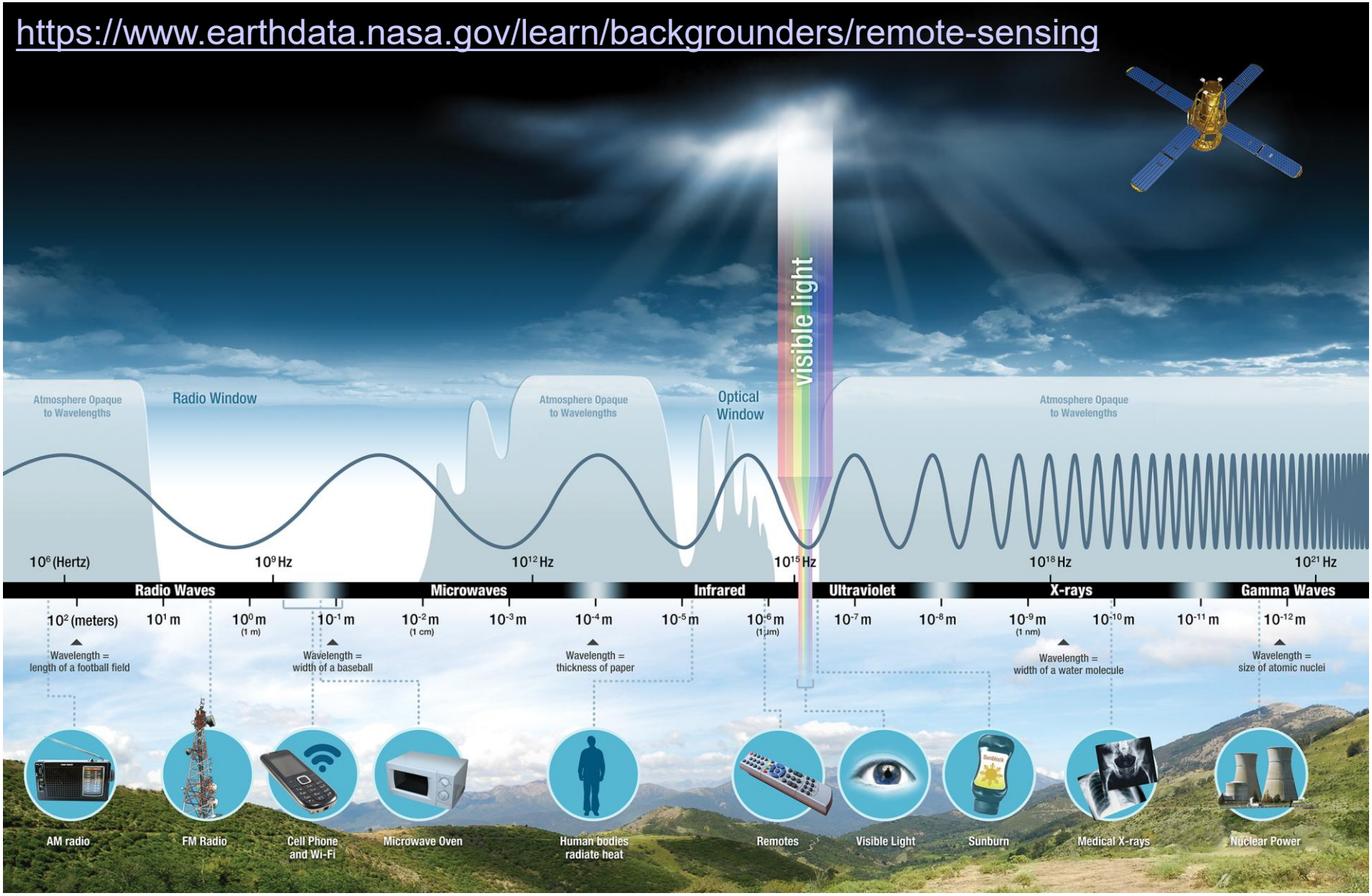
Remote sensing and the electromagnetic spectrum

