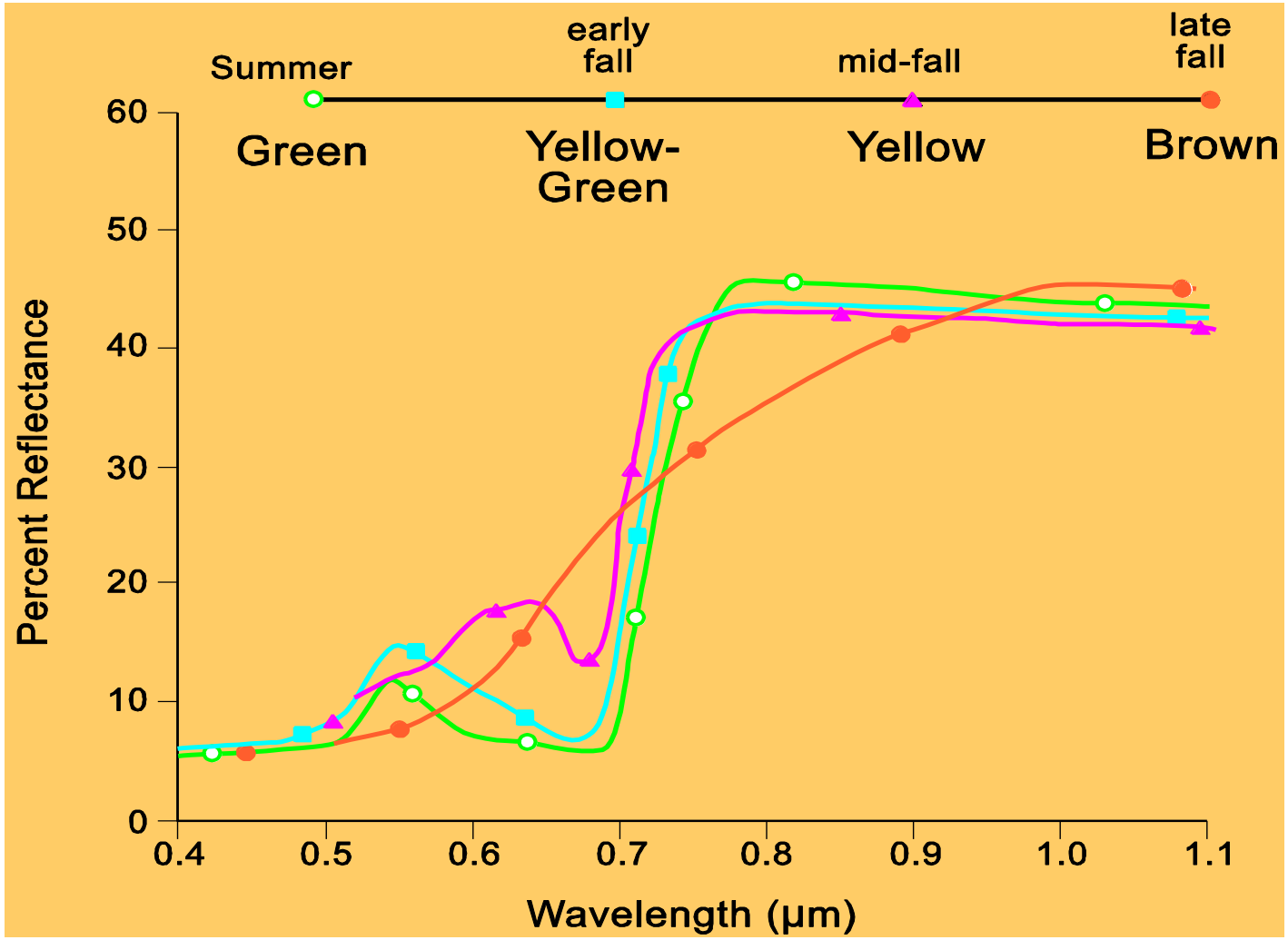
Physical Basis of Remote Sensing

- Non-green pigment absorption in the visible



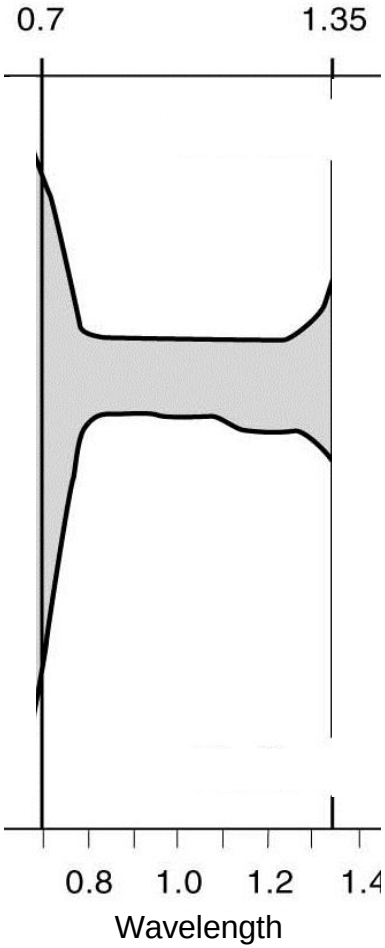
Physical Basis of Remote Sensing

- Plant senescence



Physical Basis of Remote Sensing

- Vegetation reflectance in the NIR

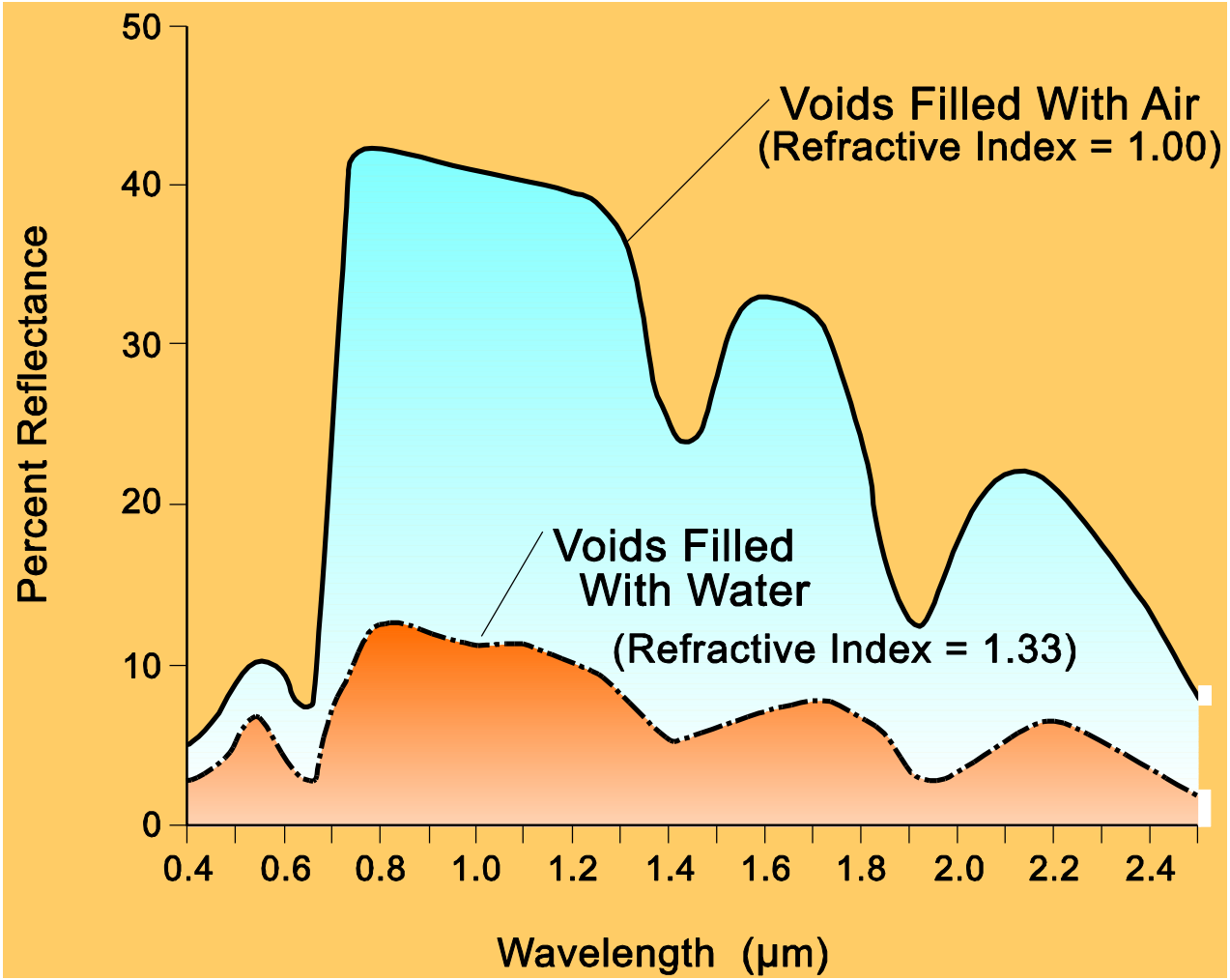


- Primary biophysical control of reflectance
  - ✓ Internal leaf structures
  - ✓ Total green canopy biomass

Physical Basis of Remote Sensing

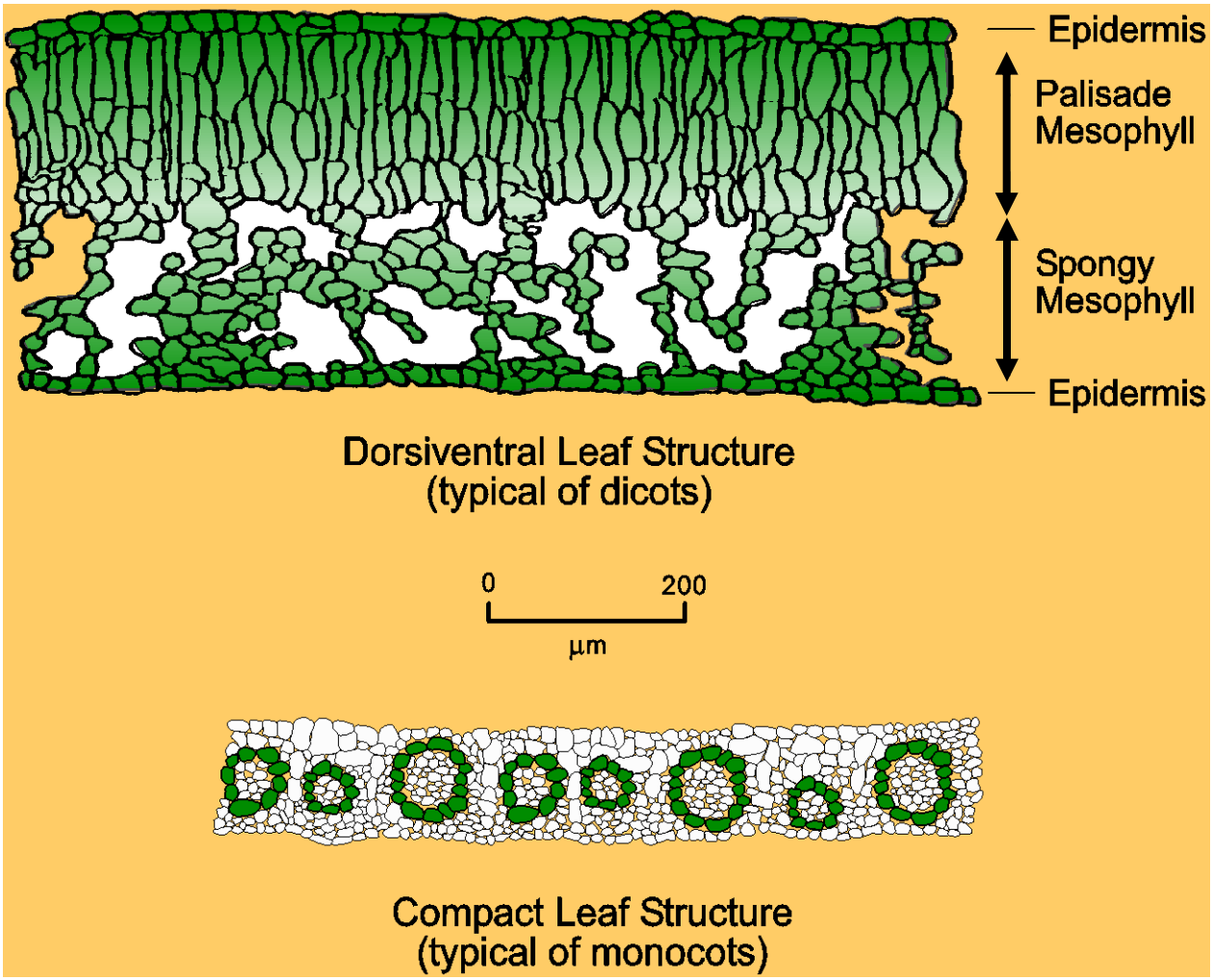
- Vegetation reflectance in the NIR

  - Dominated by internal reflectance due to large changes in the index of refraction of plant cells *vs* air voids.



