Interaction with Atmosphere

- Scattering
  - Selective
    - Rayleigh

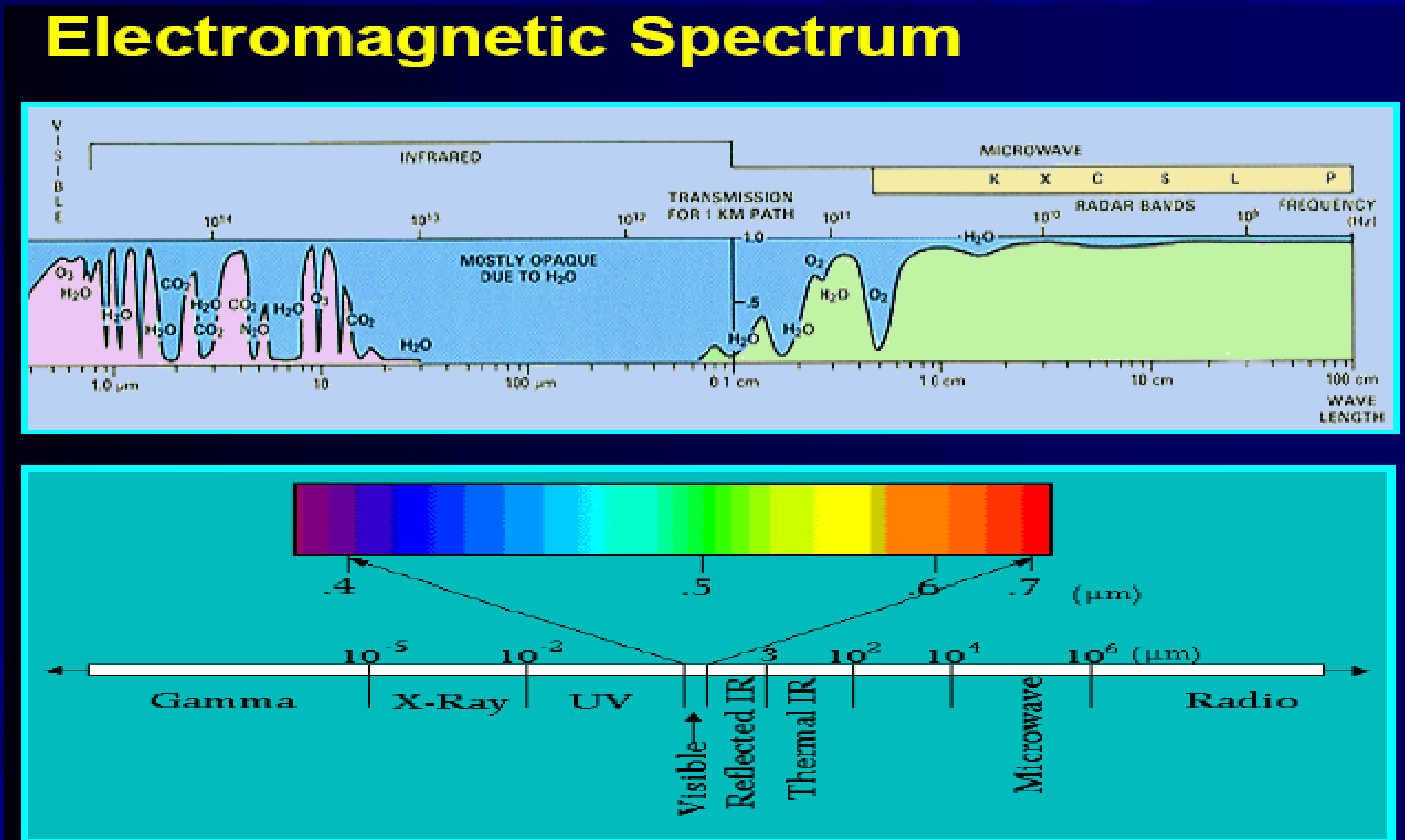
      Because of particles dia <0.1 micrometer (e.g. Gas molecules)
      inversely prop to Wave length^4
      Smaller wave lengths are more affected
    - Mie

      Because of particles dia >0.1 to 10 micrometer (smoke, dust and salts)
      inversely prop to Wave length^1~2
      Not much diff. for wave lengths
  - Nonselective

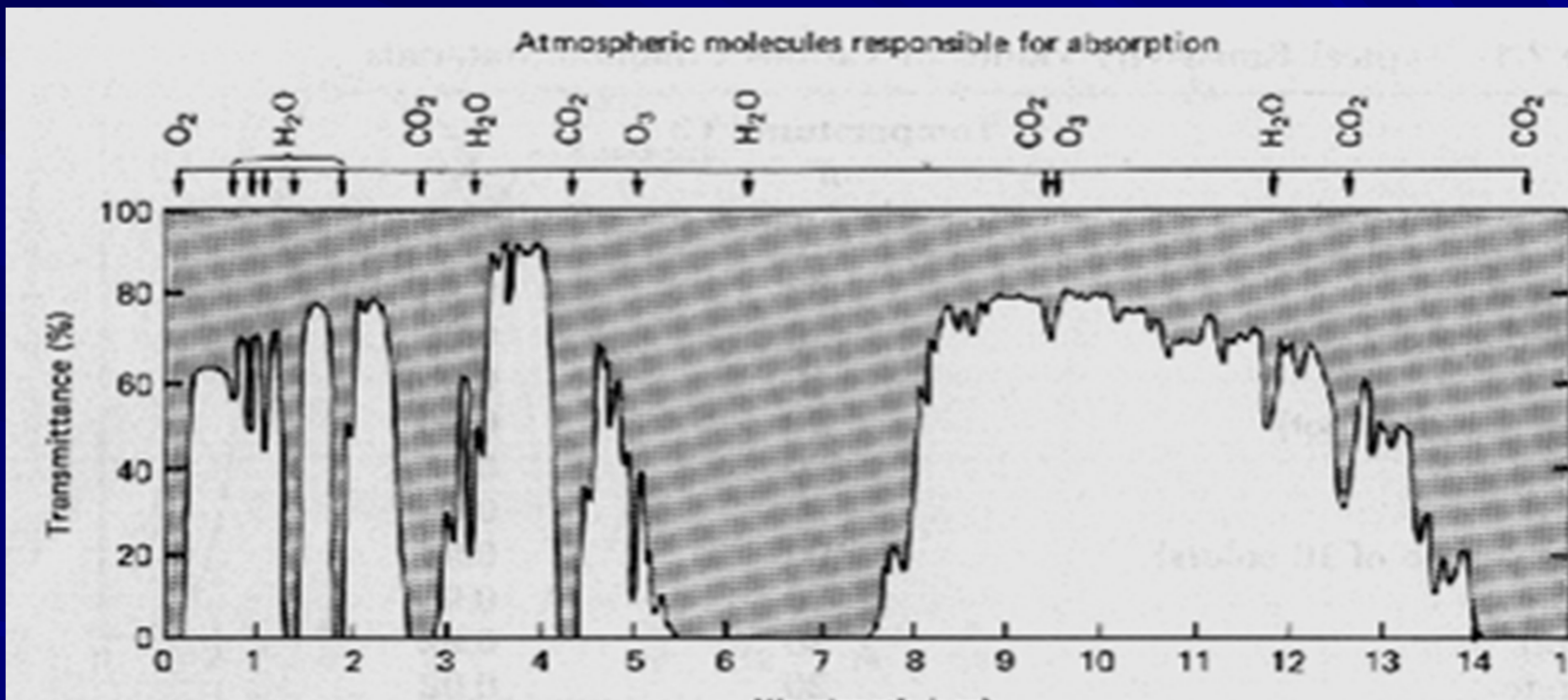
    wavelength independent
    because of larger molecules (ice, water droplets etc) >10 micrometer
- Absorption