https://www.earthdata.nasa.gov/learn/backgrounders/remote-sensing



Units of wavelength measurement

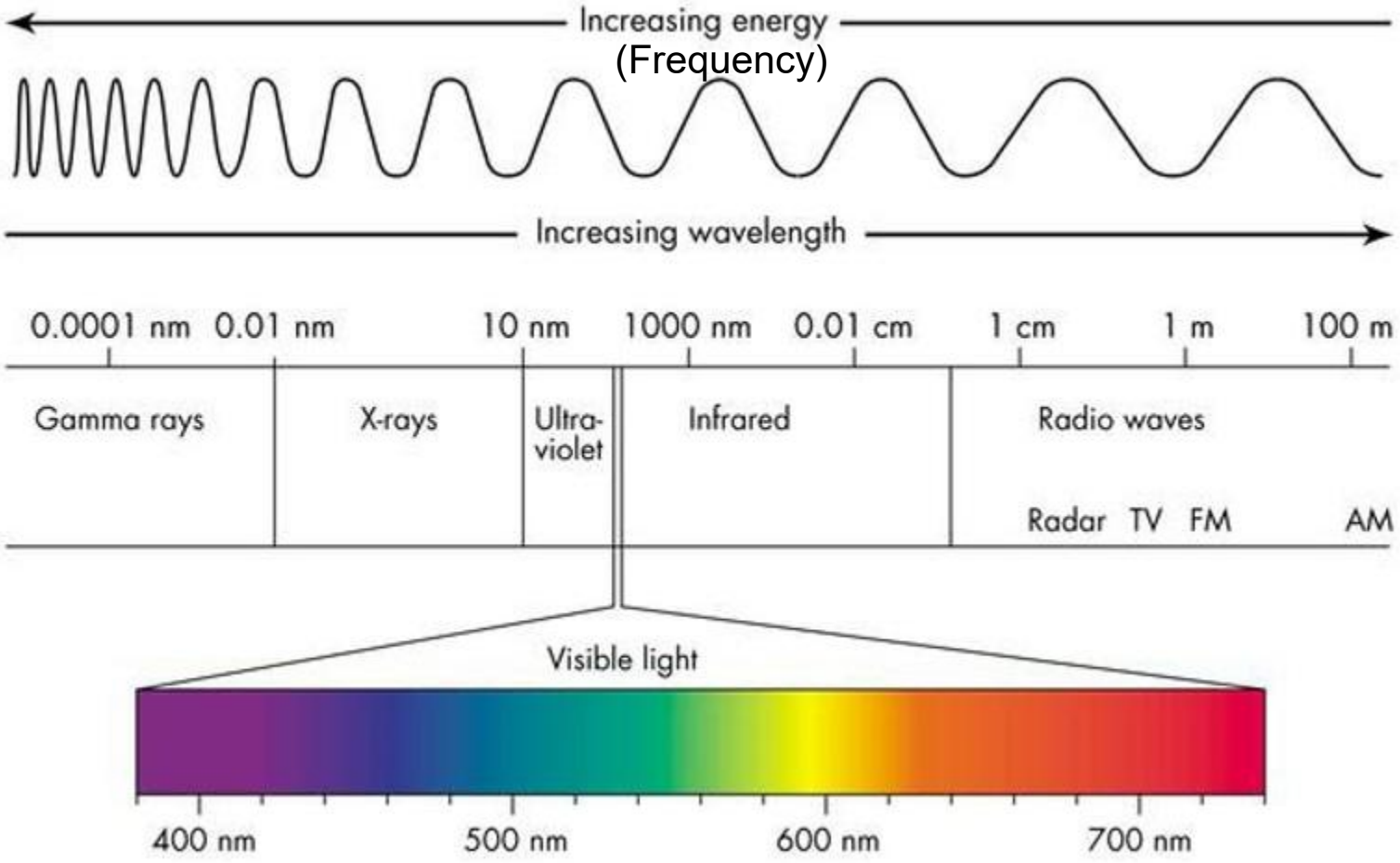