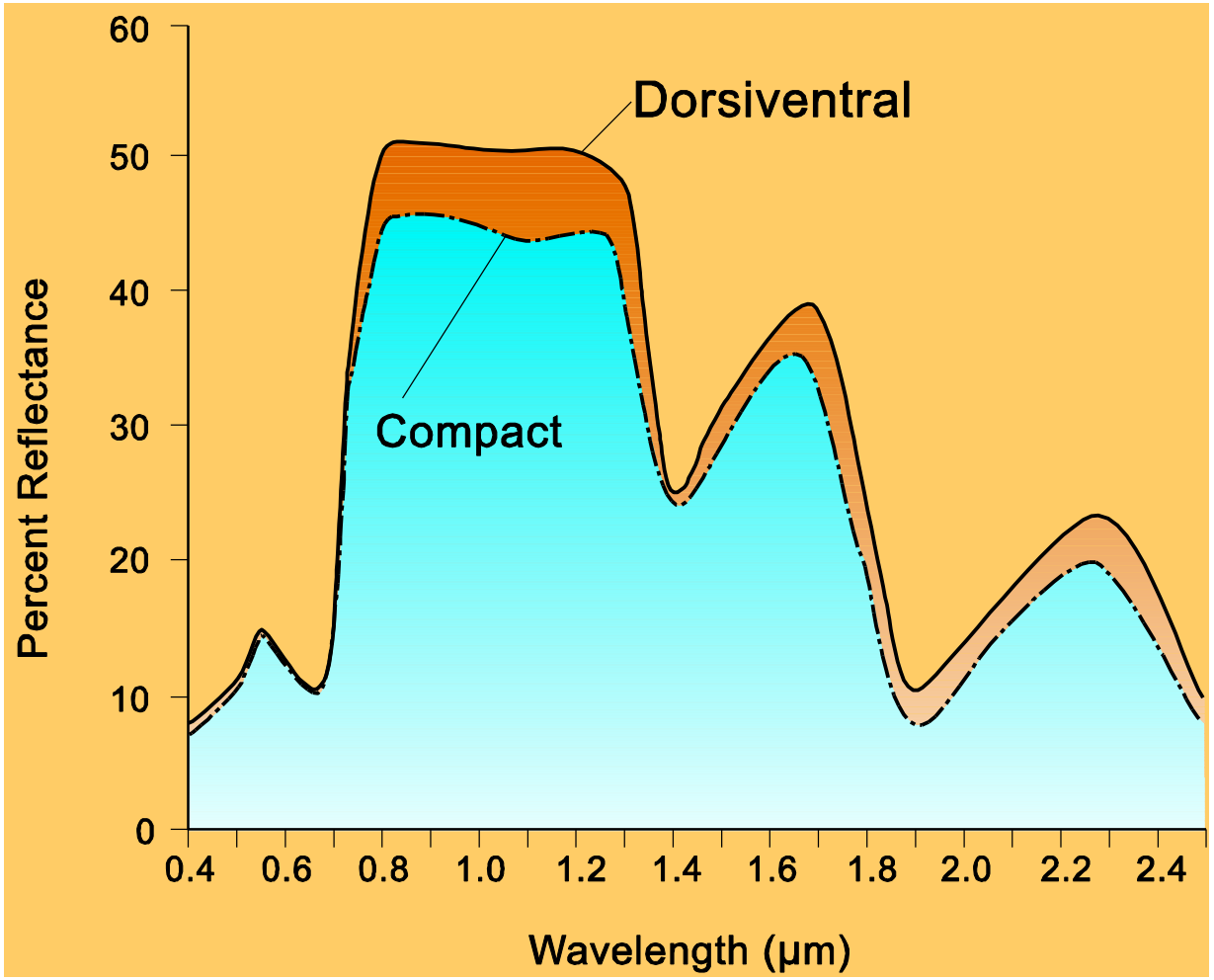
Physical Basis of Remote Sensing

- Vegetation reflectance in the NIR
  - Sensitive to internal leaf structure

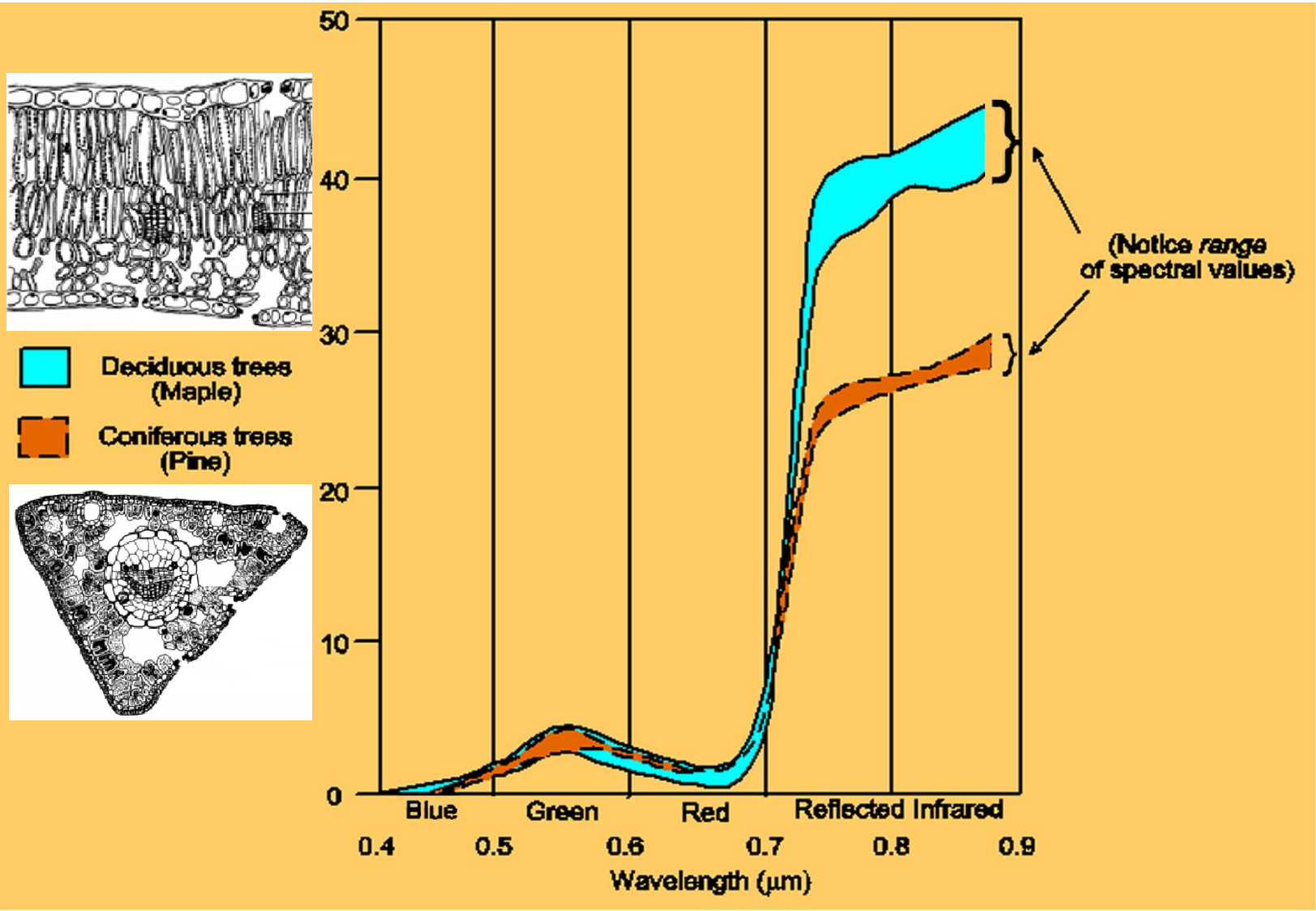


Physical Basis of Remote Sensing

- Vegetation reflectance in the NIR
  - Sensitive to internal leaf structure

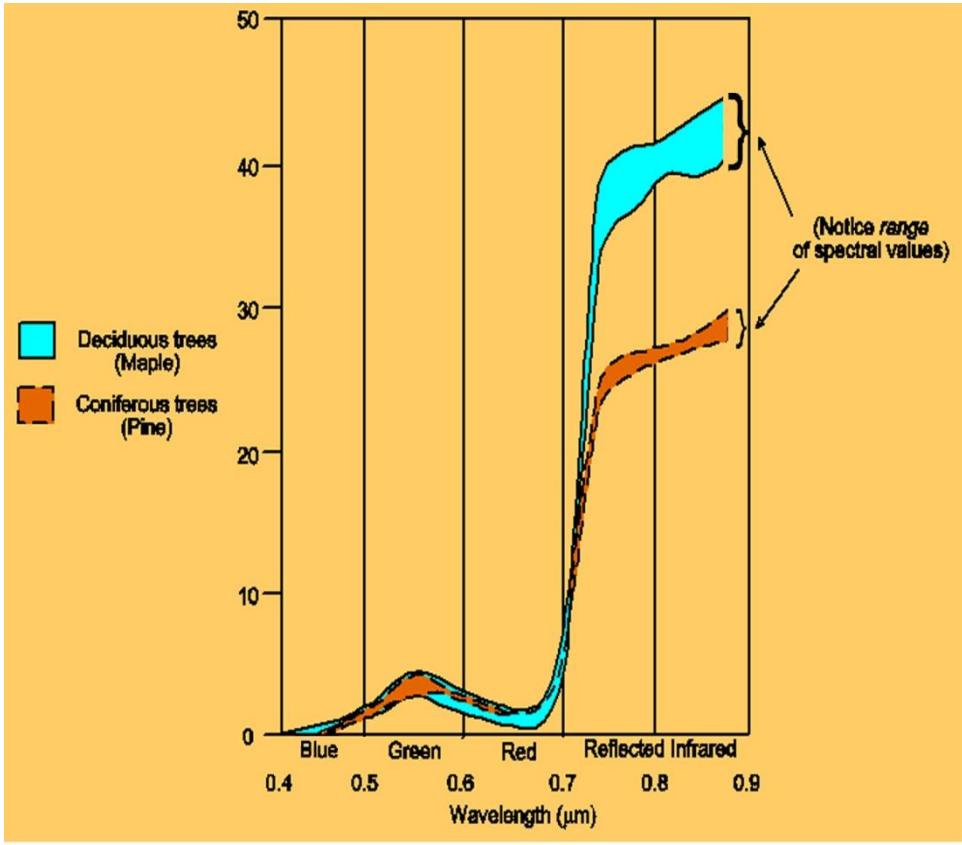


Physical Basis of Remote Sensing



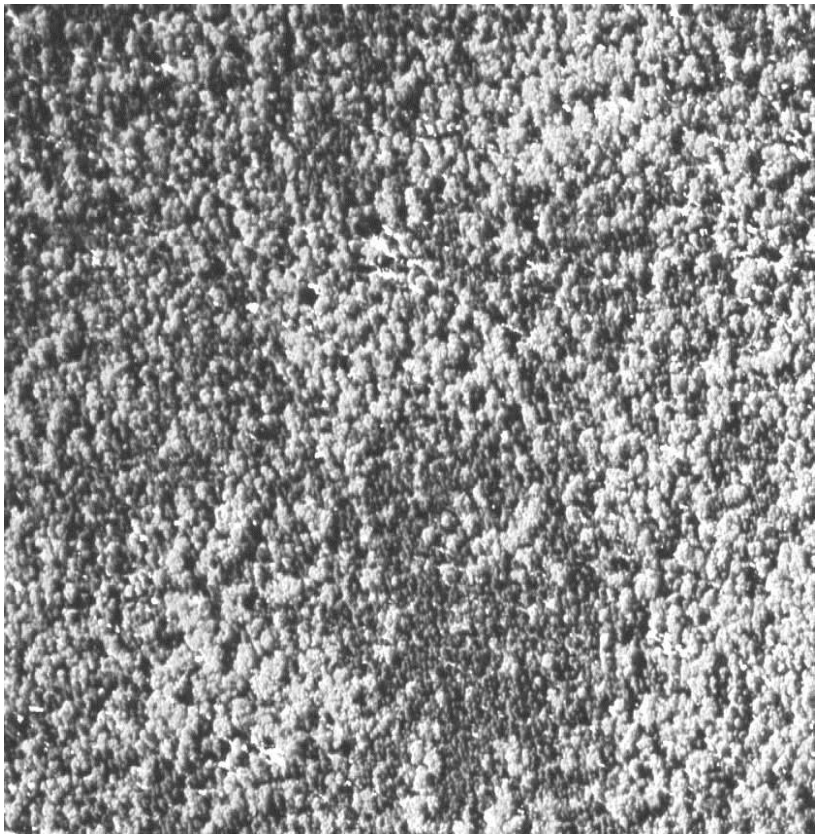
Physical Basis of Remote Sensing

- Broadleaf trees exhibit dorsiventral leaf structures *vs* the compact leaf structure of the needleleaf trees.
- Broadleaves are planar and more efficient reflectors of sunlight *vs* the cylindrical form of the needles.
- Broadleaf trees have larger green foliar biomass in their canopy compared to the needleleaf types.
- The rounded crowns (esp. of varying size due to mixed species) form a smoother canopy surface with less shadowing than a closed canopy of needleleaf trees that tend to have conical crowns of more constant size.

