GEOG 357

LECTURE 2

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Electromagnetic Spectrum

- All objects above absolute zero emit electromagnetic radiation.
  - Absolute Zero: 0 Kelvins or -273.15 Celsius
- Objects reflect radiation that has been emitted by other objects.
- Visible light is electromagnetic radiation
  - Most familiar is visible light
  - Forms only a small but important portion of the full electromagnetic spectrum

Presentation Title 2

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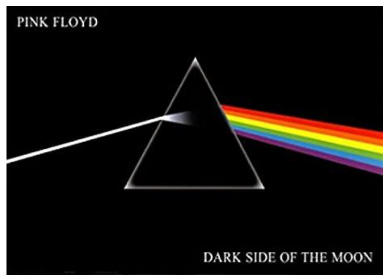
Electromagnetic Spectrum

- Light refraction is one of the beautiful sights in nature
- The electromagnetic spectrum provides the 'layers' in RS



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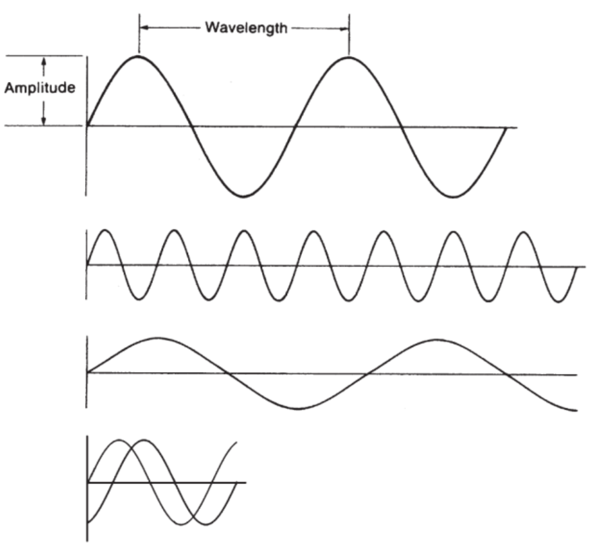

Campbell and Wynne (2011), 5th Edition

Properties of Electromagnetic Energy

- Wavelength
- Amplitude
- Frequency
- Phase

- Which of these shows:
  - Waves out of phase?
  - High frequency, short wavelength?
  - Low frequency, long wavelength?

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Units of Measurement

- In Remote Sensing the characteristic of electromagnetic energy are usually specified using wavelength

Unit	Distance	
Kilometer (km)	1,000 m	
Meter (m)	1.0 m	
Centimeter (cm)	0.01 m	$= 10^{-2}$ m
Millimeter (mm)	0.001 m	$= 10^{-3}$ m
Micrometer (μm)[a]	0.000001 m	$= 10^{-6}$ m
Nanometer (nm)		10^{-9} m
Ångstrom unit (Å)		10^{-10} m

[a]Formerly called the "micron" (μ); the term "micrometer" is now used by agreement of the General Conference on Weights and Measures.

Campbell and Wynne (2011), 5th Edition

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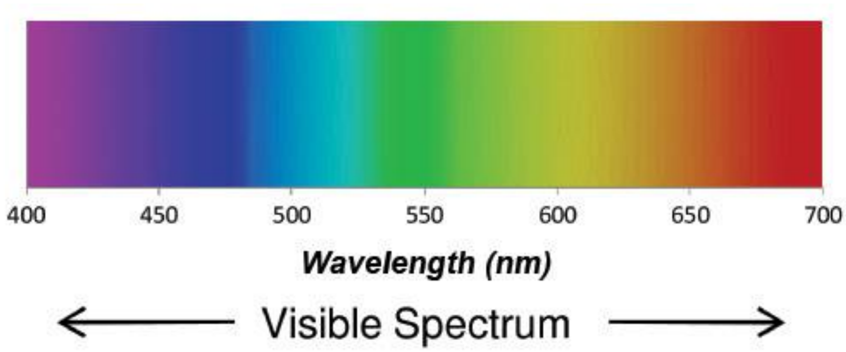
micrometres 'microns' :
- millionths of a metre

nanometres:
- billionths of a metre

- **Blue 0.4 - 0.5 μm (microns) = 400 to 500 nm**
- **Green 0.5 - 0.6 μm = 500 to 600 nm**
- **Red 0.6 - 0.7 μm = 600 to 700 nm**