  (Water, O_2, O_3, C_2O, etc)
- Atmospheric Windows

Atmospheric Interaction with EM Spectrum

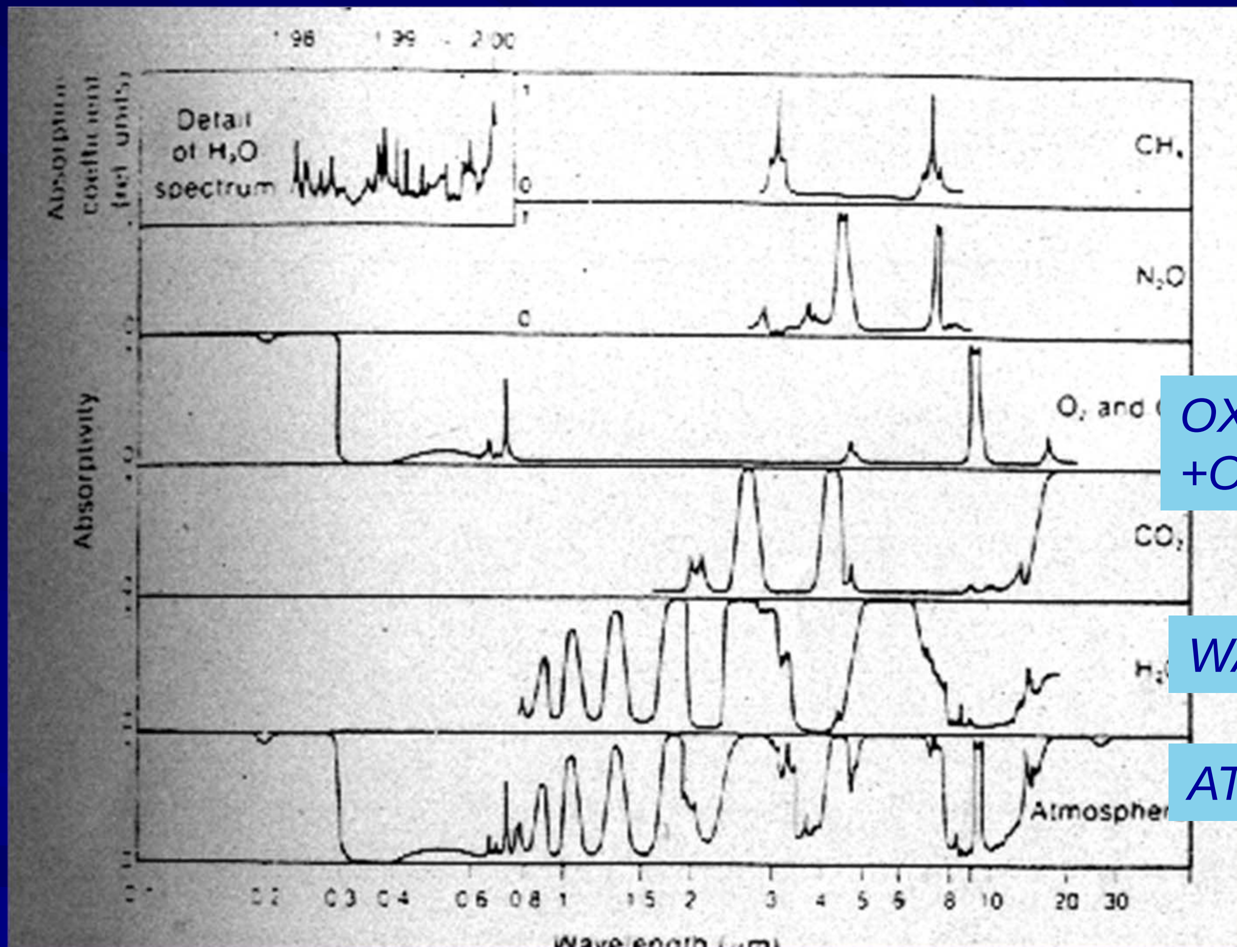


Spectral Absorption by Atmospheric Constituents -1



Atmospheric Windows:
0.3-1.3, 1.5-1.8, 2-2.5, 3.5-4.1, and 7-14 μm