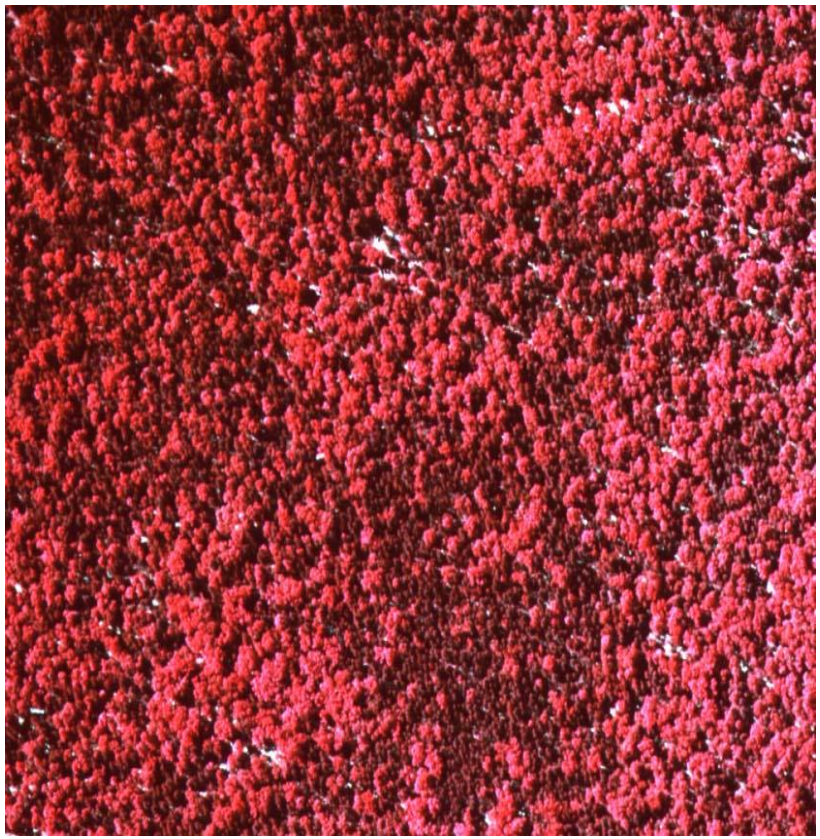


Physical Basis of Remote Sensing

- Broadleaf *vs* Needleleaf Vegetation Reflectance



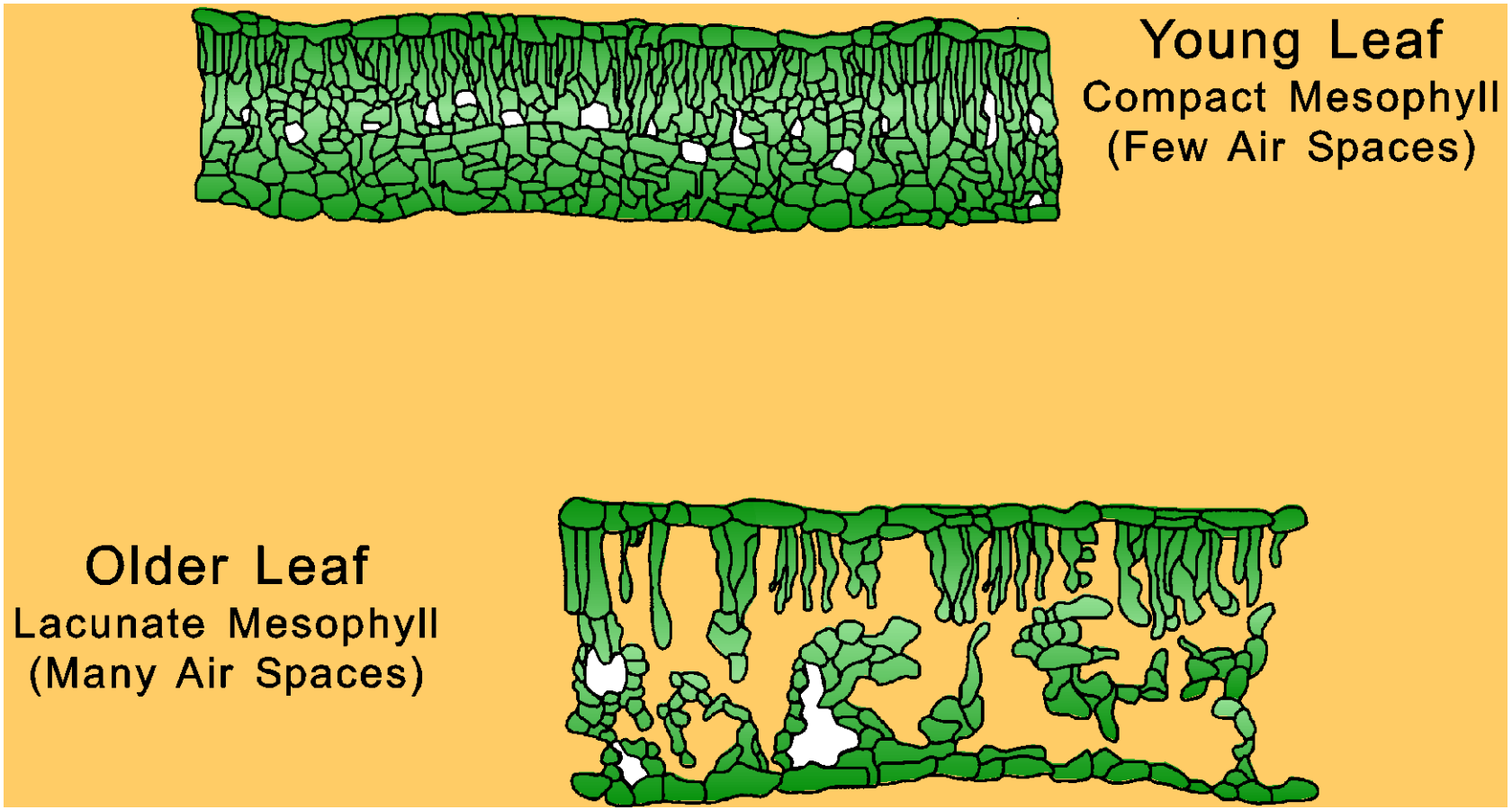
BWIR



CIR

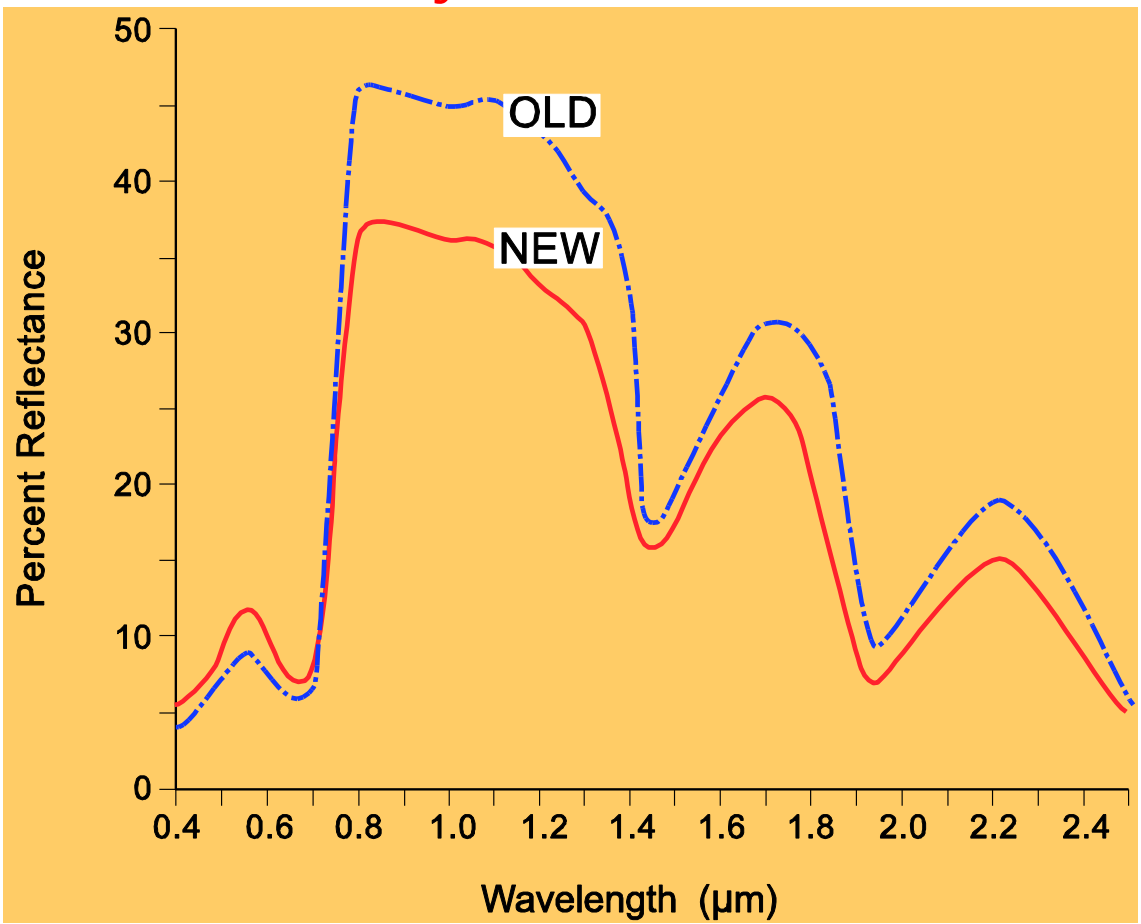
Physical Basis of Remote Sensing

- Vegetation reflectance in the NIR
  - Sensitive to maturity differences



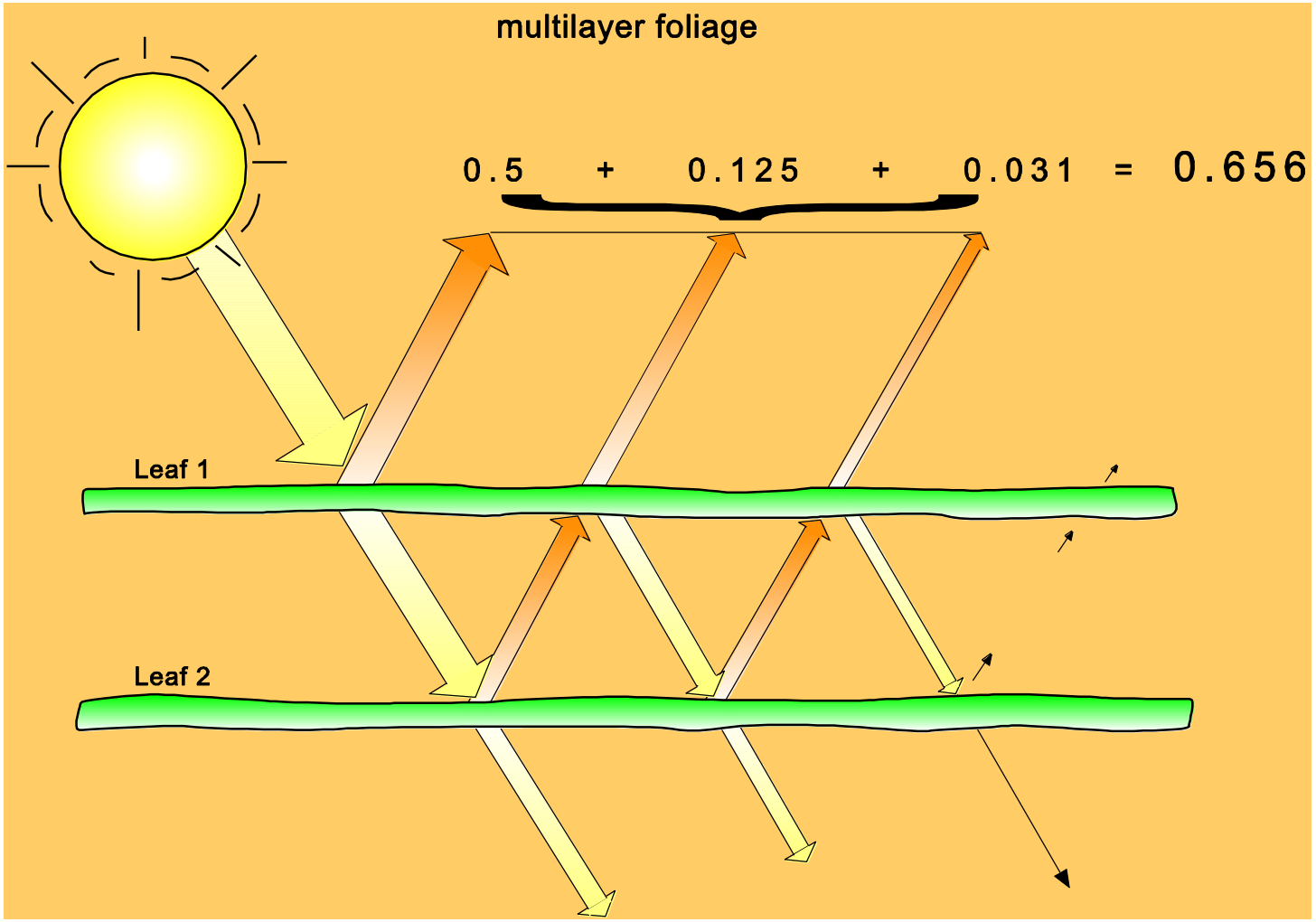
Physical Basis of Remote Sensing

- Vegetation reflectance in the NIR
  - Sensitive to maturity differences



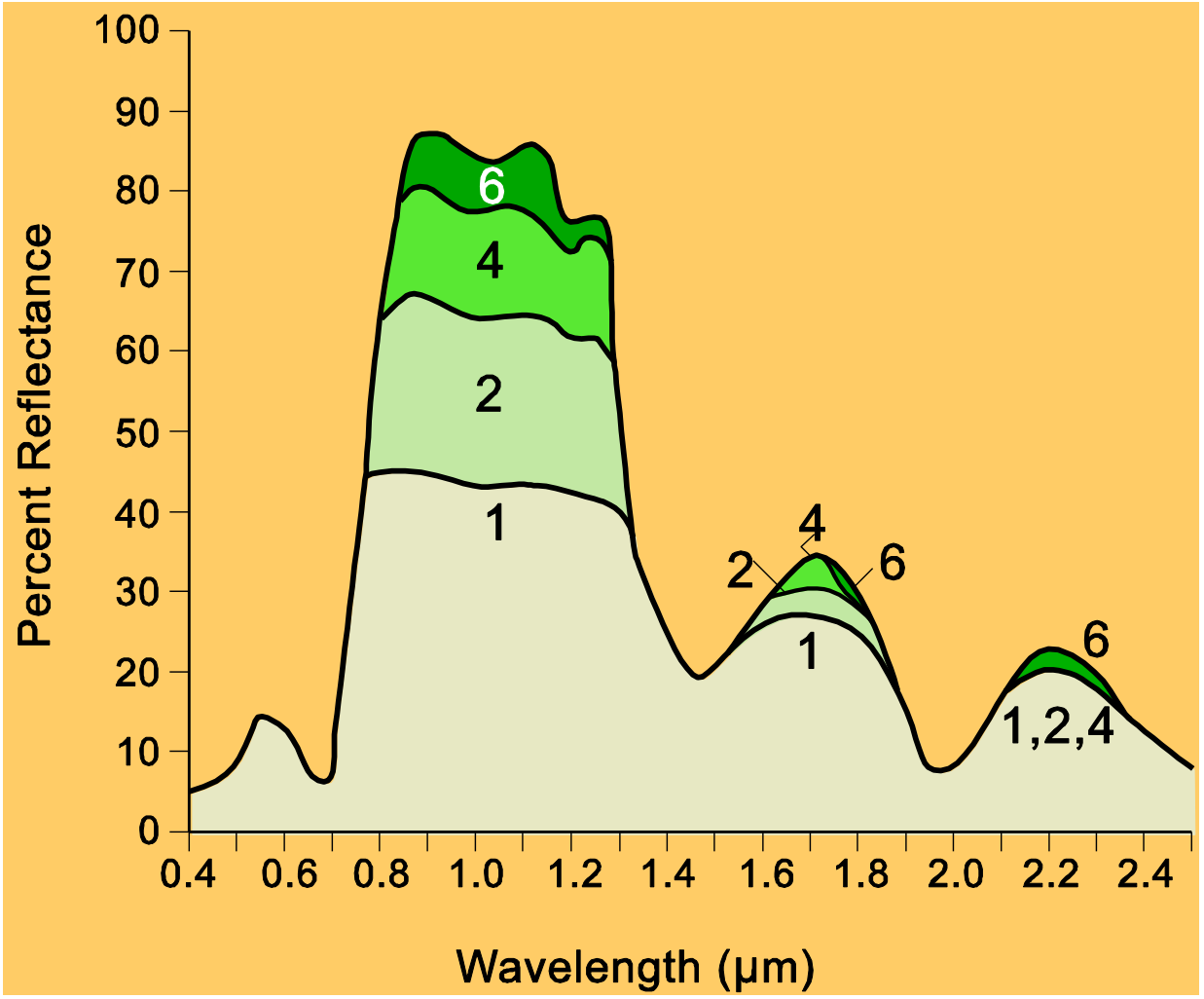
Physical Basis of Remote Sensing

- High vegetation **transmittance** in the NIR



Physical Basis of Remote Sensing

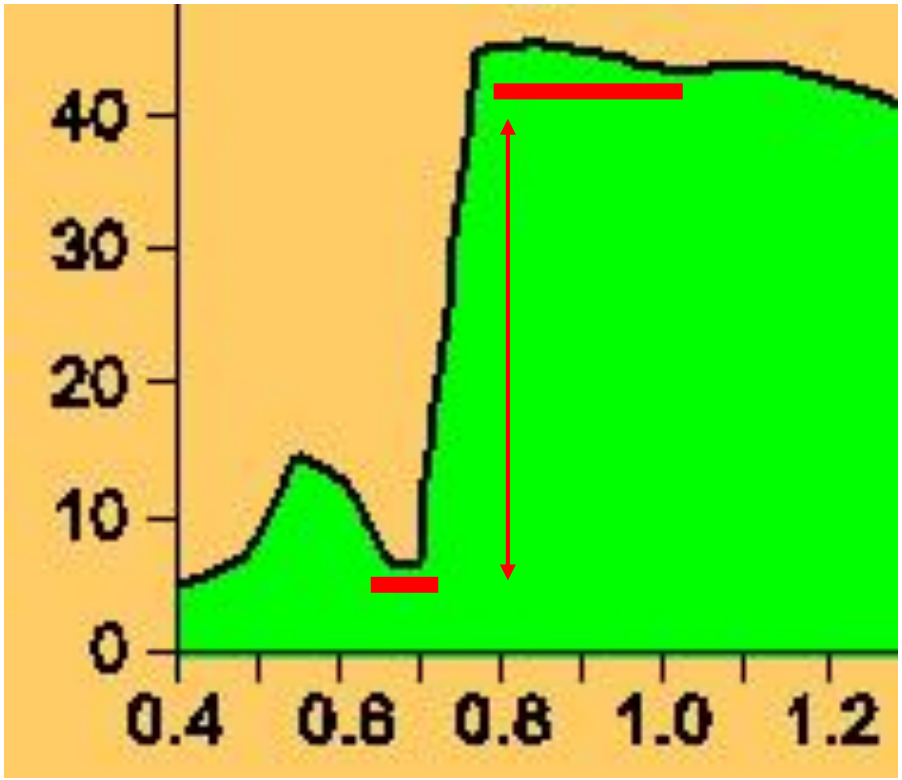
- Vegetation reflectance in the NIR
  - Sensitive to foliar biomass (LAI) due to the high transmission of NIR



Physical Basis of Remote Sensing

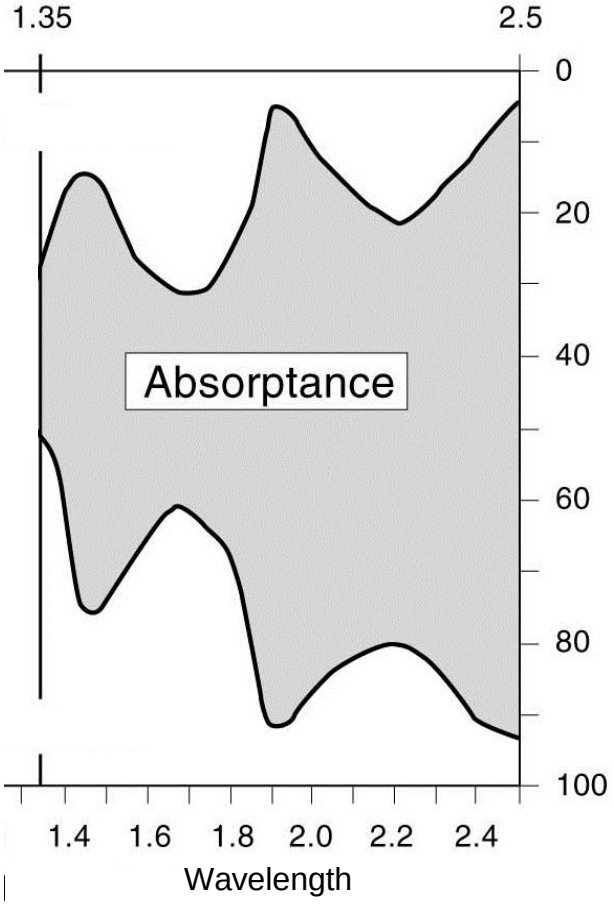