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Wavelength and Frequencies

- The speed of electromagnetic energy is constant at 299,792 km/s
- Frequency and Wavelength are related

$$\mathcal{C} = \lambda v$$

- **Longer Waves ⇢ Low Frequency**
  Shorter Waves ⇢ Higher Frequency

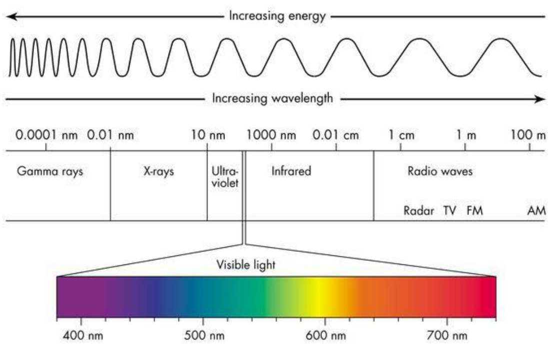
As wavelength increases, so does atmospheric penetration ….

Gamma rays: most don't reach earth

Table: penetration by energy wavelengths

Ultra-violet	Cannot get through glass
Visible	Can penetrate through glass
Infra-Red	Penetrates through haze
Thermal Infra-Red	Penetrates through smoke
Microwave	Gets through clouds, snow, and even sand

Major Divisions of the Electromagnetic Spectrum



Division	Limits
Gamma rays	< 0.03 nm
X-rays	0.03–300 nm
Ultraviolet radiation	0.30–0.38 μm
Visible light	0.38–0.72 μm
Infrared radiation	
Near infrared	0.72–1.30 μm
Mid infrared	1.30–3.00 μm
Far infrared	7.0–1,000 μm (1 mm)
Microwave radiation	1 mm–30 cm
Radio	≥ 30 cm

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Major Divisions of the Electromagnetic Spectrum

- The Ultraviolet Spectrum
  - Zone of radiation that lies between the X-ray region and limit of of human vision
  - It induces fluorescence in some materials
  - It is still limited significance in common remote sensing applications
    - It is easily scattered by the earth's atmosphere
    - Vegetation fluorescence, particularly from chlorophyll, can be used to differentiate between healthy leaves and stressed or senescent leaves

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Major Divisions of the Electromagnetic Spectrum

- The Visible Spectrum
  - Can be divided into three segments (primary colors)
    - ~ 0.4 to 0.5 µm (blue), 0.5 to 0.6 µm (green), and 0.6 to 0.7 µm (red)
  - Primary colors are defined such that no single primary can be formed from a mixture of the other two and that all other colors can be formed by mixing the three primaries in appropriate proportions.
  - Equal proportions of the three additive primaries combine to form white light.
  - The color of an object is defined by the color of the light that it reflects (Figure 2.4). Thus a "blue" object is "blue" because it reflects blue light.
  - Qn: What color do you get when you mix Red and Green?
    - What process is going for you to see this new color?

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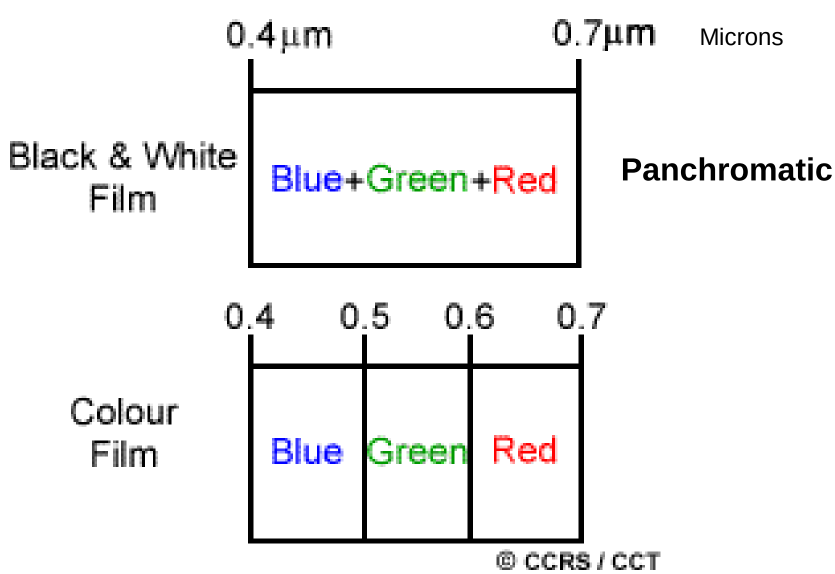