Spectral Absorption by Atmospheric Constituents -2

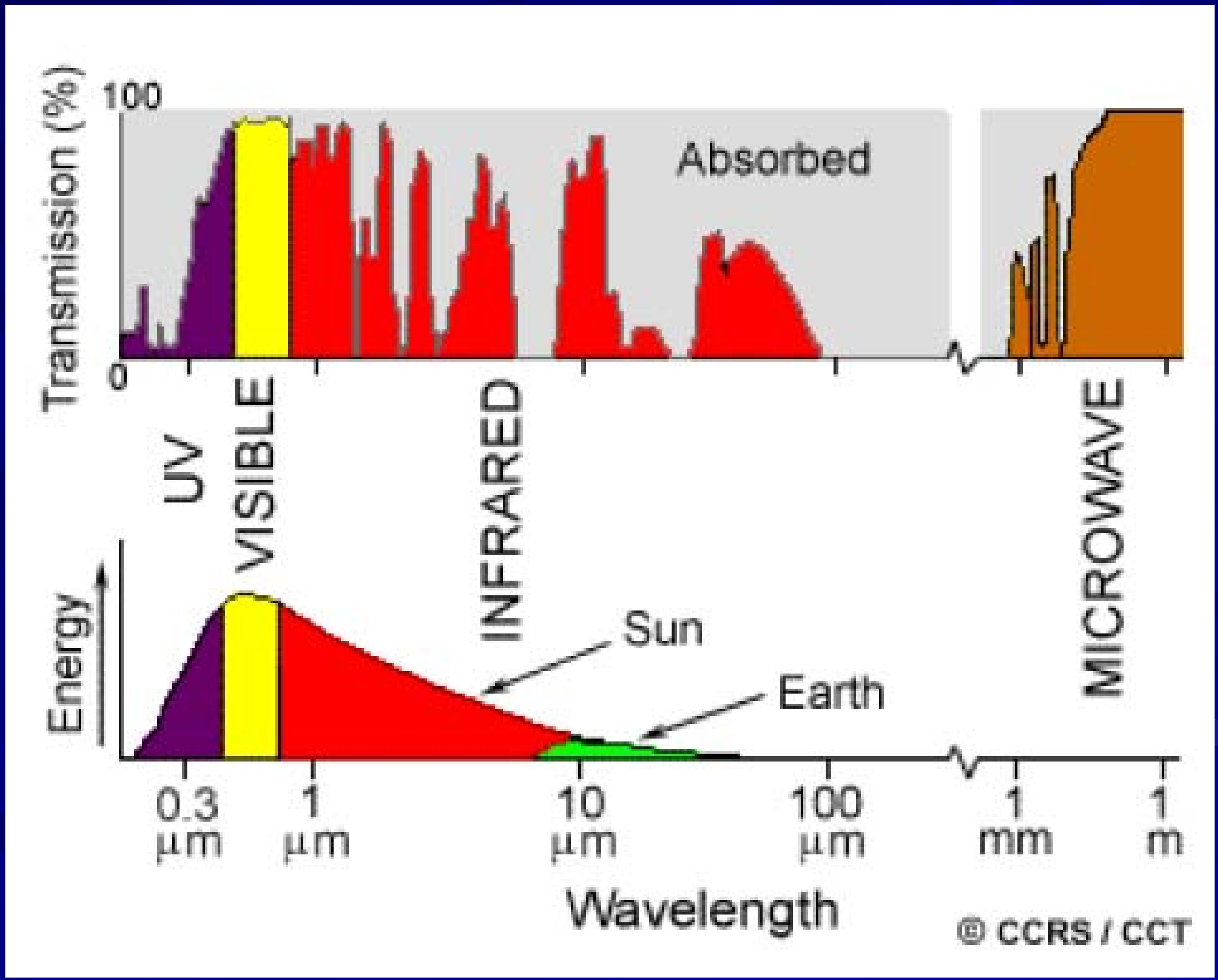


OXYGEN +OZONE

WATER

ATMOSPHERE

Atmospheric Absorption w.r.t. Energy Available

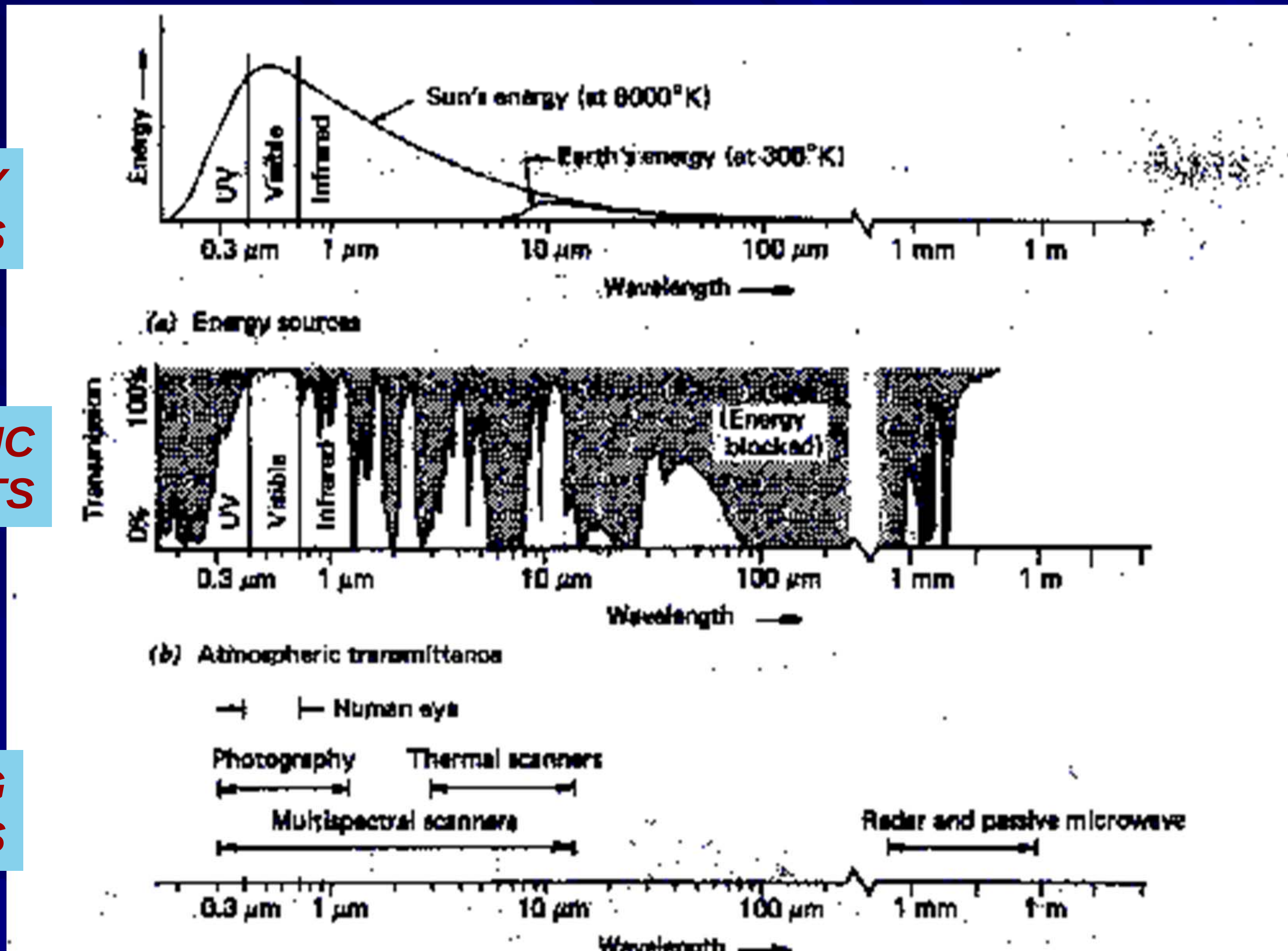


Spectral Characteristics of:

1. ENERGY SOURCES

2. ATMOSPHERIC EFFECTS

3. SENSING SYSTEMS



Interaction b/w EM Energy & Earth Features

E_I = Incoming Energy

$$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda$$

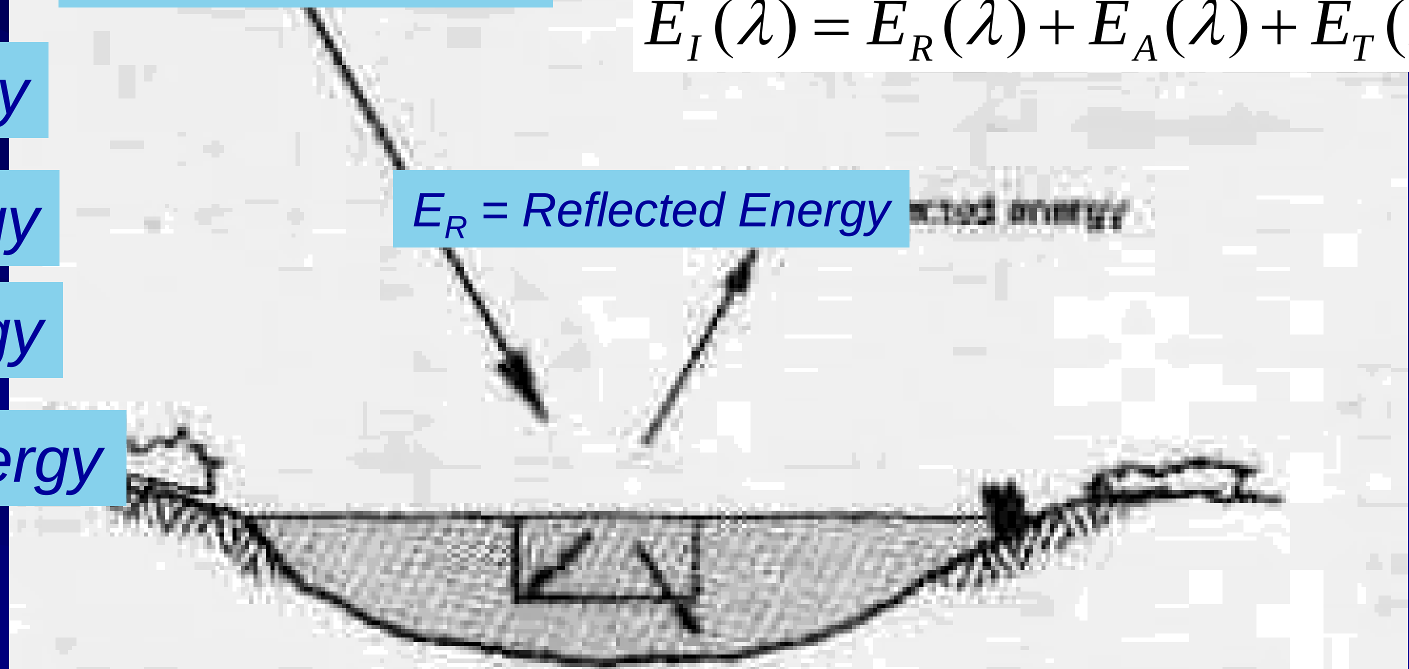
Incoming Energy

Reflected Energy

Absorbed Energy

Transmitted Energy

E_R = Reflected Energy



E_A = Absorbed Energy

E_T = Transmitted Energy

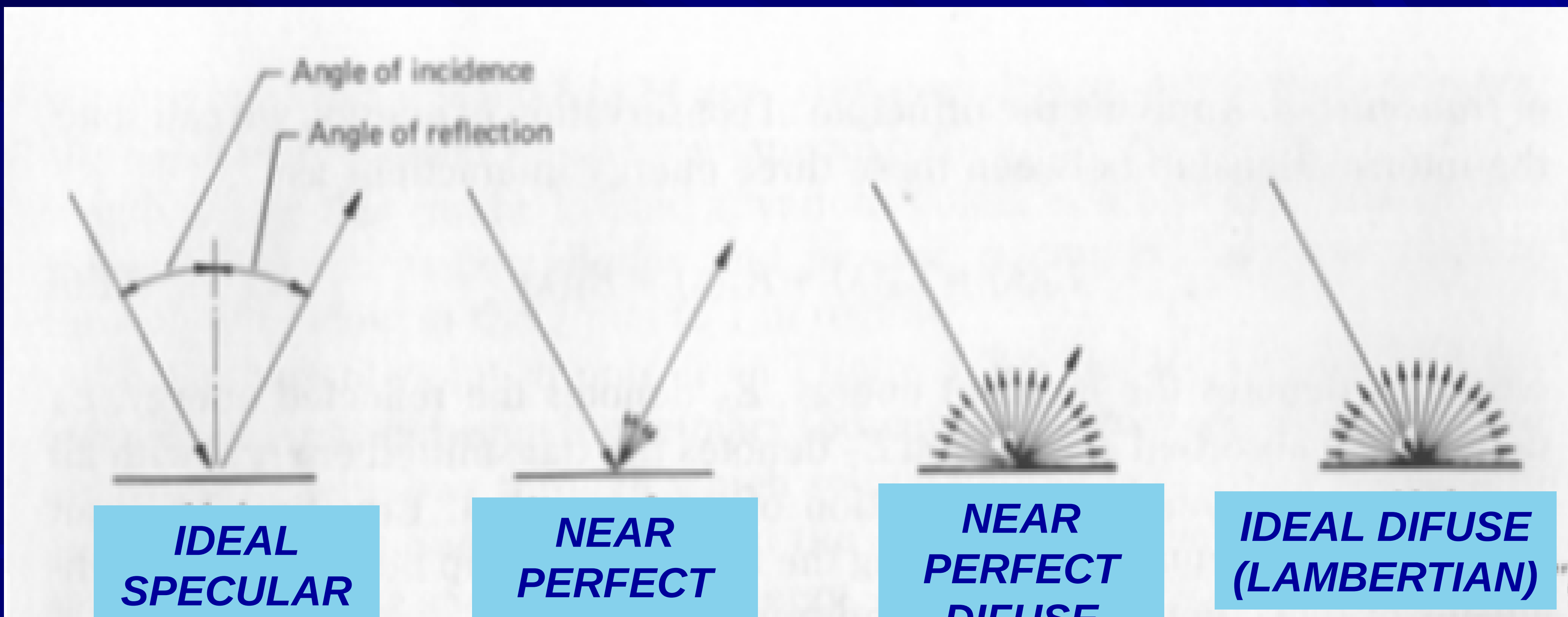
Energy Balance Equation

- Er, Et, Ea not necessarily same
- There variation from object to object help us distinguish different objects.

$$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$$

$$E_R(\lambda) = E_I(\lambda) - \left[E_A(\lambda) + E_T(\lambda)\right]$$

Reflectors



IDEAL SPECULAR

NEAR PERFECT SPECULAR

NEAR PERFECT DIFUSE

IDEAL DIFUSE (LAMBERTIAN)

Spectral Reflectance

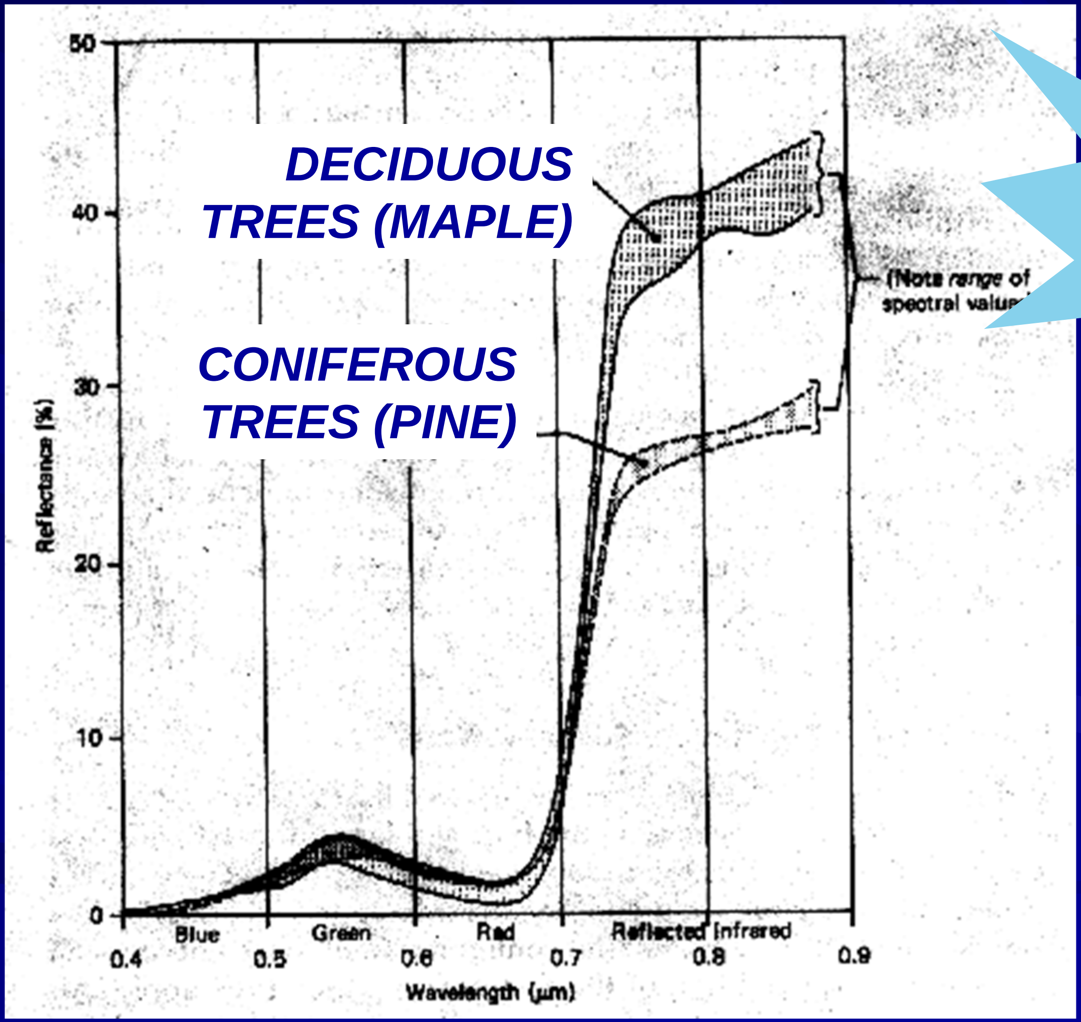
$$R_\lambda = \frac{E_R(\lambda)}{E_I(\lambda)}$$

$$= \frac{Energy of Wave Length \lambda reflected from Object}{Energy of Wave Length \lambda incident upon Objet}$$