Metres: thousandths of a km

Millimetres: thousandths of a metre

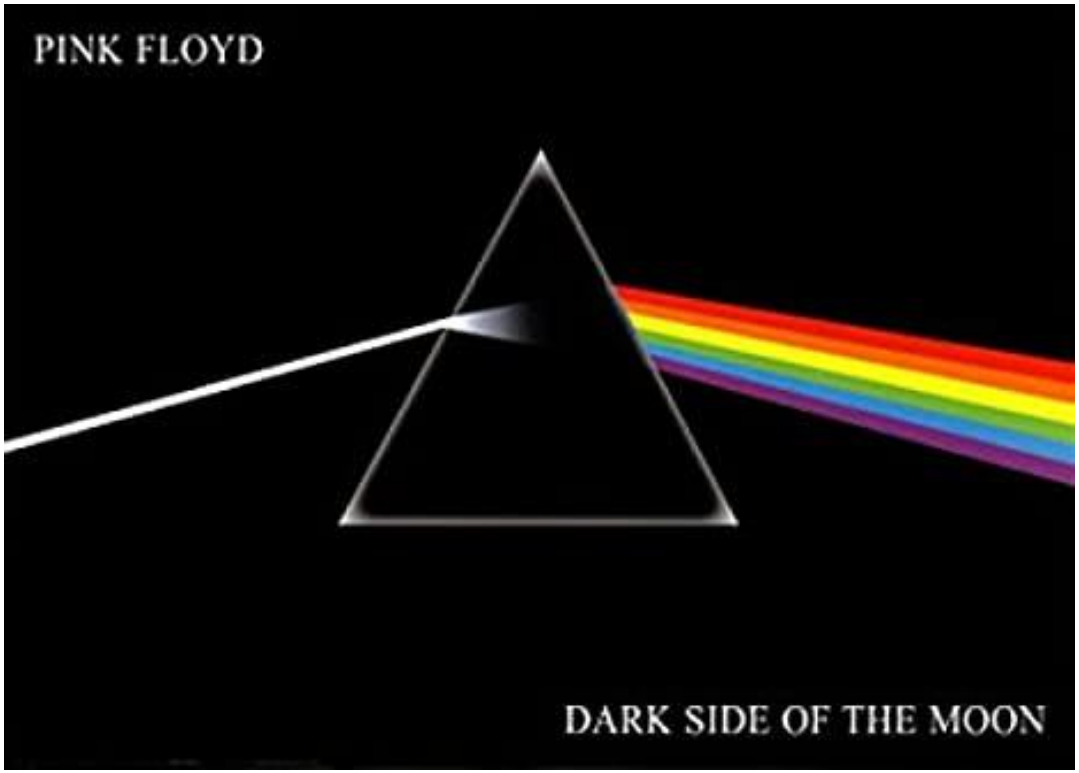
micrometres: millionths of a metre (microns)