- NDVI – normalized difference vegetation index

$$\frac{NIR - Red}{NIR + Red}$$



Physical Basis of Remote Sensing

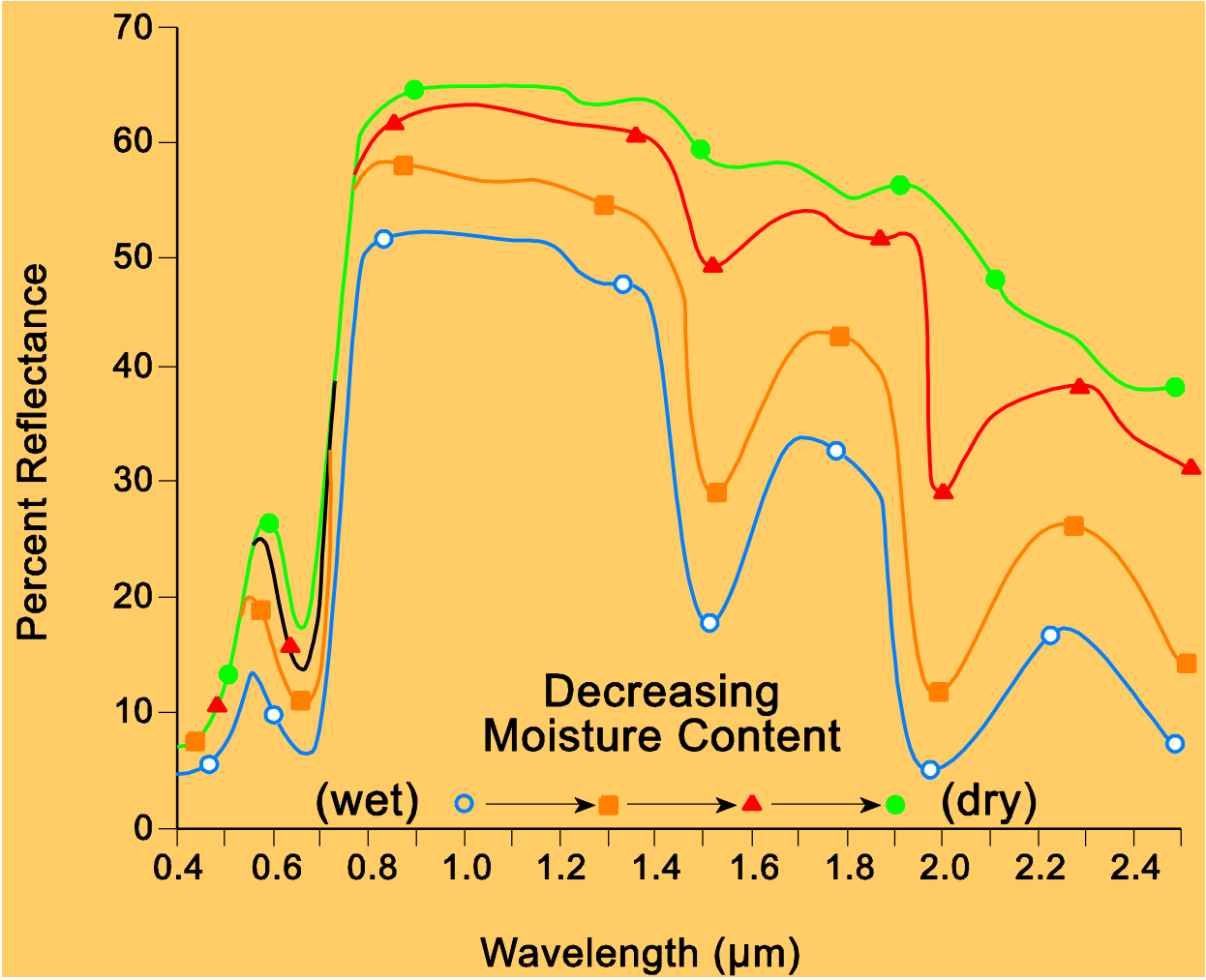
- Vegetation reflectance in the SWIR



- Primary biophysical control of reflectance
  - ✓ Internal leaf moisture content
- Secondary biophysical controls of reflectance
  - ✓ Total green canopy biomass
  - ✓ Within-canopy shadows

Physical Basis of Remote Sensing

- Vegetation reflectance in the SWIR
  - Primary biophysical control of reflectance
  - ✓ Internal leaf moisture content

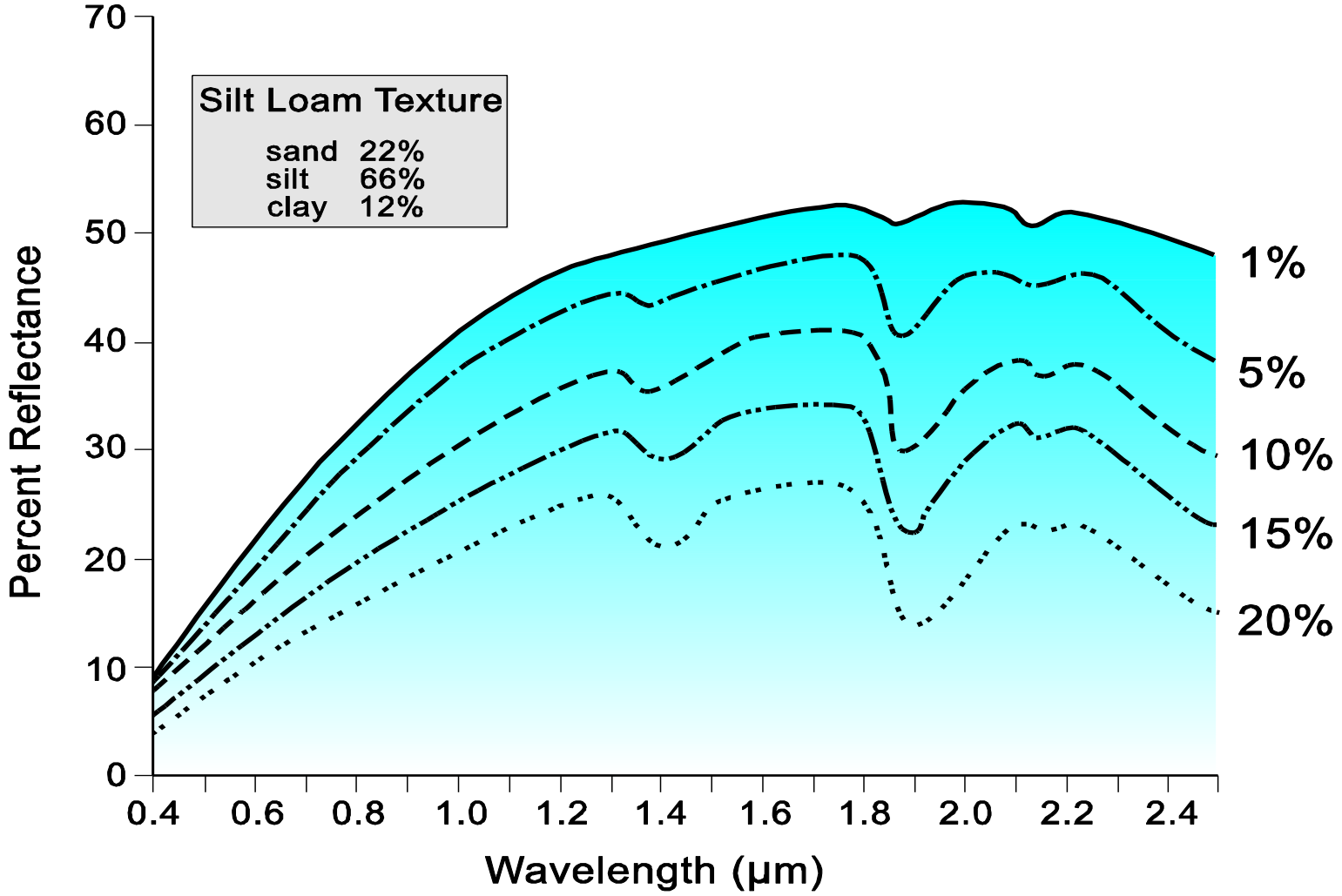


Physical Basis of Remote Sensing

- Soil reflectance
  - Most important factors
    - ✓ Moisture content
    - ✓ Organic matter content
  - Other factors
    - ✓ Particle size (surface)
    - ✓ Iron oxide content
    - ✓ Mineralogy
    - ✓ Structure