%age Reflectance as Recorded by MSS of Landsat

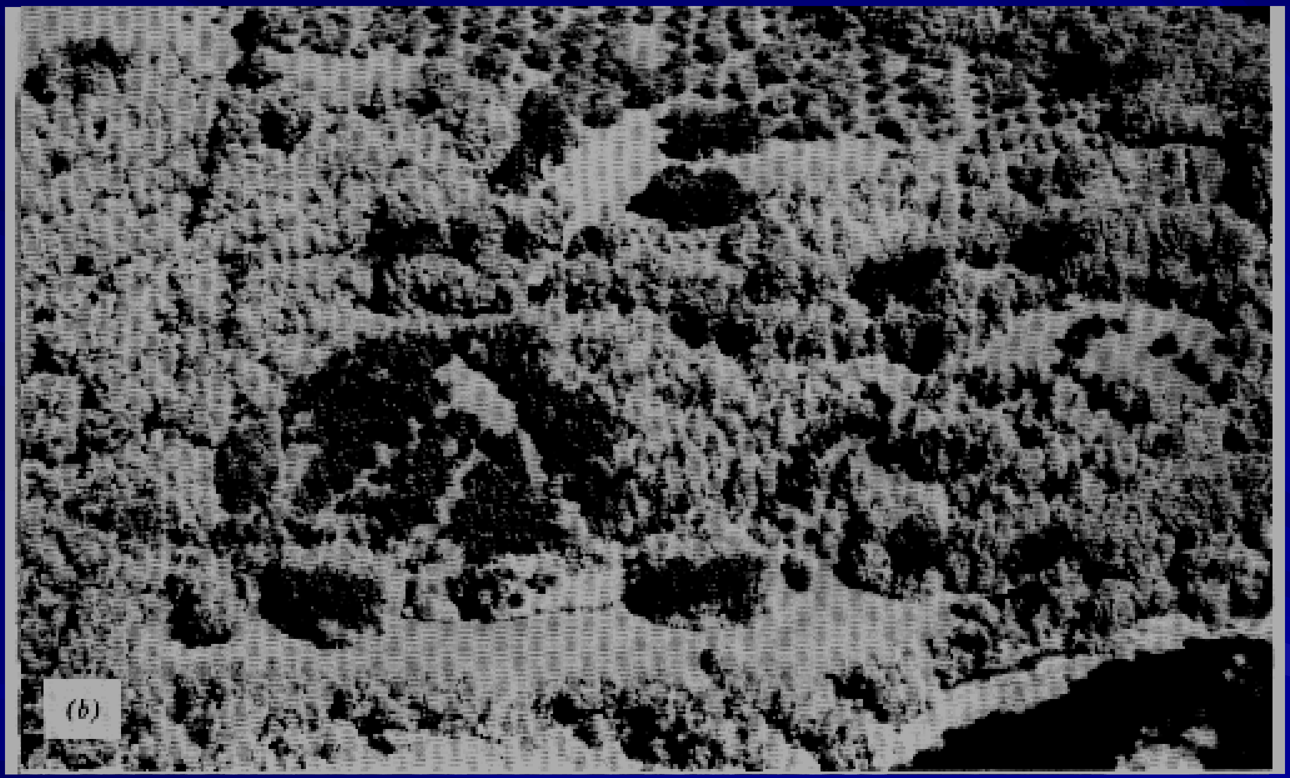
	Reflectance (%)			
	Band 1 (0.5–0.6 μm)	Band 2 (0.6–0.7 μm)	Band 3 (0.7–0.8 μm)	Band 4 (0.8–1.1 μm)
Rock and soil materials and covers				
Sand	5.19	4.32	3.46	6.71
Loam 1% H_2O	6.70	6.79	6.10	14.01
Loam 20% H_2O	4.21	4.02	3.38	7.57
Ice	18.30	16.10	12.20	11.00
Snow	19.10	15.00	10.90	9.20
Cultivated land	3.27	2.39	1.58	(not given)
Clay	14.34	14.40	11.99	(not given)
Gneiss	7.02	6.54	5.37	10.70
Loose soil	7.40	6.91	5.68	(not given)
Vegetation				
Wheat (low fertilizers)	3.44	2.27	3.56	8.95
Wheat (high fertilizers)	3.69	2.58	3.67	9.29
Water	3.75	2.24	1.20	1.89
Barley (healthy)	3.96	4.07	4.47	9.29
Barley (mildewed)	4.42	4.07	5.16	11.60
Oats	4.02	2.25	3.50	9.64
Oats	3.21	2.20	3.27	9.46
Soybean (high H_2O)	3.29	2.78	4.11	8.67
Soybean (low H_2O)	3.35	2.60	3.92	11.01