nanometres: billionths of a metre

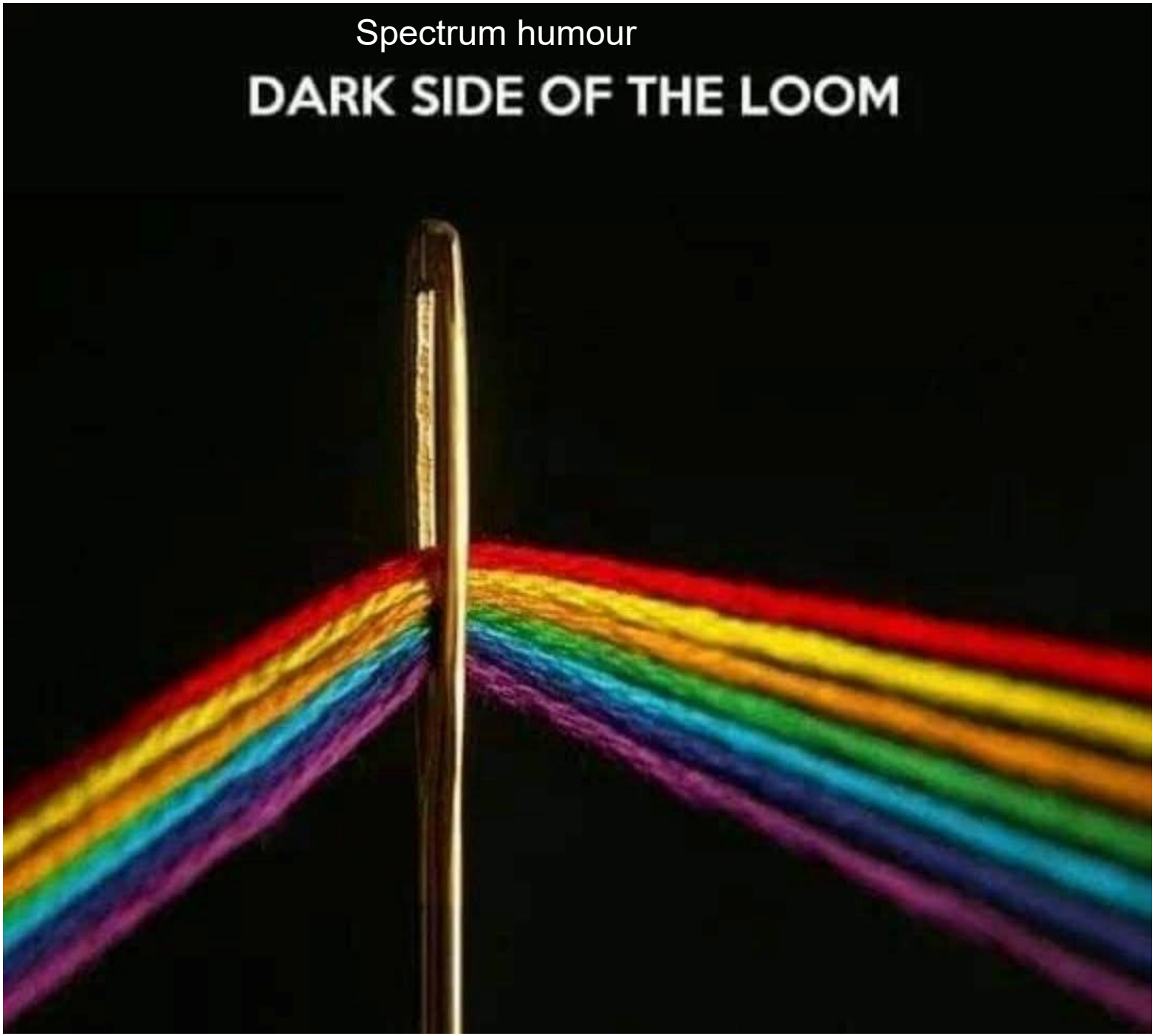
The spectrum provides the 'layers' in RS and is key to the data collected / applied.