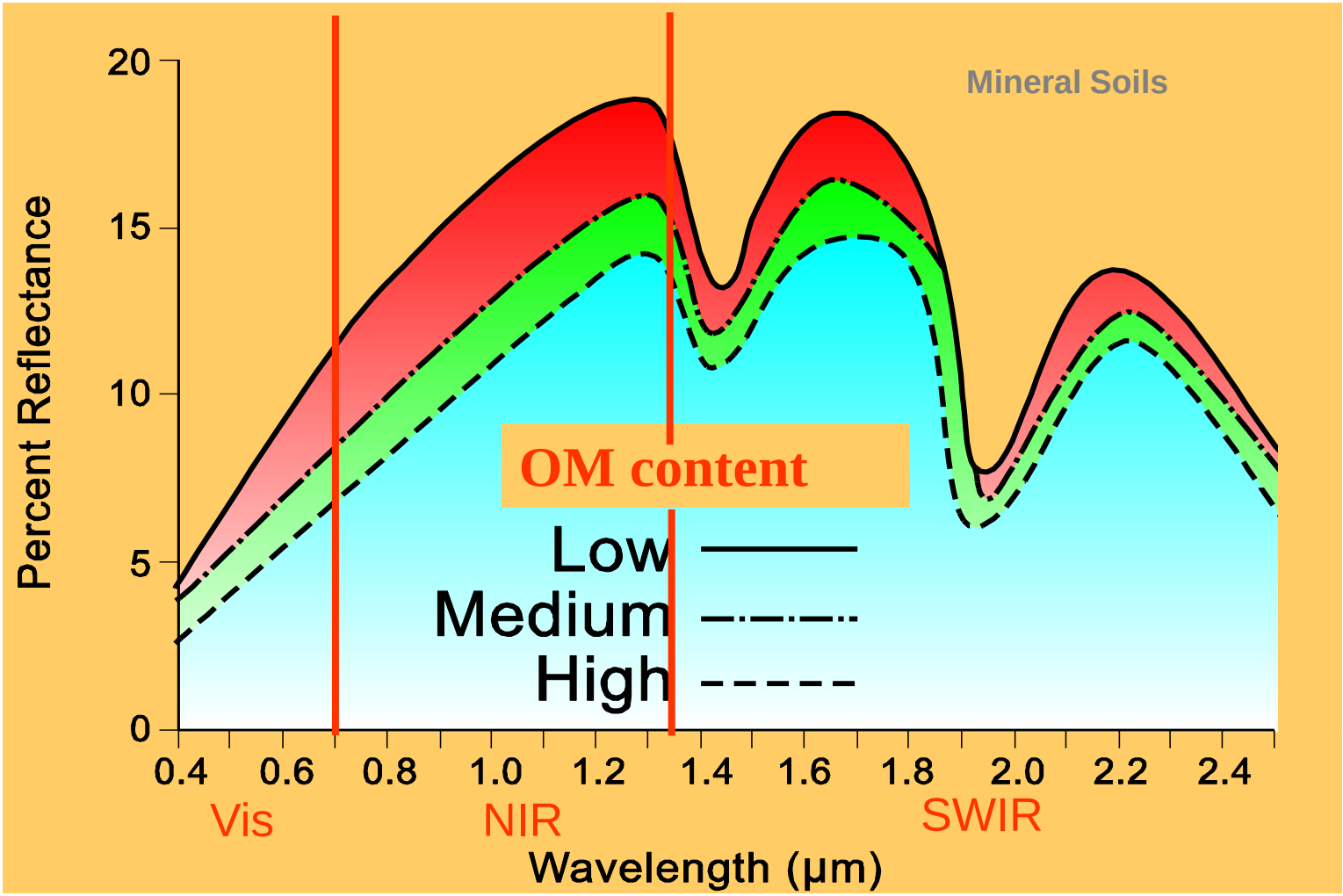
Physical Basis of Remote Sensing

- Soil reflectance: #1 control = moisture content



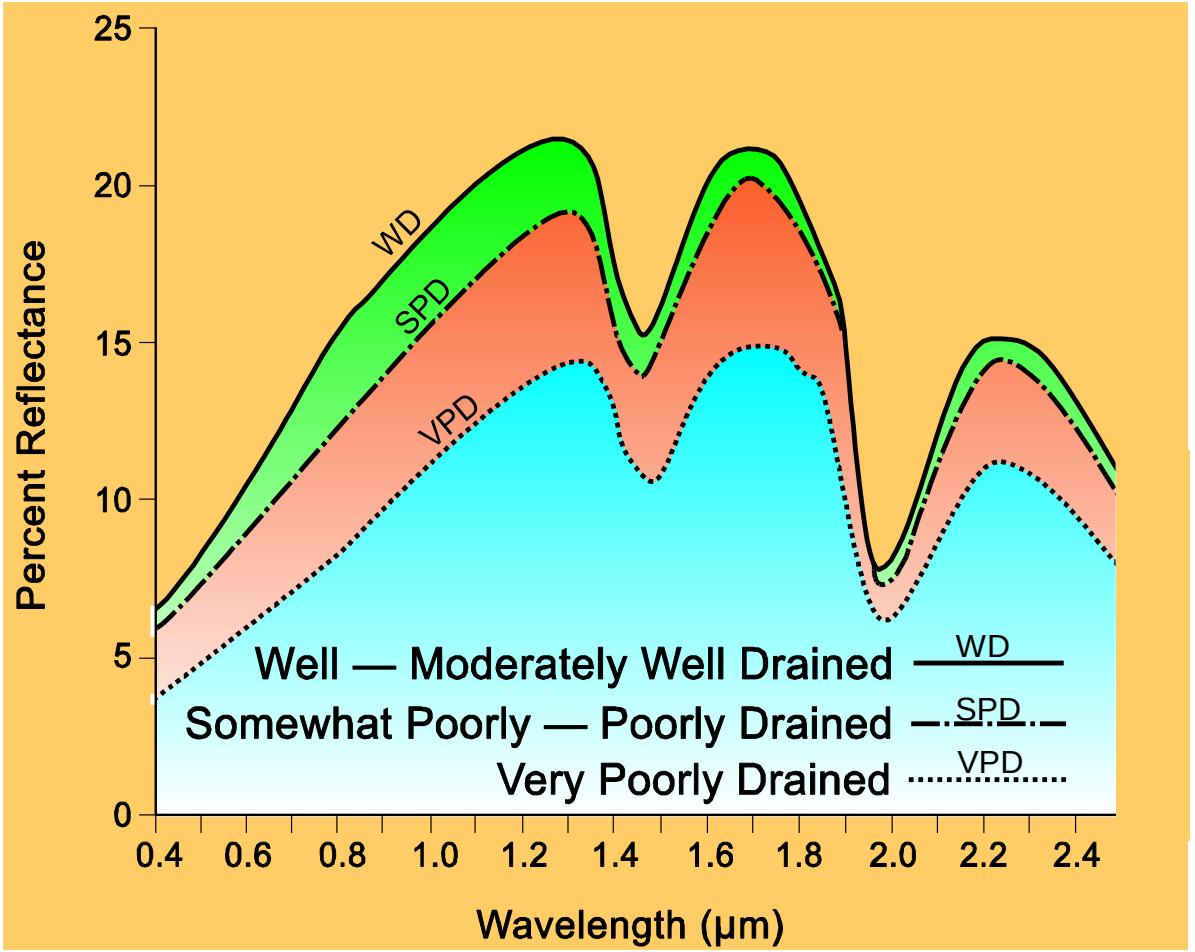
Physical Basis of Remote Sensing

- Soil reflectance: #2 control = organic matter content



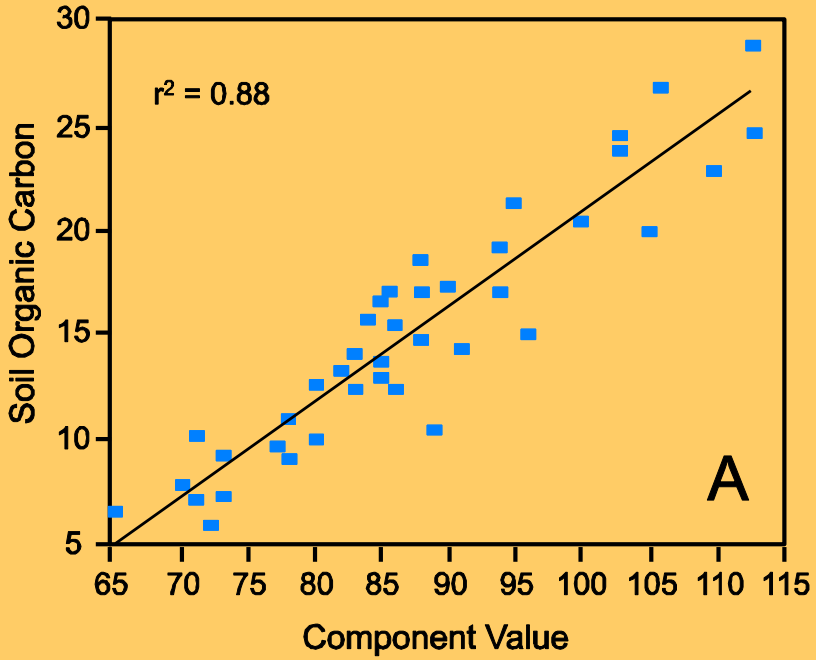
Physical Basis of Remote Sensing

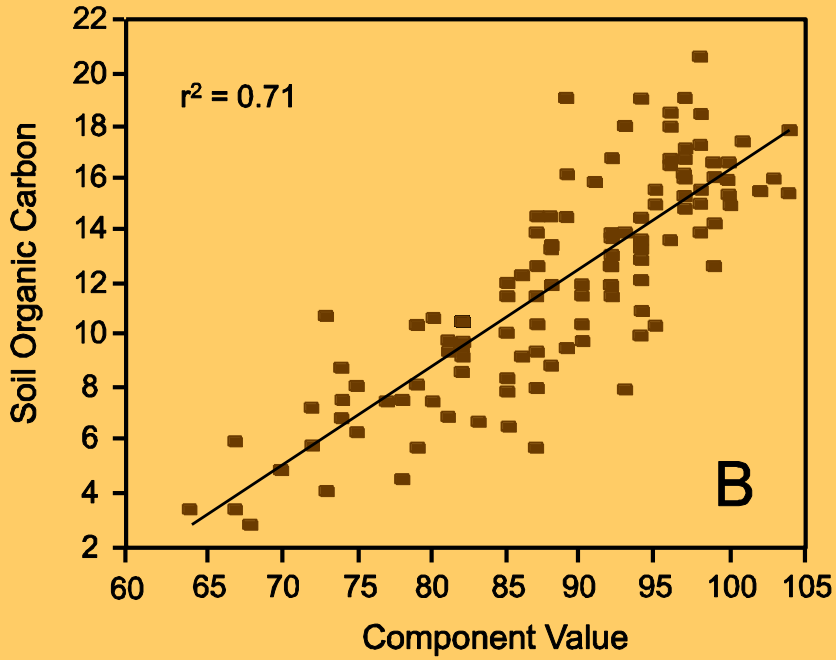
- Soil reflectance: #2 control = organic matter content
  - Since all these soil samples were brought to the same moisture content before measurement, this graph actually shows the covariant relationship to OM content.



Physical Basis of Remote Sensing

- Soil organic carbon assessed from Landsat TM



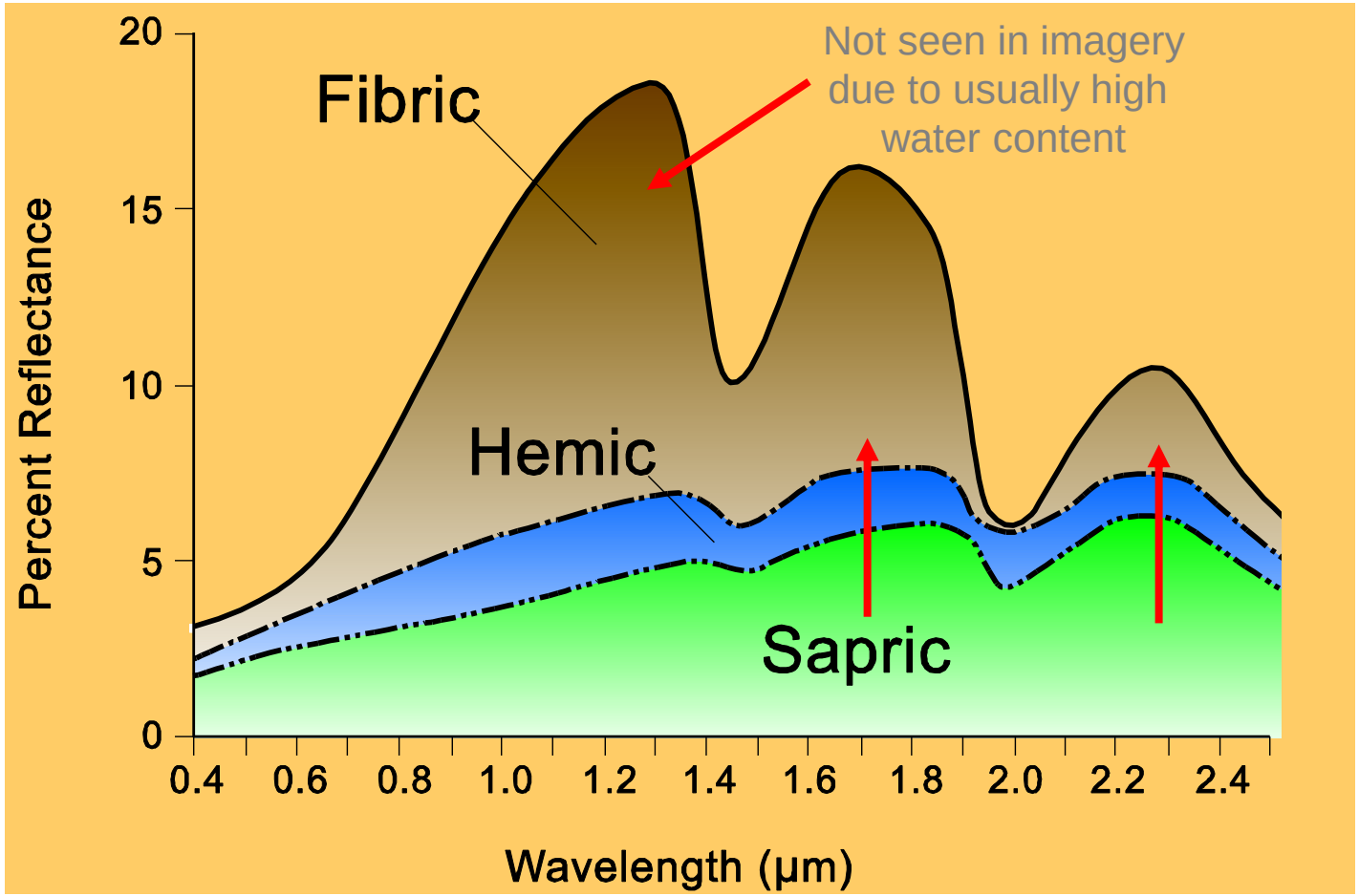


TM data were atmospherically corrected and converted to radiance then processed by band ratioing and principle component analysis

Regression function comparing the association between measured s.o.c. content and observed Landsat TM values for the pooled Plaza and Pullman, Washington field sites (A) and the pooled Thera and St. John, Washington field sites.