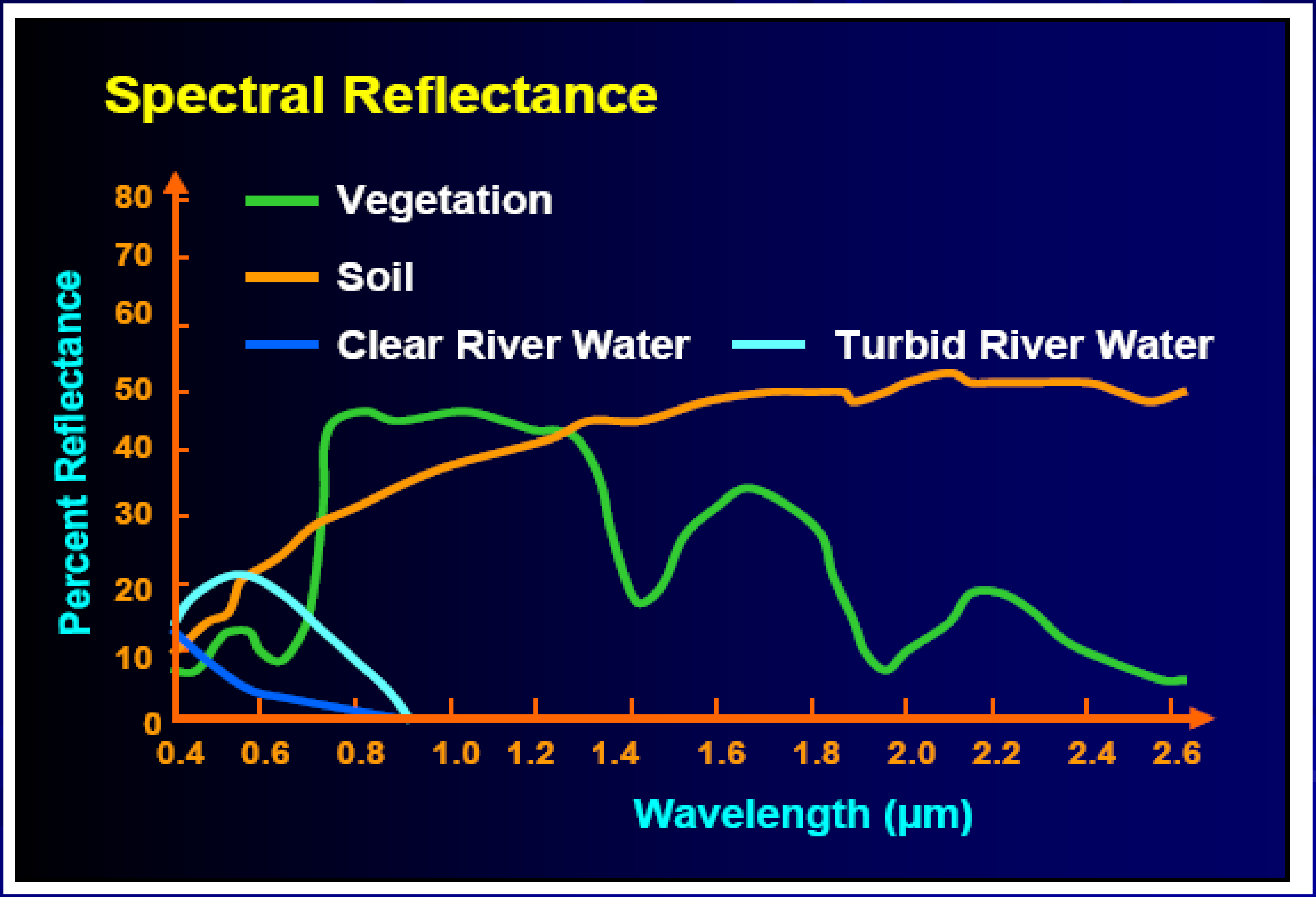
Spectral Reflectance Curve



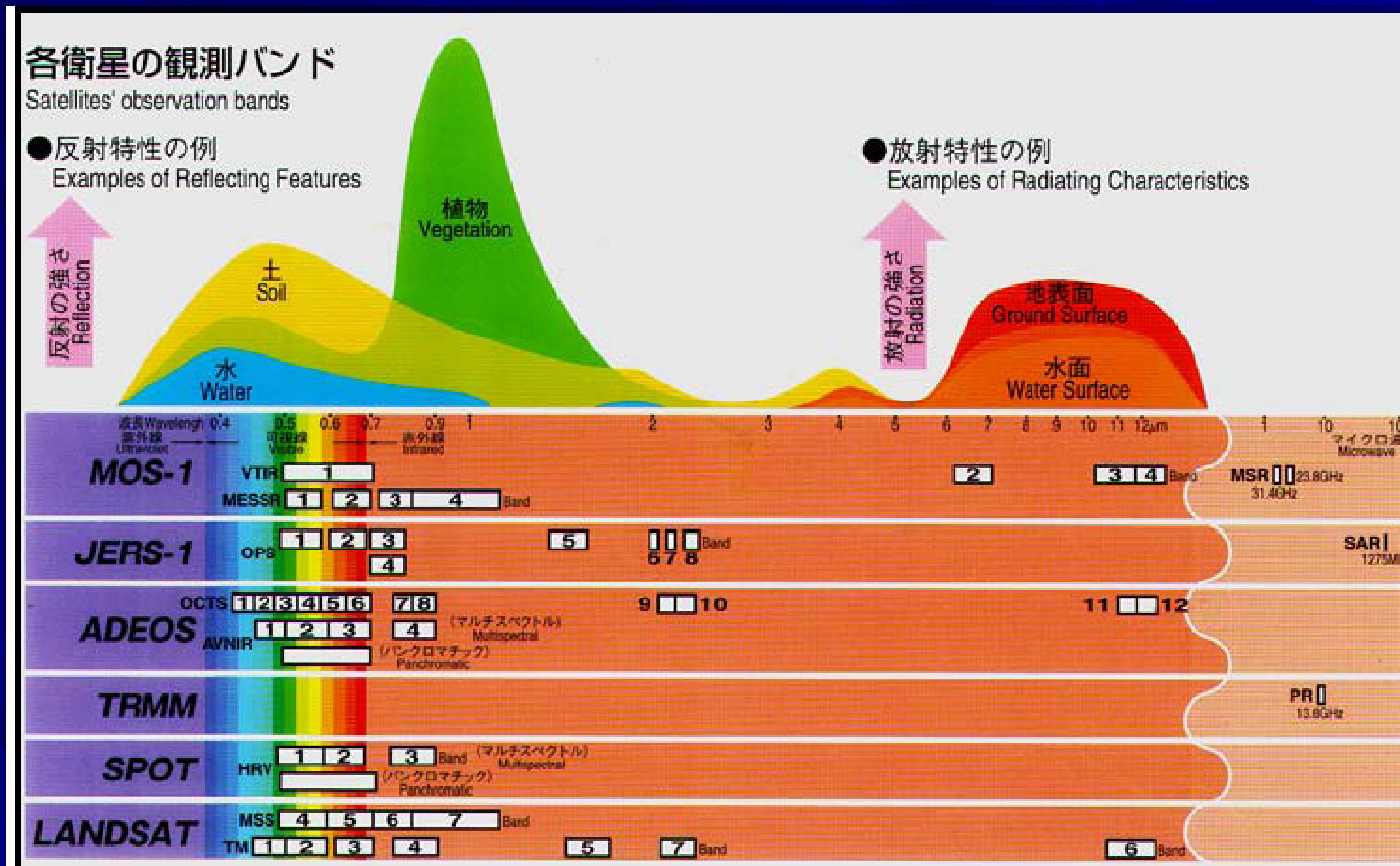
Which Wave Length is Best to Differentiate?

Panchromatic
vs
Reflected Infra Red




Spectral Reflectance
Vegetation
Soil
Clear River Water
Turbid River Water
Percent Reflectance
80
70
60
50
40
30
20
10
0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
Wavelength (µm)

What sattelite/bands are suitable



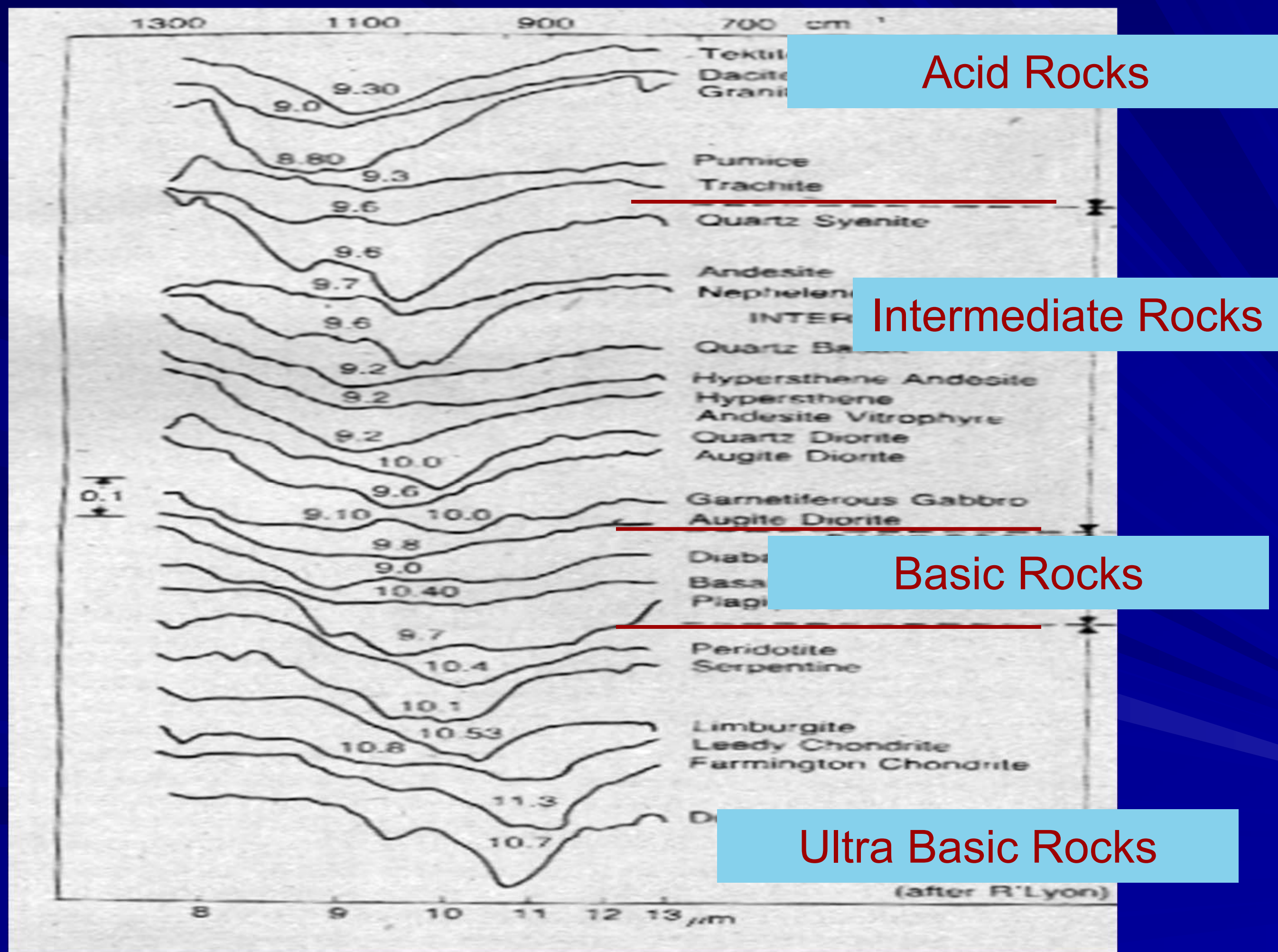
Landsat Thematic Mapper (TM)