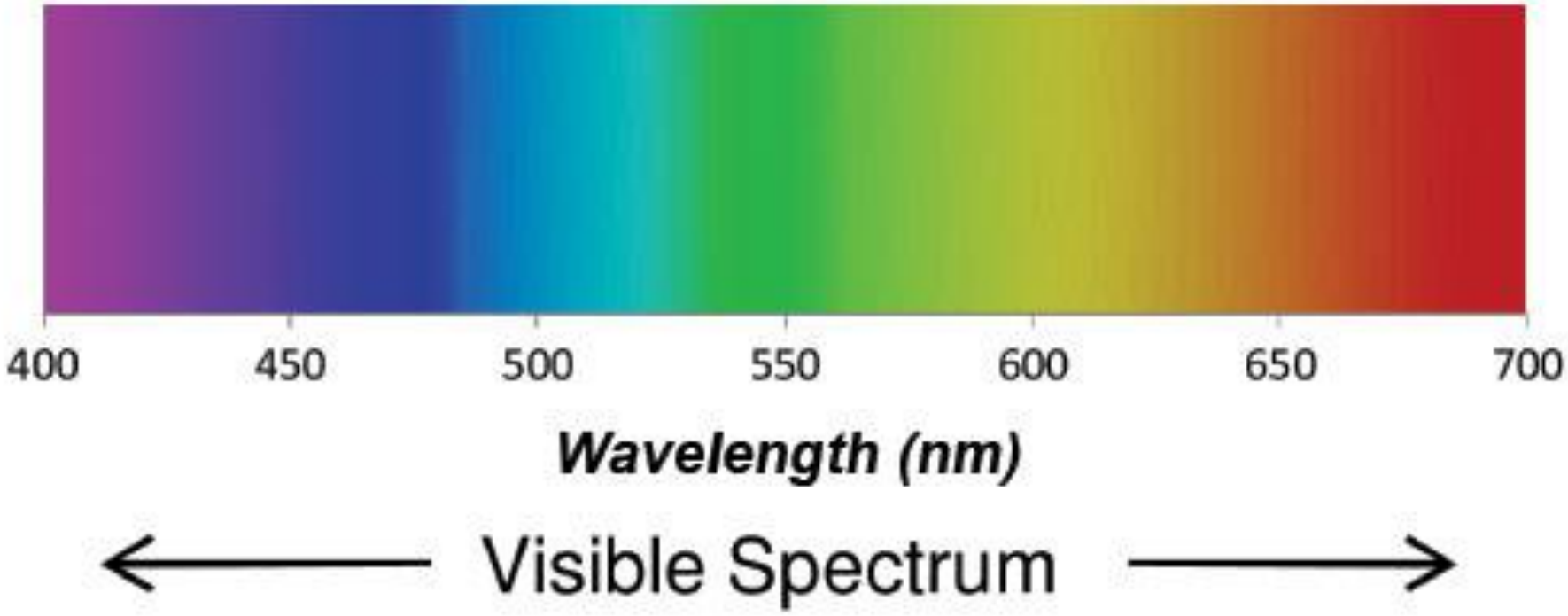


Spectral wavelengths of visible light via a prism or rainbow (differential refraction)
Red is refracted least



Spectrum humour





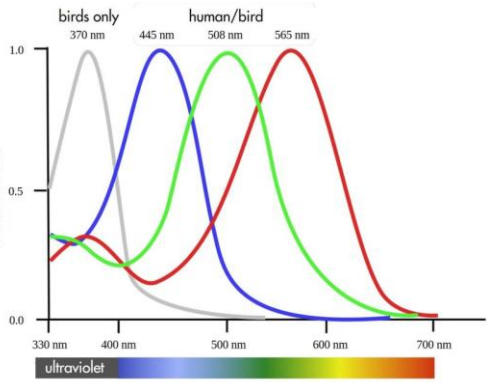
Here are the 7 rainbow colours from shortest to longest wavelength.

- Violet 400 - 420 nm = shortest visible wavelength
- Indigo 420 - 440 nm
- Blue 440 - 490 nm
- Green 490 - 570 nm
- Yellow 570 - 585 nm
- Orange 585 - 620 nm
- Red 620 - 700 nm = longest visible wavelength