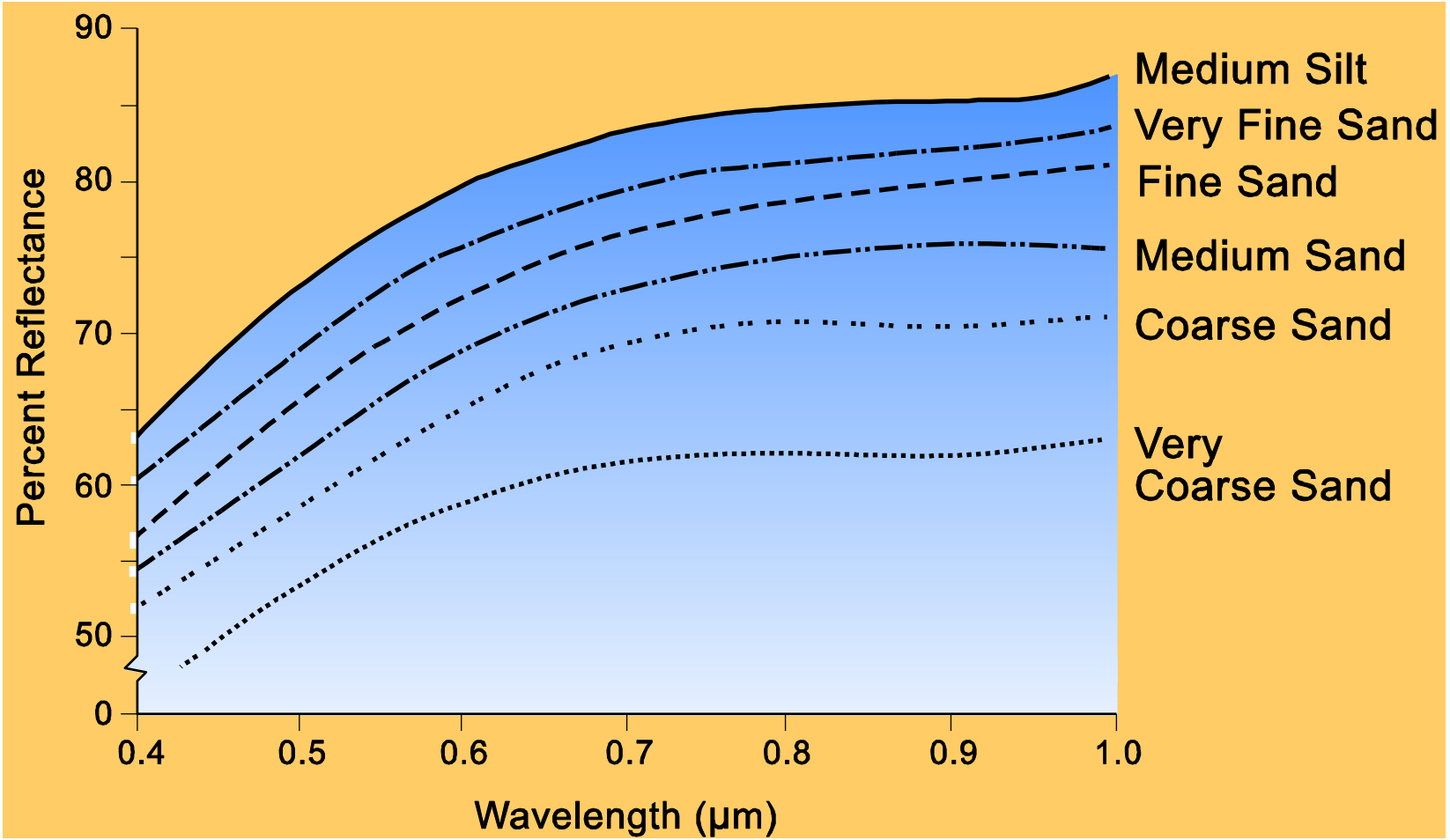
Physical Basis of Remote Sensing

- Histosol reflectance: peaks in the SWIR



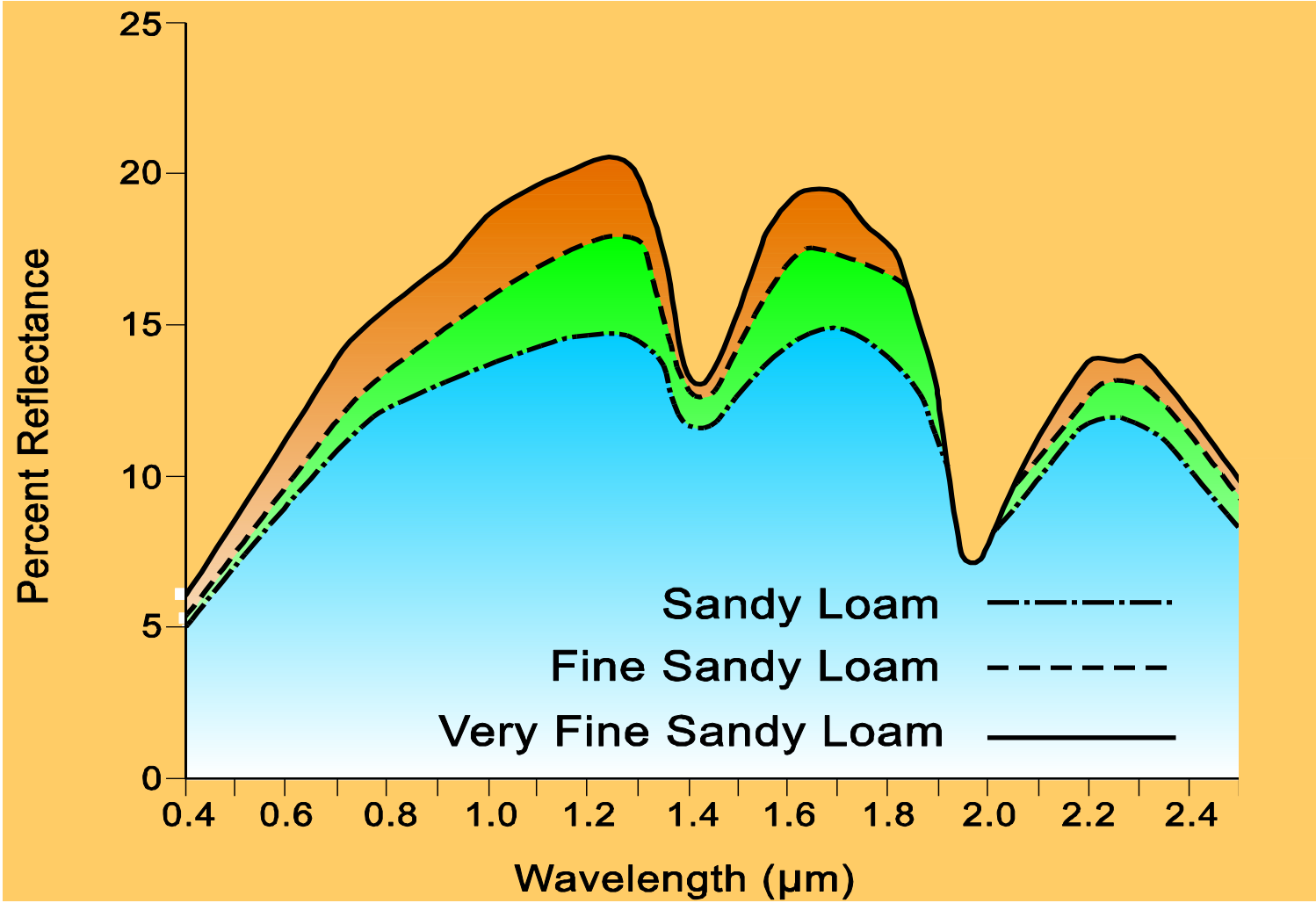
Physical Basis of Remote Sensing

- Particle size *vs* soil reflectance



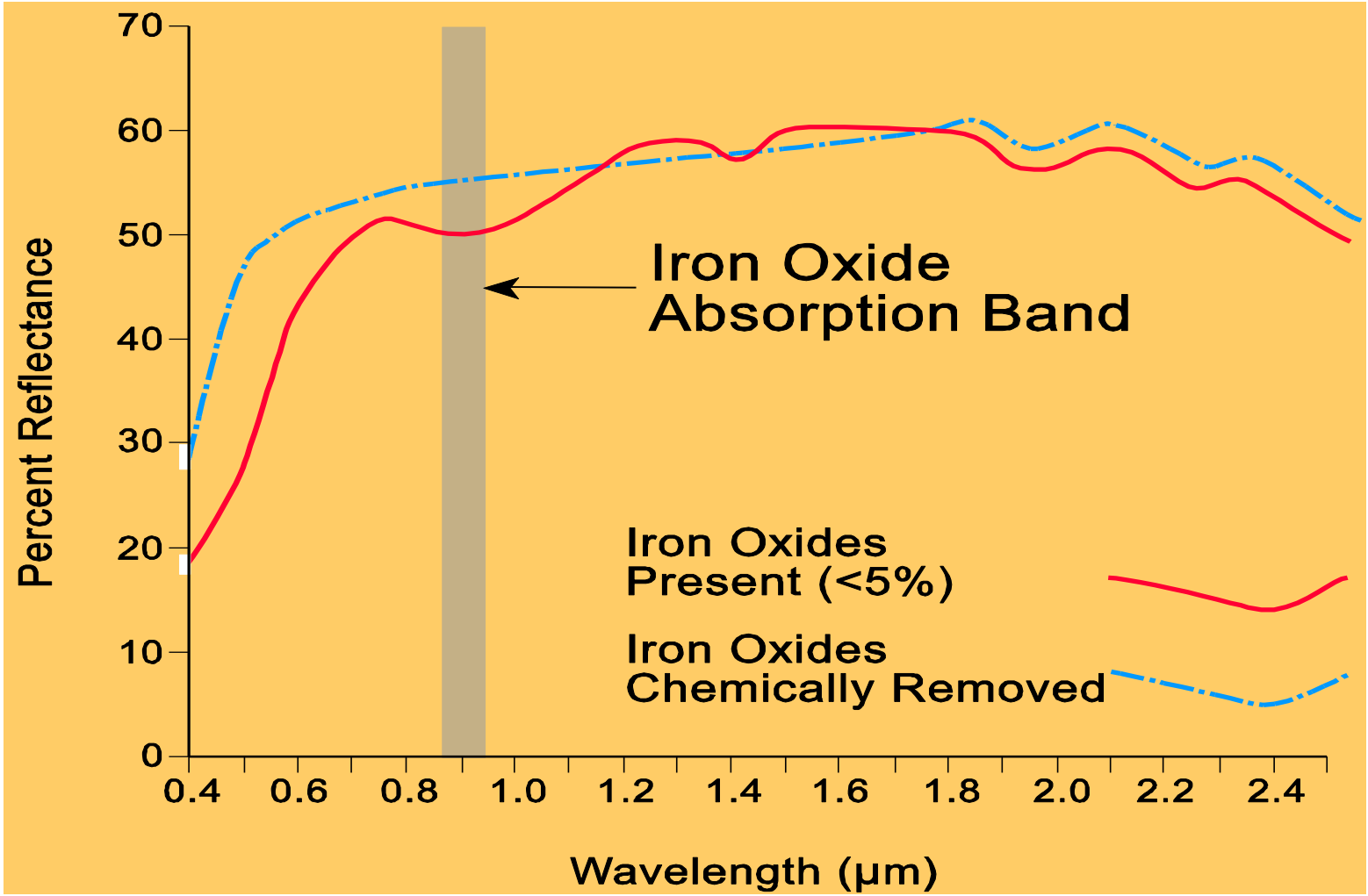
Physical Basis of Remote Sensing

- Surface texture *vs* soil reflectance



Physical Basis of Remote Sensing

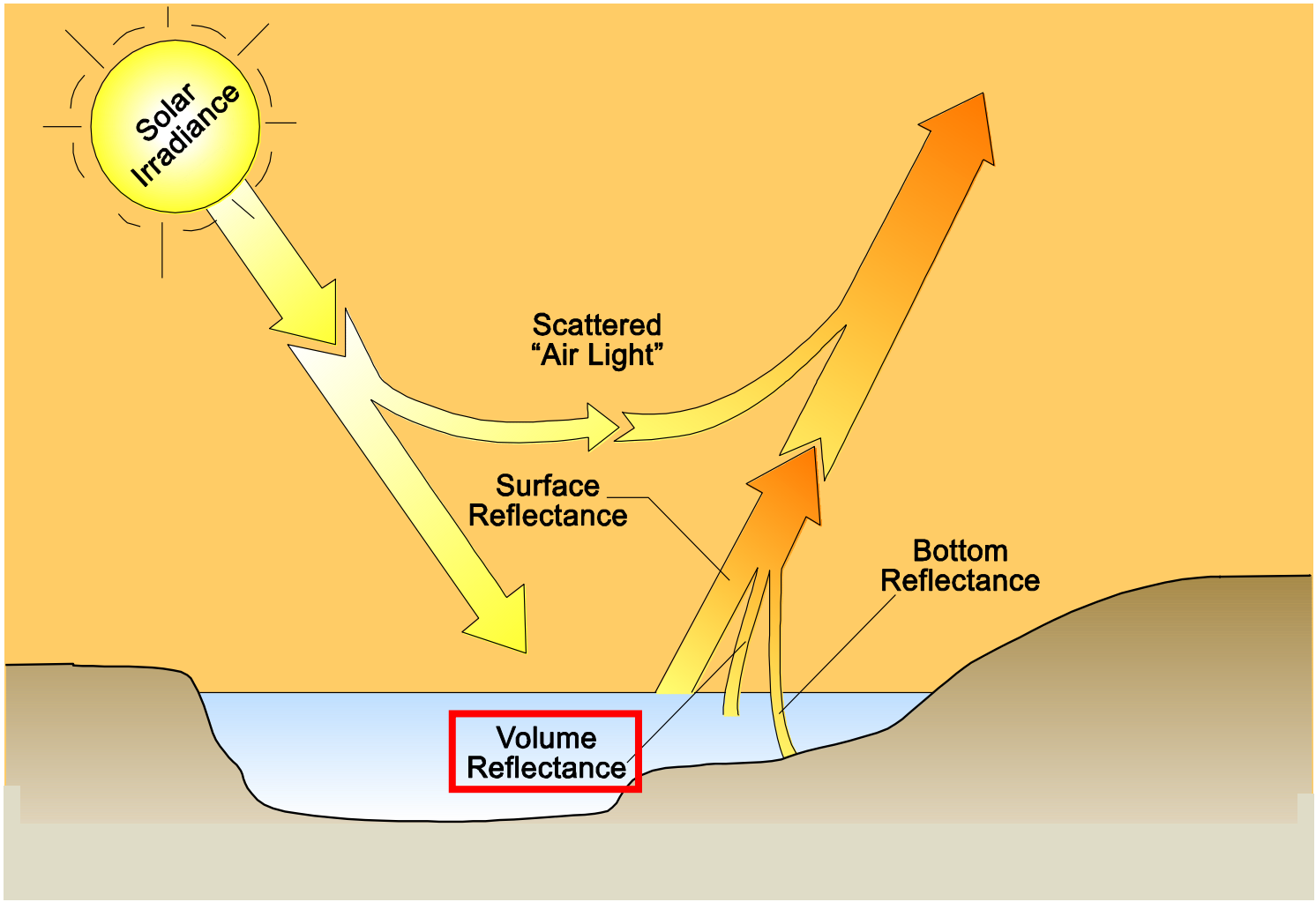
- Iron oxide in soil



Physical Basis of Remote Sensing