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Color air photo: 15th / University Way

Panchromatic air photo: 15th / University Way

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COMMON ANIMALS AND THE COLORS THEY CAN SEE		
ANIMAL	**THE COLORS THEY SEE**	**RELATIVE TO HUMANS**
SPIDERS (jumping spiders)	ULTRAVIOLET AND GREEN	Different
INSECTS (bees)	ULTRAVIOLET, BLUE, YELLOW	Different
CRUSTACEANS (crayfish)	BLUE AND RED	Less
CEPHALOPODS (octopi and squids)	BLUE ONLY	Less
FISH	MOST SEE JUST TWO COLORS	Less
AMPHIBIANS (frogs)	MOST SEE SOME COLOR	Less
REPTILES (snakes*)	SOME COLOR AND INFRARED	Different
BIRDS	FIVE TO SEVEN COLORS	More
MAMMALS (cats)	TWO COLORS BUT WEAKLY	Less
MAMMALS (dogs)	TWO COLORS BUT WEAKLY	Less
MAMMALS (rabbit)	BLUE AND GREEN	Less
MAMMALS (rats)	ULTRAVIOLET, BLUE, GREEN	Different
MAMMALS (squirrels)	BLUES AND YELLOWS	Less
MAMMALS (primates-apes and chimps)	SAME AS HUMANS	Same
MAMMALS (African monkeys)	SAME AS HUMANS	Same
MAMMALS (South American monkeys)	CAN'T SEE RED WELL	Less
* pit vipers, some boas and some pythons		

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Major Divisions of the Electromagnetic Spectrum

- Infrared Spectrum
  - A large segment relative to the visible region, as such it encompasses radiation with varied properties.
  - Near infrared (NIR) and infrared (IR)—defined as those regions of the infrared spectrum closest to the visible.
    - Behaves in much the same way as visible light.
  - The far infrared (Thermal Infrared) consists of wavelengths well beyond the visible, extending into regions that border the microwave region
    - Emitted by the Earth commonly called "thermal energy."

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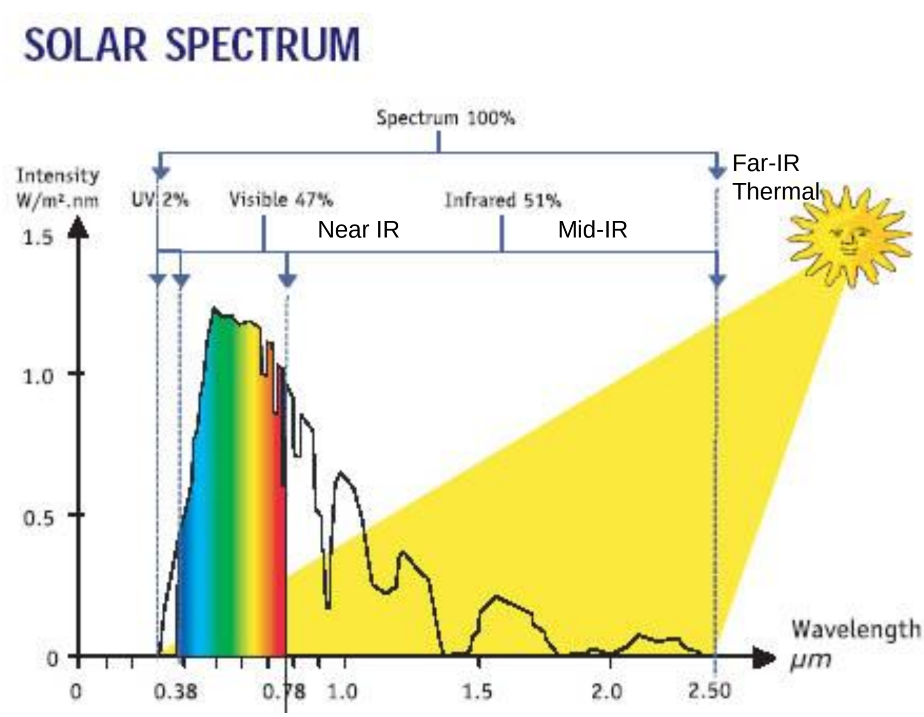