Visible wavelengths range from 0.4- 0.7 microns / 400-700nm

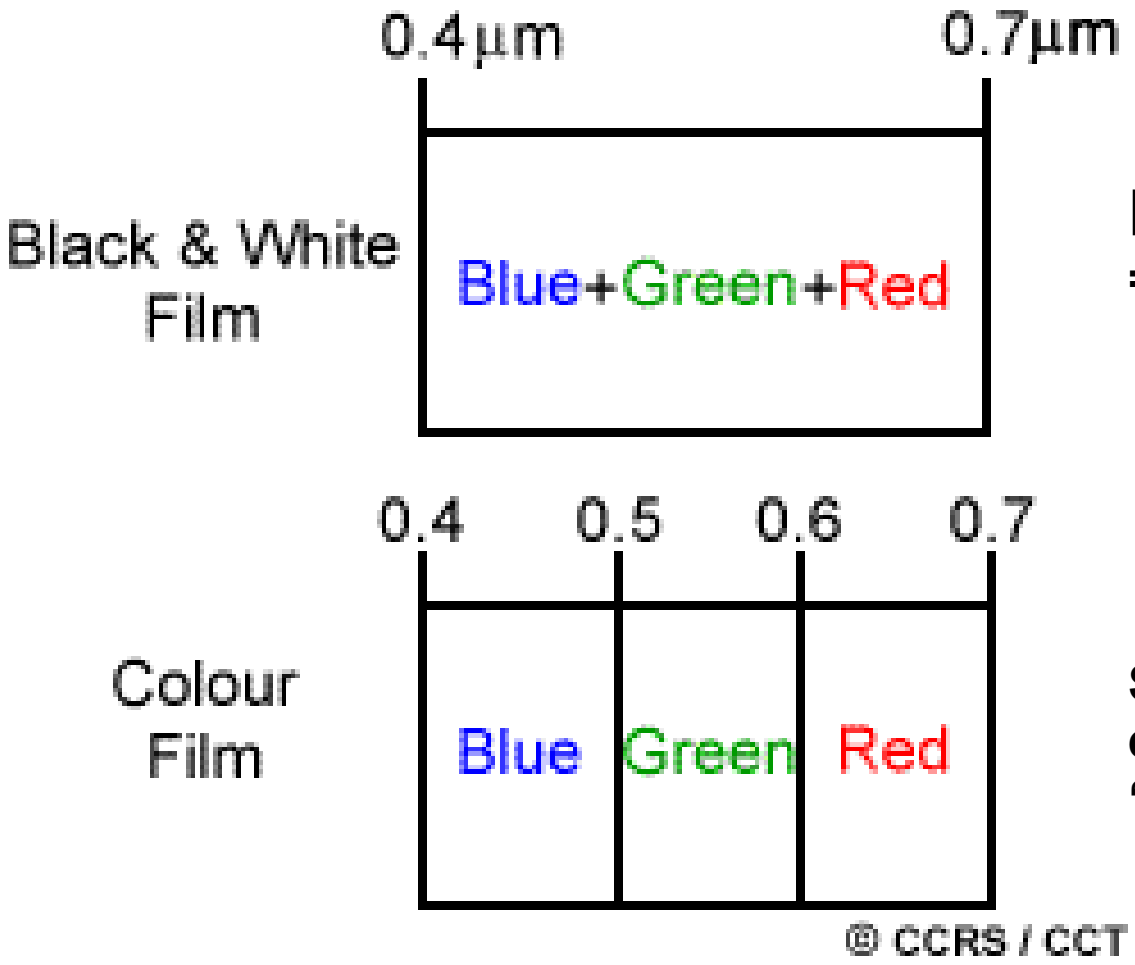
Animals and vision across the EM spectrum

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		



Reptiles can see into the IR

Layers or bands in colour film / digital / scanners



Panchromatic
= more combined energy

Similarly for digital data e.g. cameras with 3 'sensors' for RGB

Panchromatic air photo: 15th / University Way

Colour air photo: 15th / University Way

There is limited ‘extra information’ compared to PAN-most air photos were PAN with film