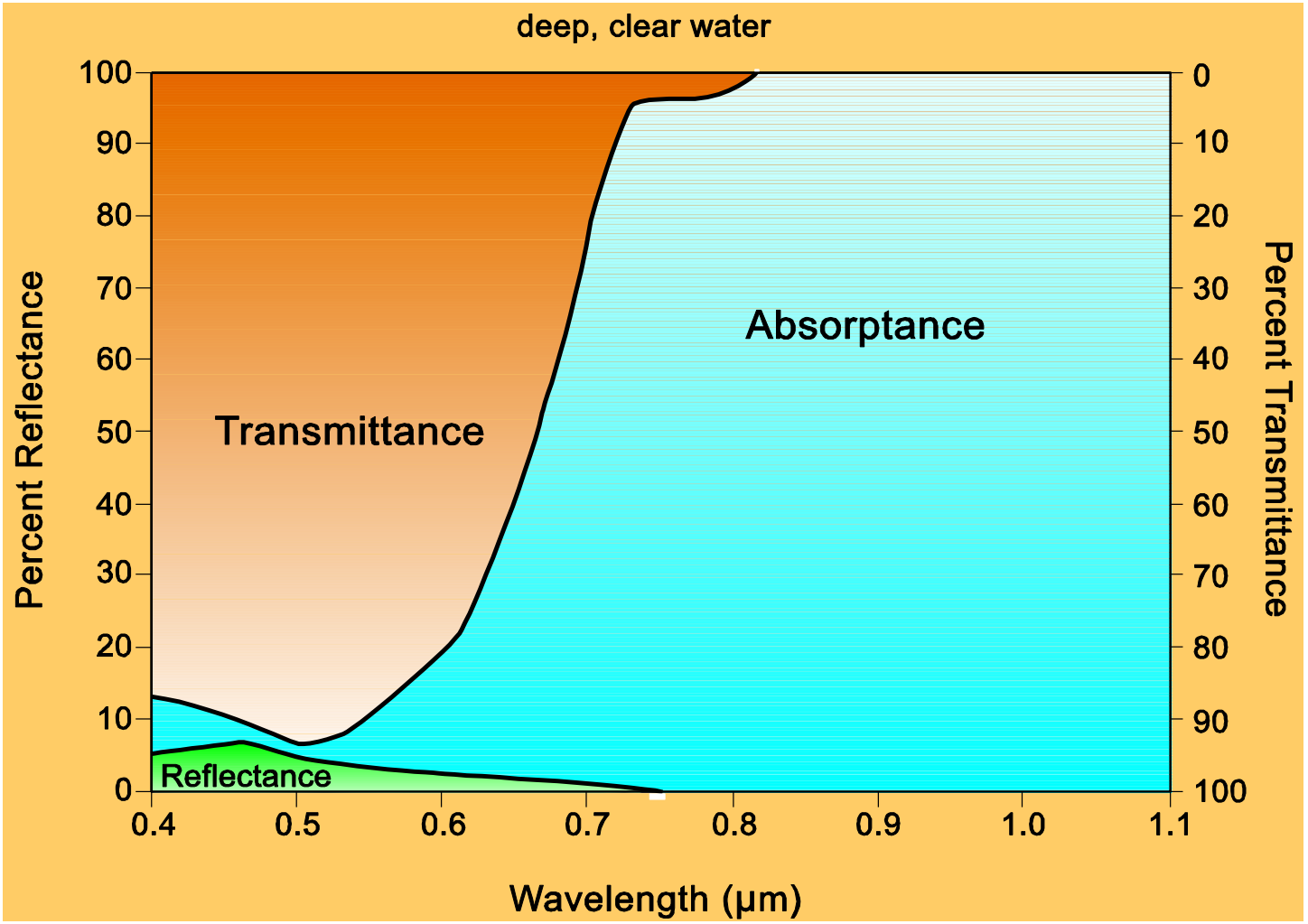
Physical Basis of Remote Sensing

- Water reflectance



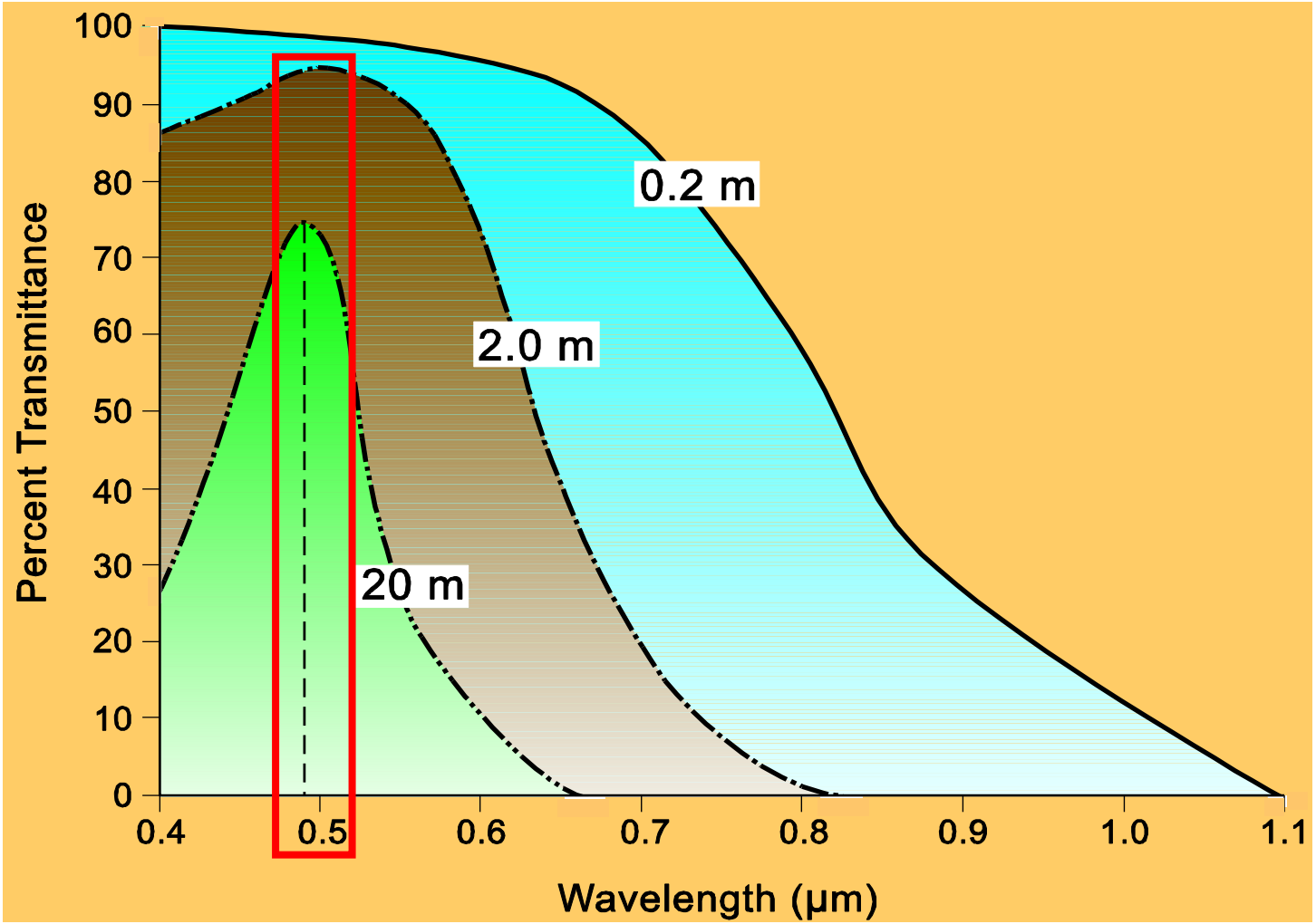
Physical Basis of Remote Sensing

- Spectral partitioning by water



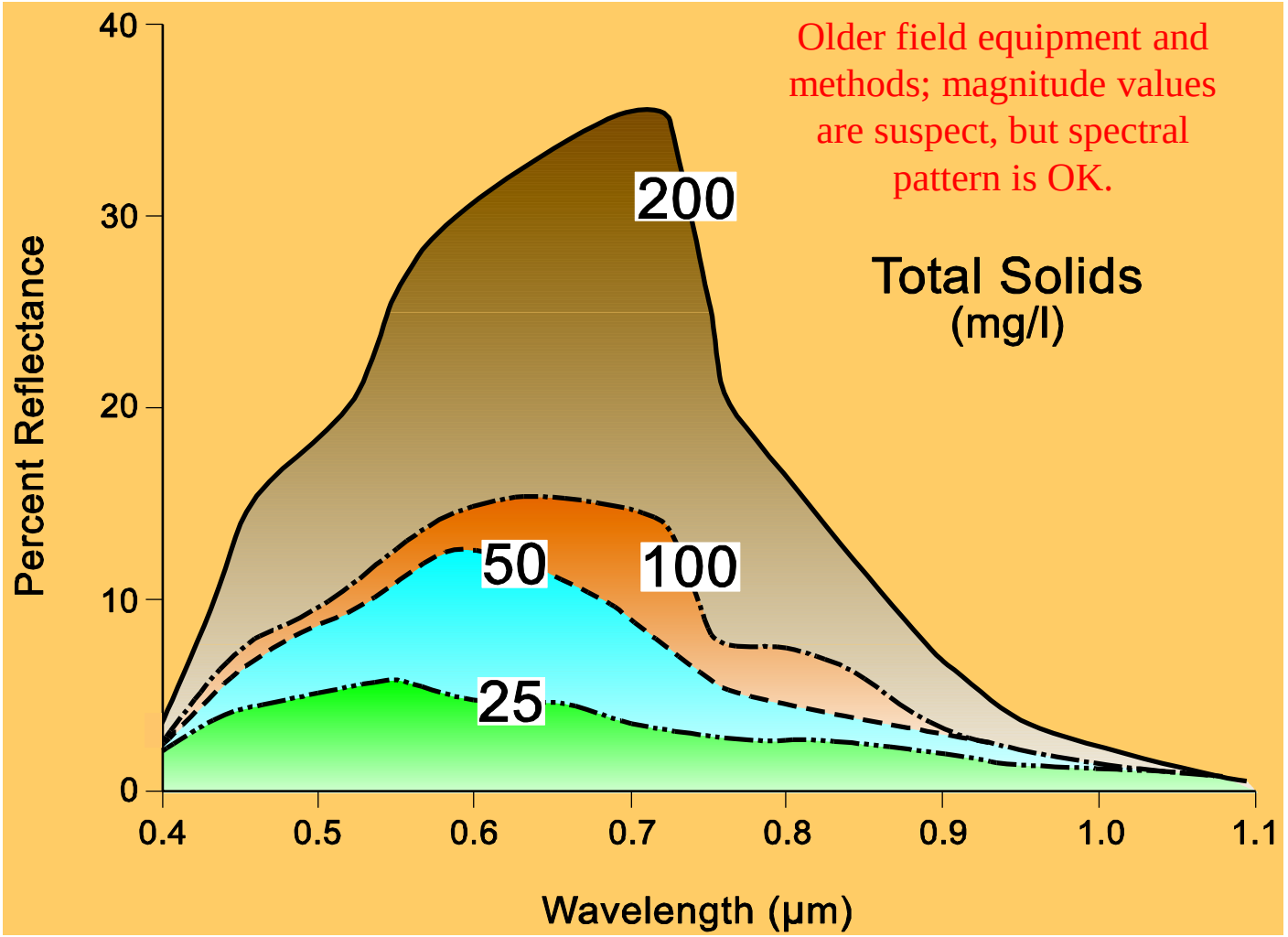
Physical Basis of Remote Sensing

- Water transmittance – peak in the blue-green



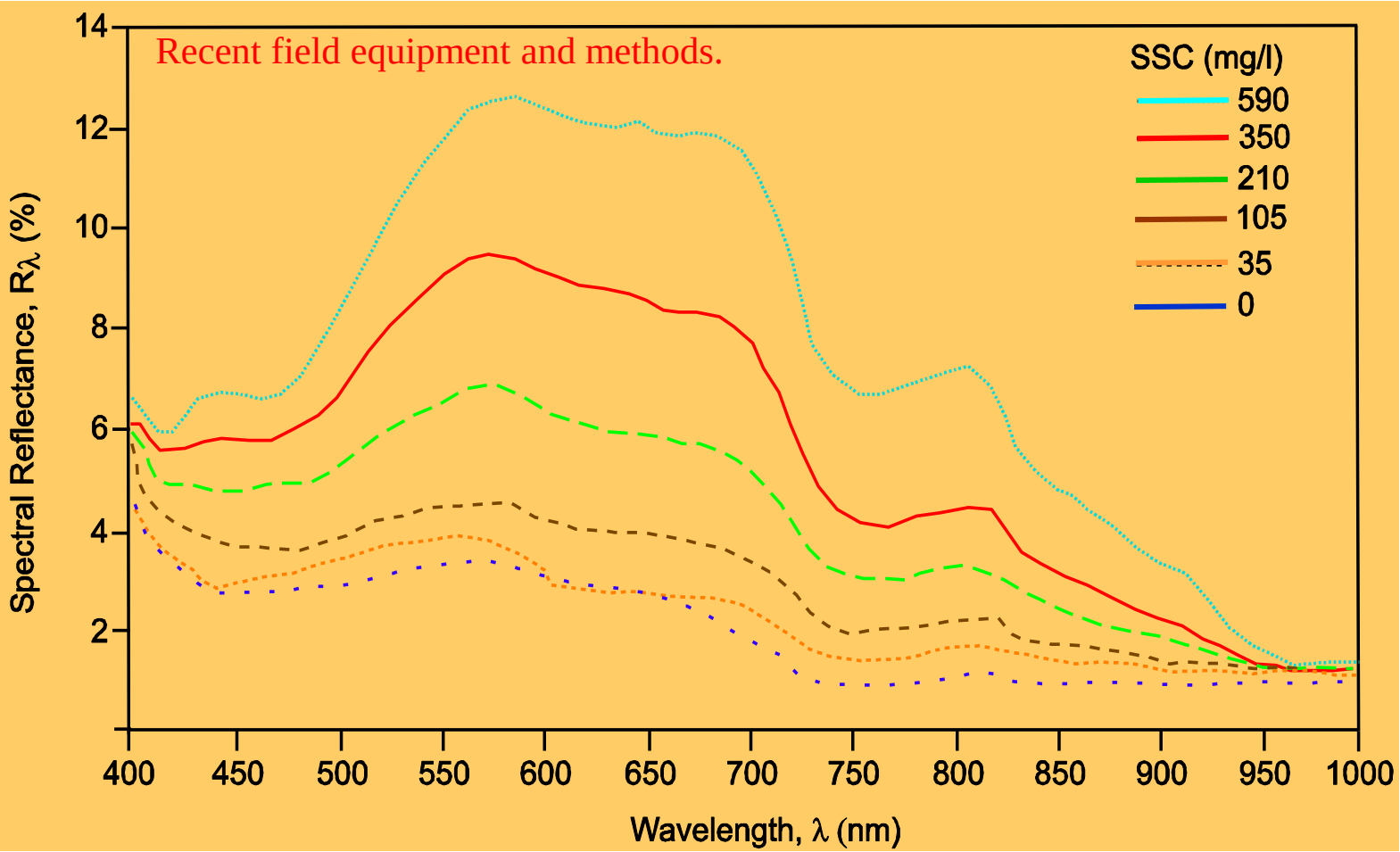
Physical Basis of Remote Sensing

- Water turbidity *vs* volume reflectance