Band No.	*Wavelength Interval (μm)*	*Spectral Response*	*Resolution (m)*
1	0.45-0.52	Blue-Green	30
2	0.52-0.60	Green	30
3	0.63-0.69	Red	30
4	0.76-0.90	Near-IR	30
5	1.55-1.75	Mid-IR	30
6	10.40-12.50	Thermal-IR	120
7	2.08-2.35	Mid-IR	30

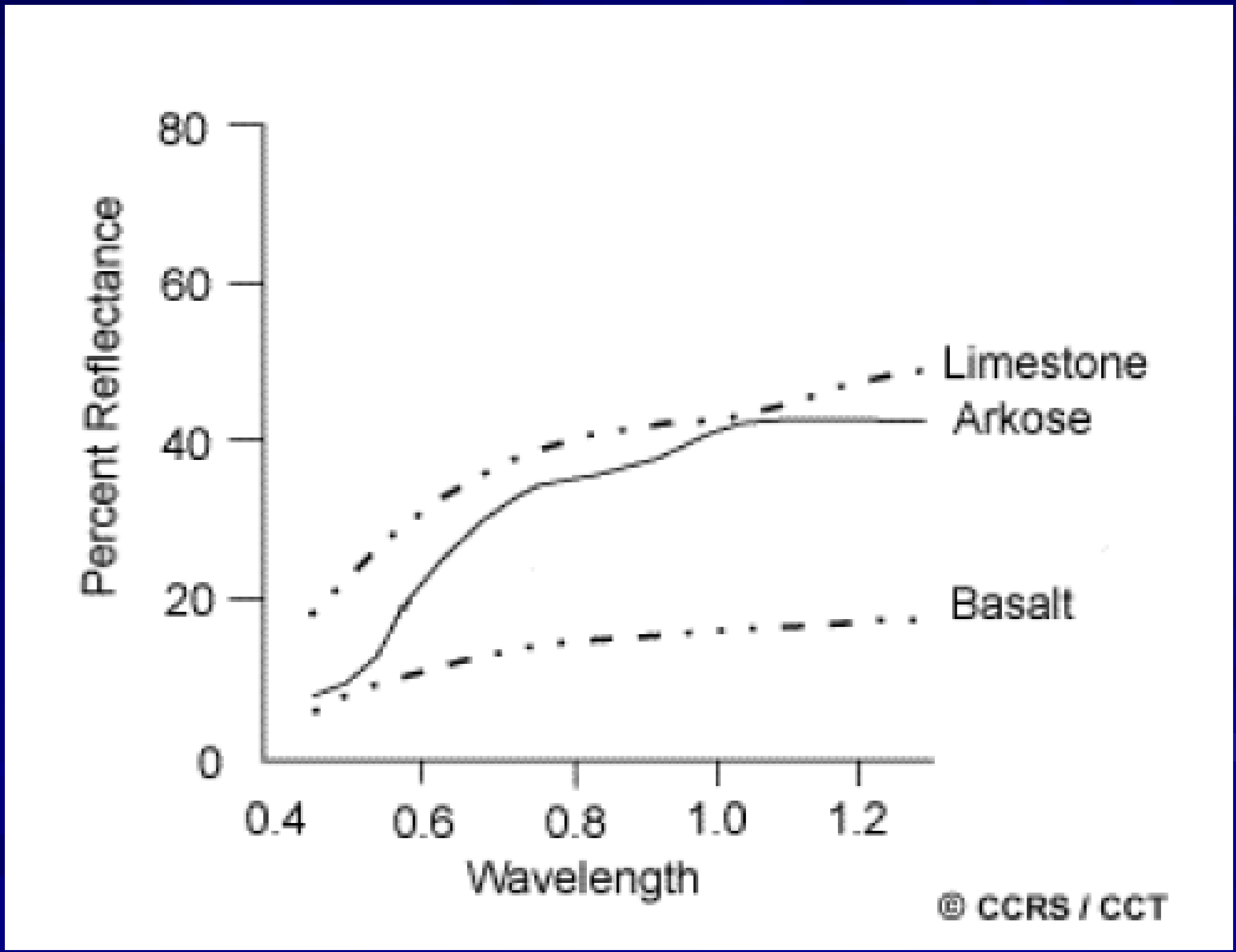
(TM) has been added to Landsats 4 (1982), 5 (1984), 6 (failed to attain orbit during launch and thus has never returned data) and 7 (1999).