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Landsat 5 Thematic Mapper bands (1984-2011)

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

Multi-spectral remote sensing

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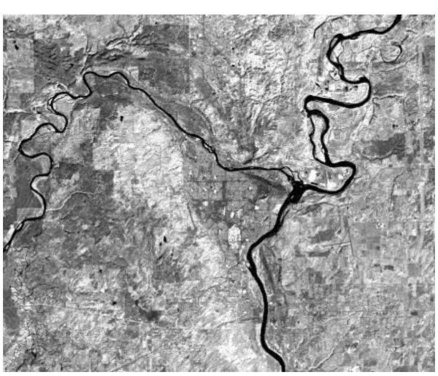
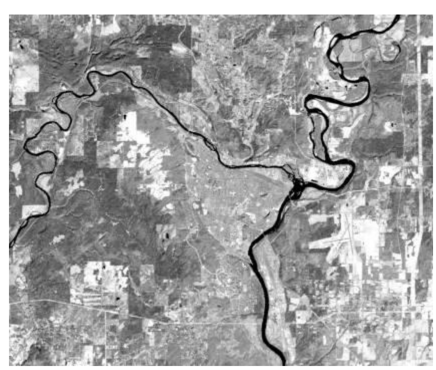
The **near IR** (0.7-1.3 microns) records energy related to **vegetation vigour** (health), while the **mid- IR** (1.3-3.0 microns) is (soil) **moisture**.

Neither have to do with temperature (or not much)

Near-IR **Mid-IR**





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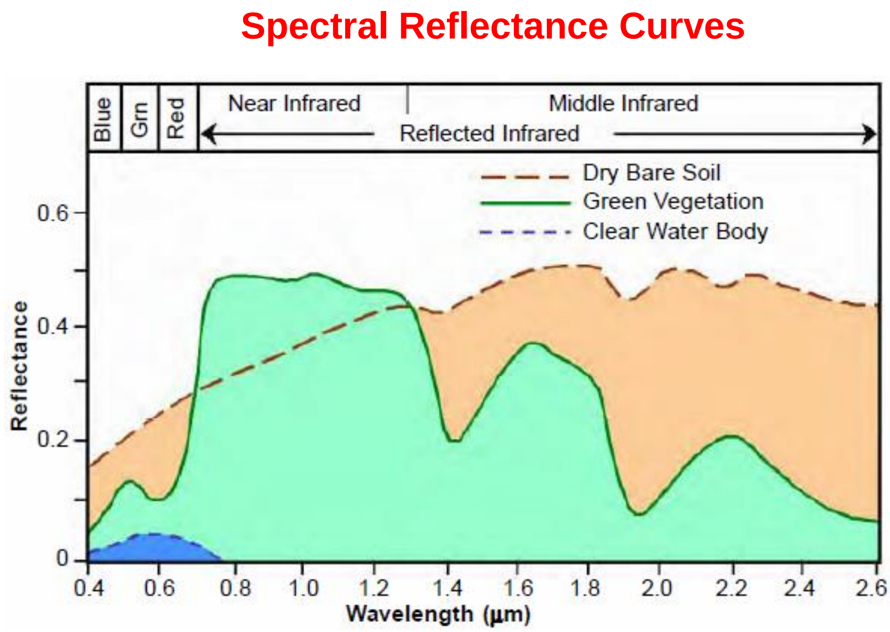
advantages of Infra-Red wavelengths: contrast



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- 1950s: Infra-red (IR) photography

- IR was developed during the Korean War to distinguish between healthy vegetation (refelecting IR) and camouflage. Hence it was known as 'camouflage detection' film or 'false colour'.