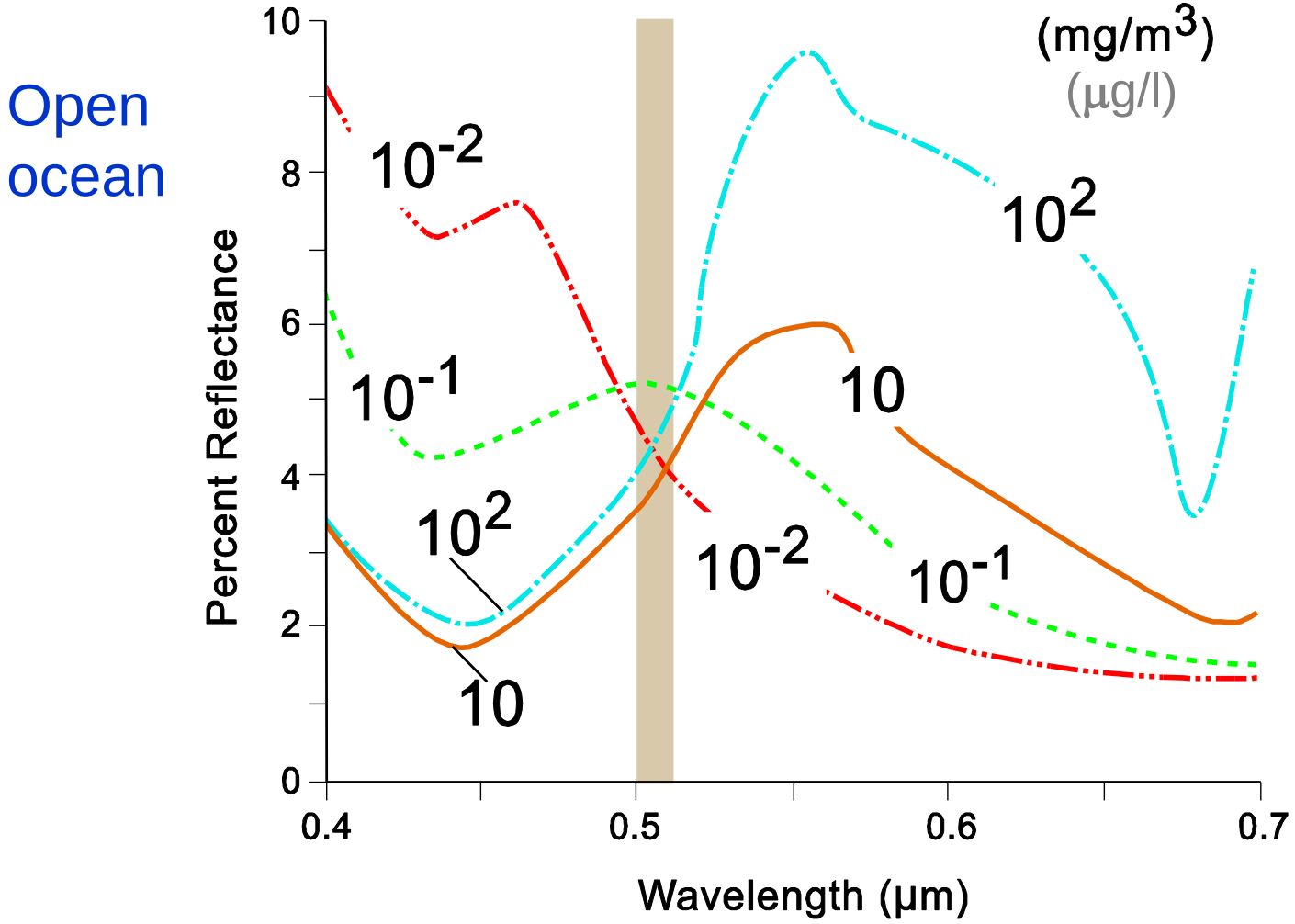
Physical Basis of Remote Sensing

- Water turbidity *vs* volume reflectance



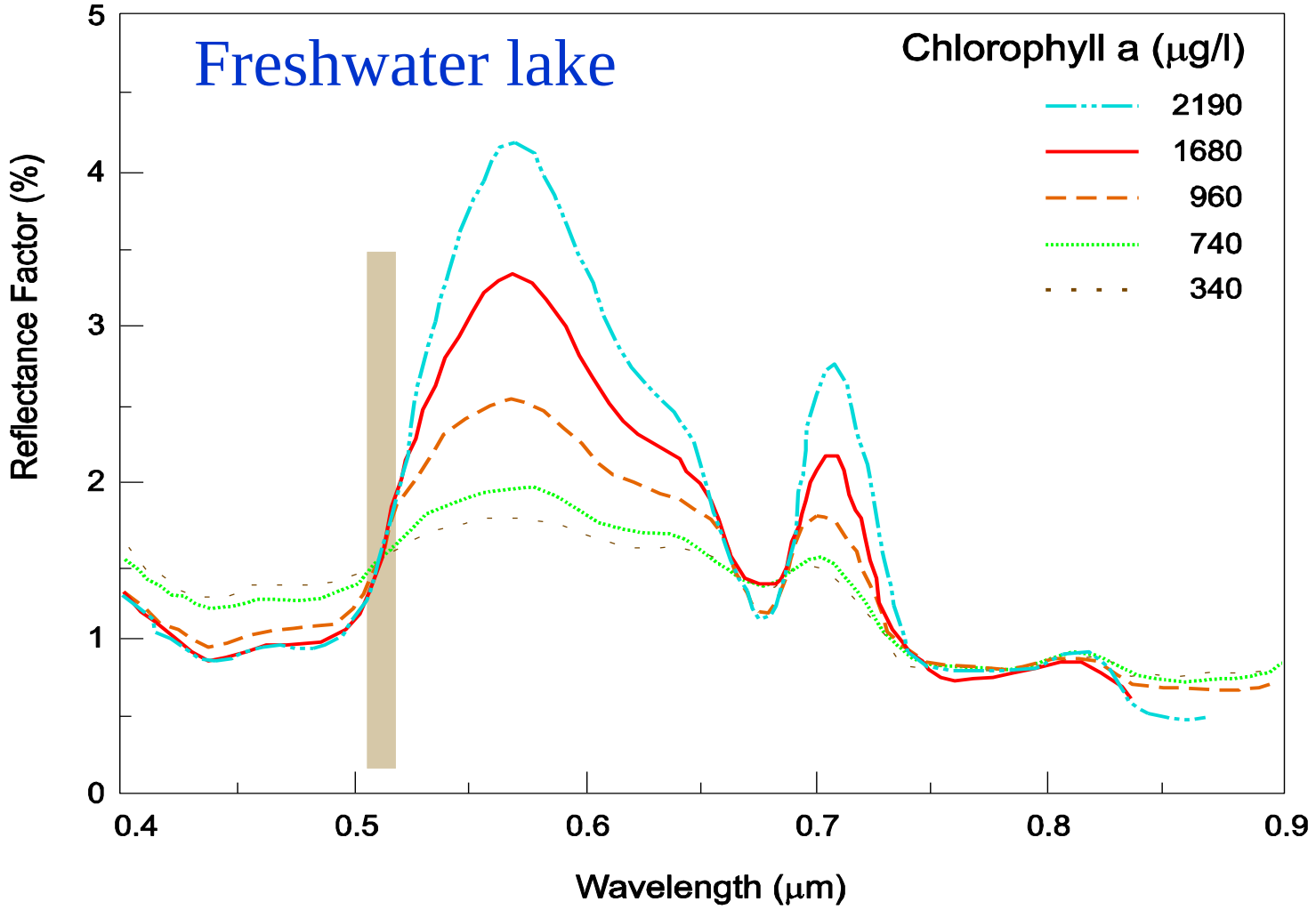
Physical Basis of Remote Sensing

- Chlorophyll *vs* water volume reflectance



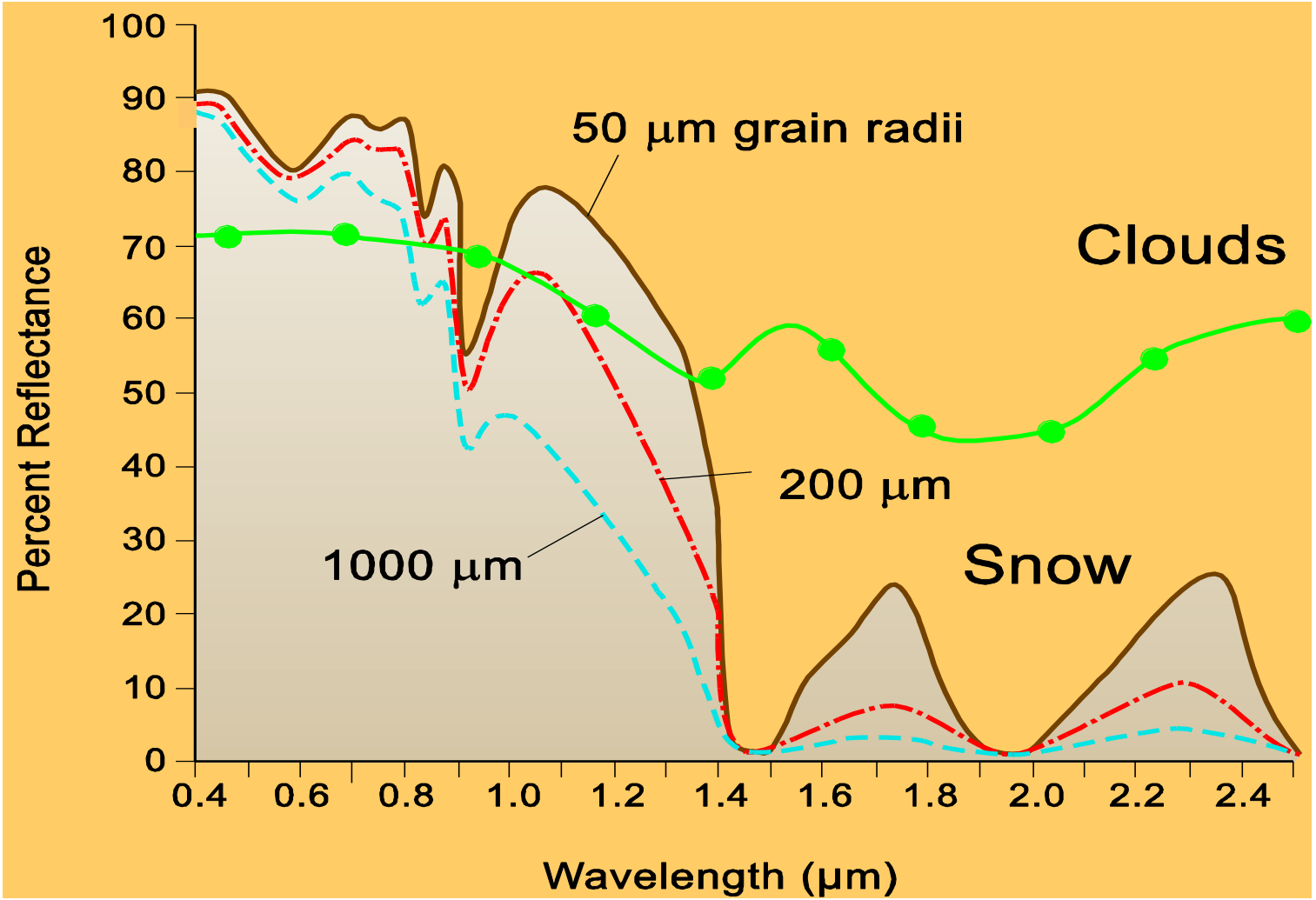
Physical Basis of Remote Sensing

- Chlorophyll *vs* water volume reflectance



Physical Basis of Remote Sensing

- Snow and clouds reflectance



Physical Basis of Remote Sensing

- Snow and ice reflectance