1950s: Infra-red (IR) photography

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

Herb Martin IR photos:
https://pbase.com/pgonline/infrared

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

/ screen display

B

G

R

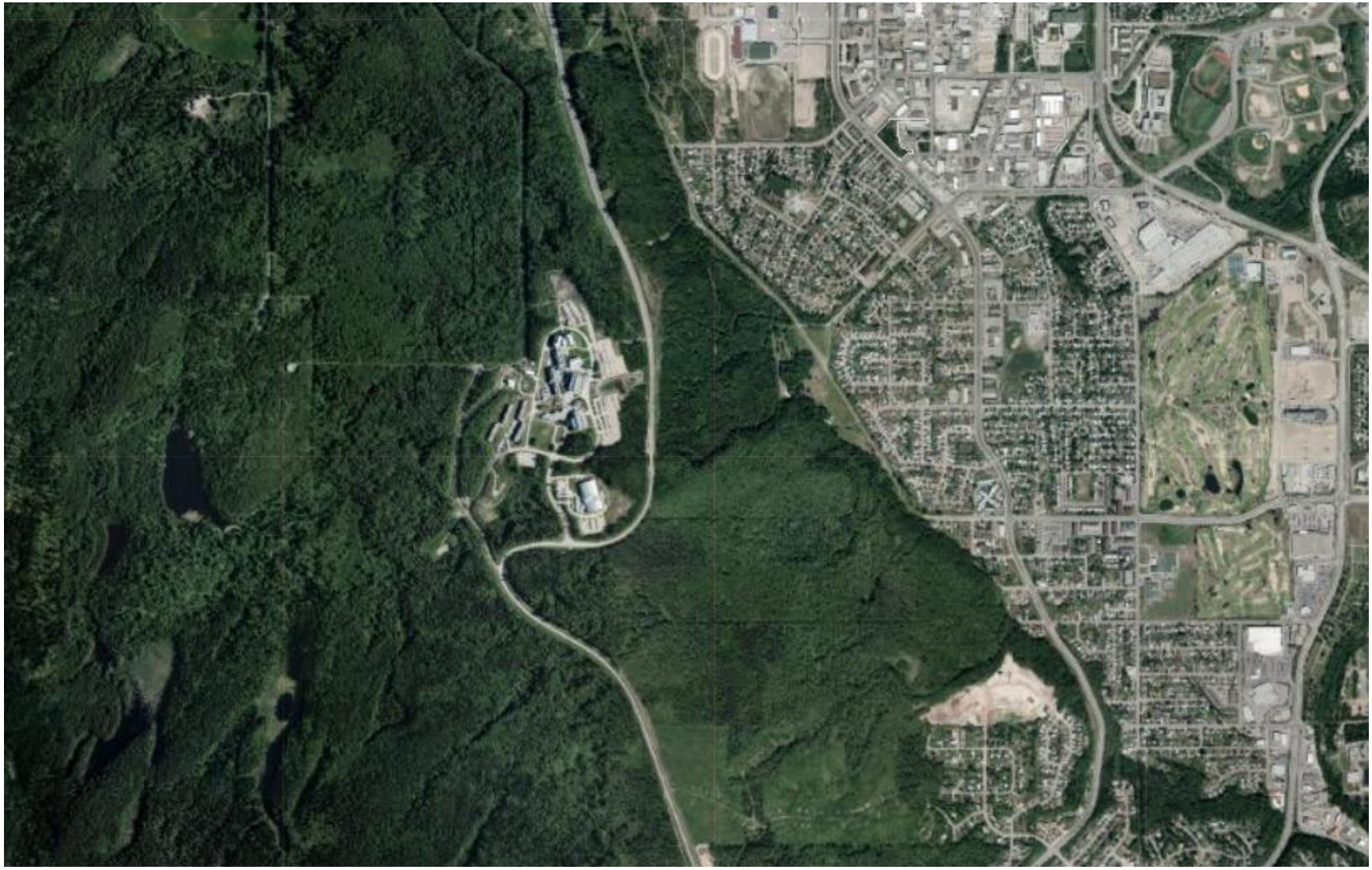
Healthy vegetation:

Red (IR) overwhelms Visible (Green /Blue)

… and on ‘Pan IR’