Spectral Response Pattern / Signature

IR Emission



Spectral Response of few Rocks



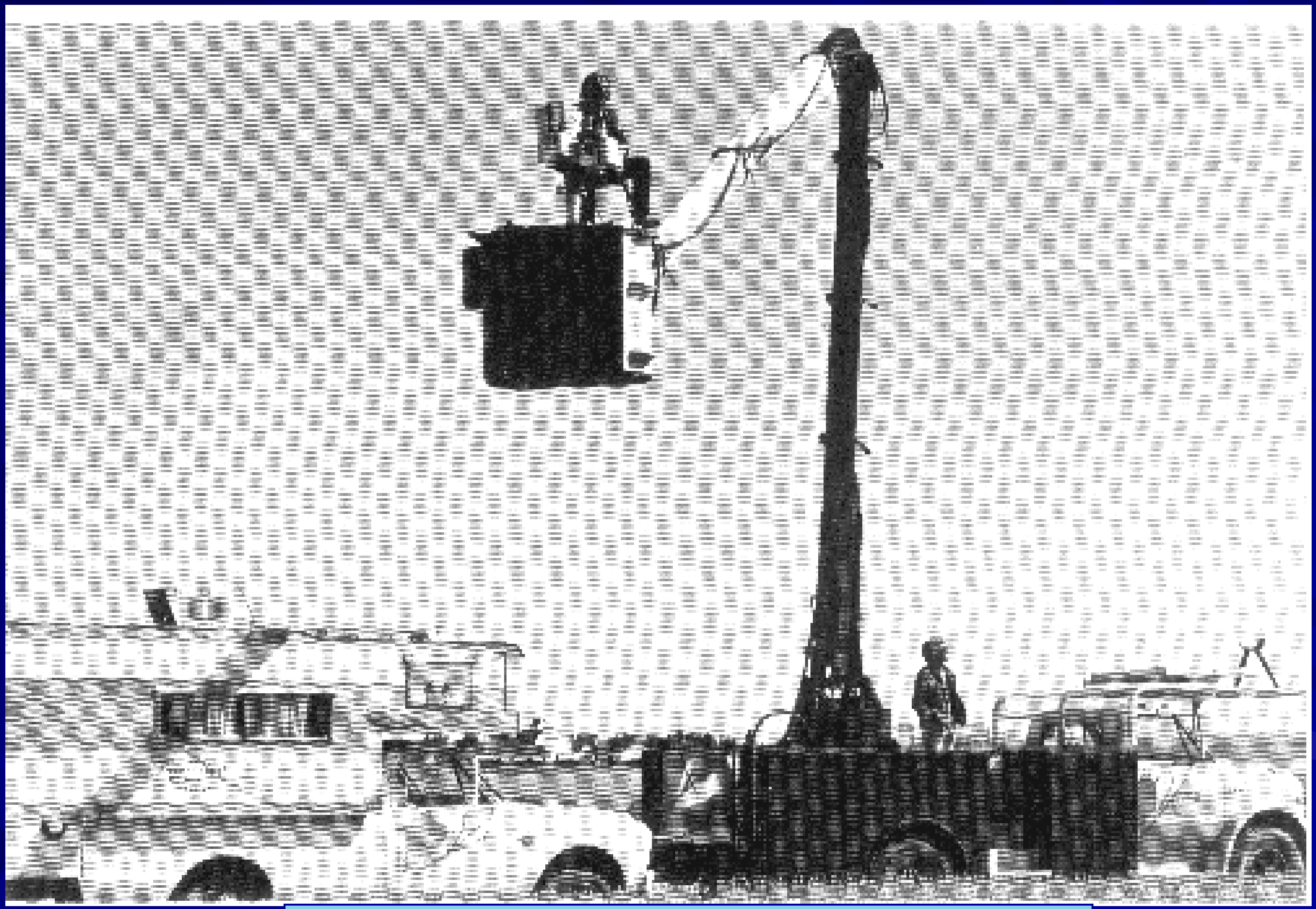
Typical Albedo/Reflectance Values

Type of surface	Surface	Albedo % of incident shortwave radiation
Soils	Fine sand	37
	Dry black soil	14
	Moist ploughed field	14
	Moist black soil	8
Water surfaces	Dense, clean and dry snow	86–95
	Woody farm, snow-covered	33–40
	Sea ice	36
	Ice sheet with water covering	26
Vegetation	Desert shrubland	20–29
	Winter wheat	16–23
	Oaks	18
	Deciduous forest	17
	Pine forest	14
	Prairie	12–13
	Swamp	10–14
	Heather	10
Geographic locations	Yuma, Arizona	20
	Winnipeg (July)	13–16
	Washington, DC (September)	12–13
	Great Salt Lake, Utah	3

Reference Data

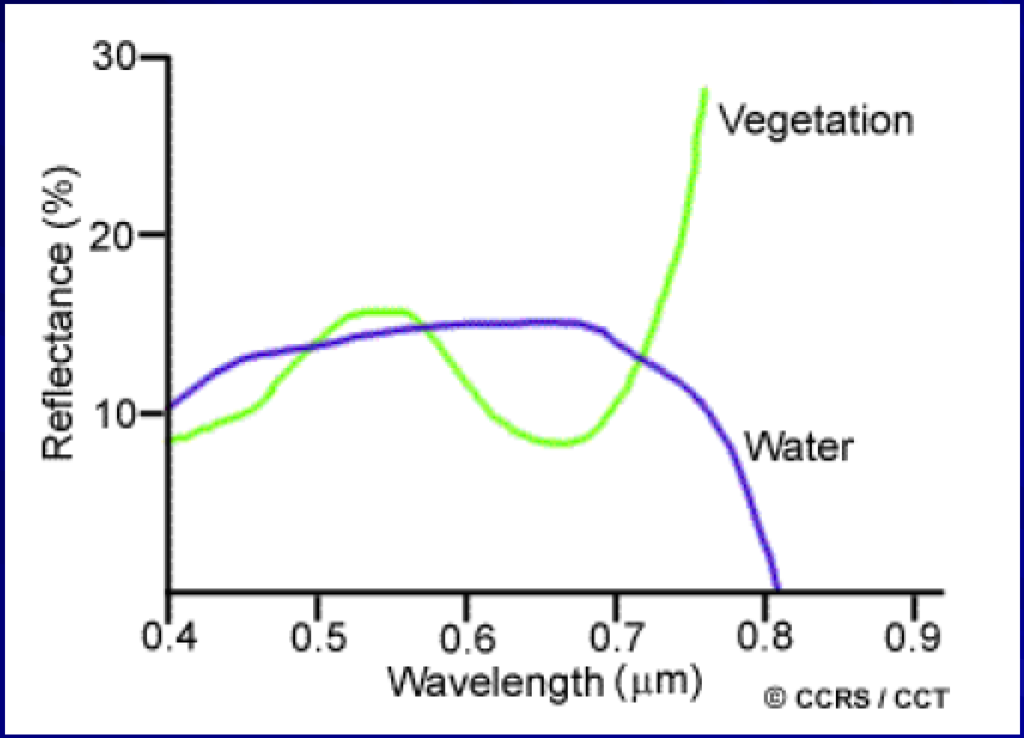
- To Aid in analysis and Interpretation of RS Data
- To Calibrate Sensor
- To Verify Information extracted form RS

Reference Data / Ground Truth

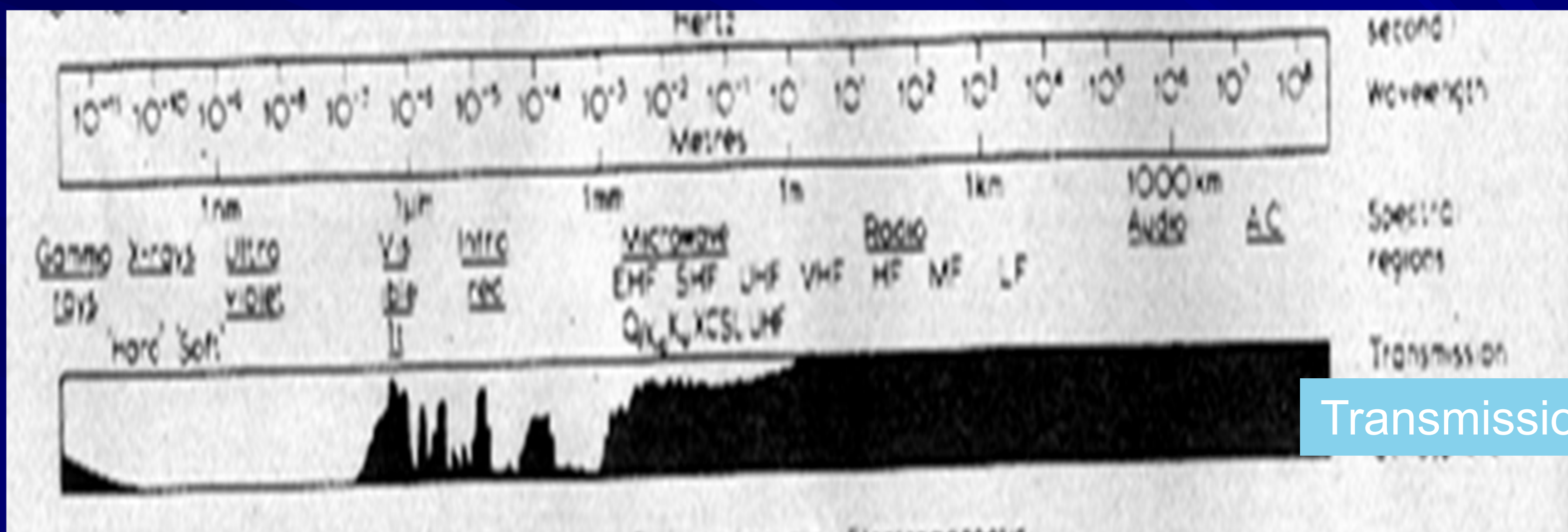


Mobile Spectrometer Unit

Thanks


30
20
10
Reflectance (%)
Vegetation
Water
0.4
0.5
0.6
0.7
0.8
0.9
Wavelength (µm)
© CCRS / CCT

EM Spectrum on Ground Surface



Transmission

Wave Length

Spectral Response Pattern / Signature

Reflectance