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Table 2 : Characteristics of normal colour and false colour film

Normal colour film (Energy captured by film)	IR film (Energy captured by film)	Colour that results on film
B	G	Blue
G	R	Green
R	IR	Red

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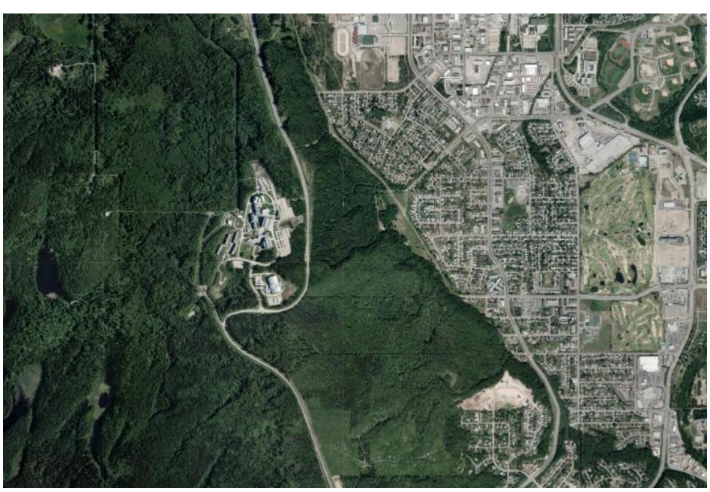

- PGmap spring 2014 natural colour

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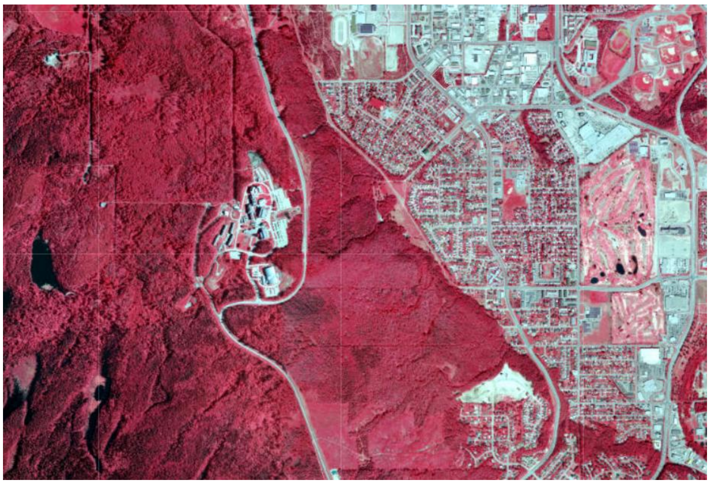

- PGmap spring 2014 IR image

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Summary of advantages of (near) Infra-Red wavelengths:

- Vegetation differences are enhanced e.g. coniferous v deciduous etc..
- Land-water distinctions are enhanced
- Blue -most susceptible to haze- is removed

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Landsat TM band combinations: Visible versus IR combination

Visible wavelengths image

e.g. Google maps, earth (3-2-1)

Including Infrared (NIR / SWIR)

e.g. BC imap / GEOG357 labs (5-4-3)

The best displays include one band each from the visible, near-IR and mid-IR

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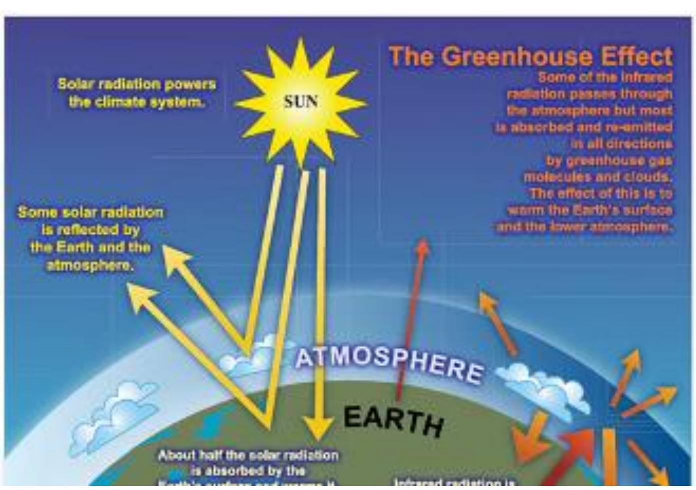
Thermal Infrared (3-14 microns)



- This records longer wavelengths (shown in orange) and a measure of temperature as it is emitted **<u>NOT</u>** reflected IR - Works day / night

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Prince George Landsat 5   Band 6 - thermal-IR

‘Brightness temperature’ – related to surface thermal qualities

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Major Divisions of the Electromagnetic Spectrum

- Microwave energy
  - The longest wavelengths commonly used in remote sensing are those from about 1 mm to 1 m in wavelength.

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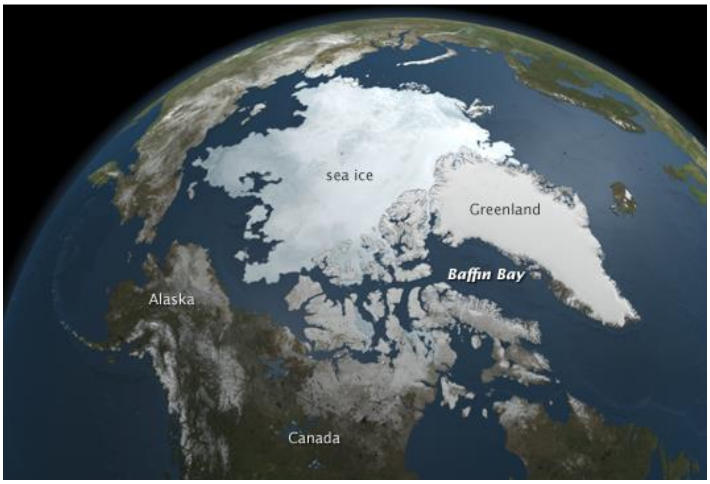

- **Microwave: 1mm - 1 meter wavelength**

- These wavelengths beyond the infra-red can 'see through' clouds, light rain, and snow, but there is a low amount of it
- … why we use these wavelengths for communications

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In general, remote sensing activity is classified into three groups based on the wavelengths used, and type/source of data:

1. Visible and Near/Mid Infrared (reflected) = 'optical'

2. Thermal Infrared (emitted from earth)

3. Microwave (= cloud-free … includes Radar)

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Interactions with the Atmosphere

- All radiation passes through the Earth's atmosphere
  - Effects on the image quality may be negligible for a low flying sensor and significant for satellite imagery
  - We can appreciate the effects of dust, smoke, haze, and other atmospheric impurities due to their high concentrations. But even on a clear day, visual effects of the atmosphere are numerous and can be of great significance for remote sensing.
  - Radiation is affected by physical process of *scattering, absorption* and *refraction*

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Scattering

- Scattering is the redirection of electromagnetic energy by particles suspended in the atmosphere or by large molecules of atmospheric gases.
- The amount of scattering depends on the sizes of the particles, their abundance, the wavelength of the radiation, the depth atmosphere (distance) through which the radiation has to pass
- It redirects radiation so that a portion of the incoming beam is directed back toward space, as well as toward the Earth's surface.
- Because it is wavelength dependent, blue light is scattered much more than red light and ultraviolet light is scattered much more than Blue light.
  - Qn: What is the cause of the blue color of the sky and brilliant red and orange colors at sunset?

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Refraction

- Refraction is the bending of light rays at the contact area between two media that transmit light e.g. lenses of cameras or magnifying glasse.
- Refraction in the atmosphere as light passes through atmospheric layers of varied clarity, humidity, and temperature.
  - For example, the shimmering appearances on hot summer days of objects viewed in the distance as light passes through hot air near the surface of heated highways

Absorption

- Absorption occurs when the atmosphere prevents the transmission of radiation.
  - Ozone (O_3) is formed by the interaction of ultraviolet radiation
  - Carbon dioxide absorbs radiation in the mid and far infrared regions of the spectrum.
  - Water vapor absorbs radiation although it varies a lot in time and place