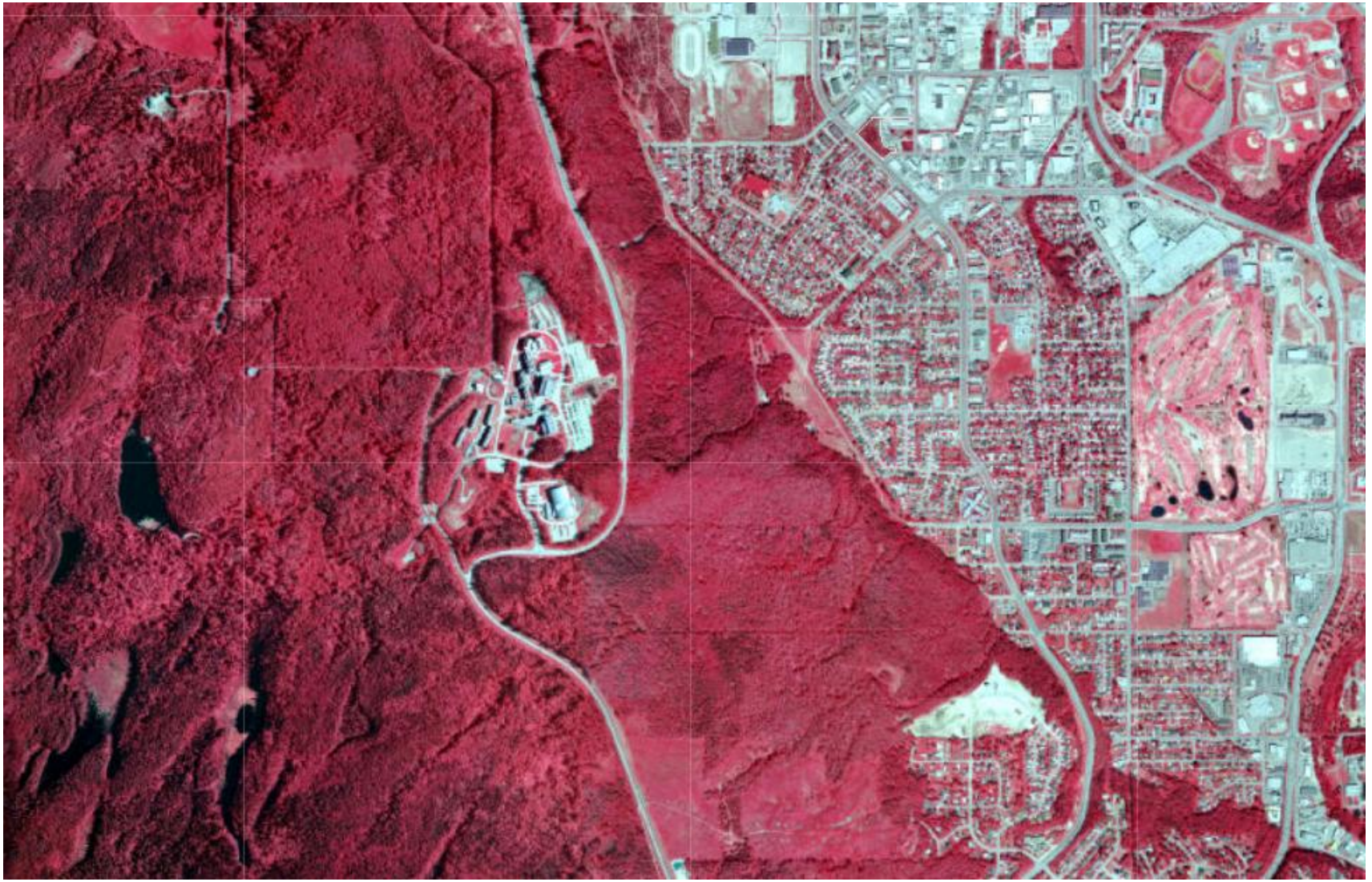
Herb Martin IR photos:
https://pbase.com/pgonline/infrared

PGmap spring 2014 natural colour



https://pgmap.princegeorge.ca/Html5Viewer/index.html?viewer=PGMap

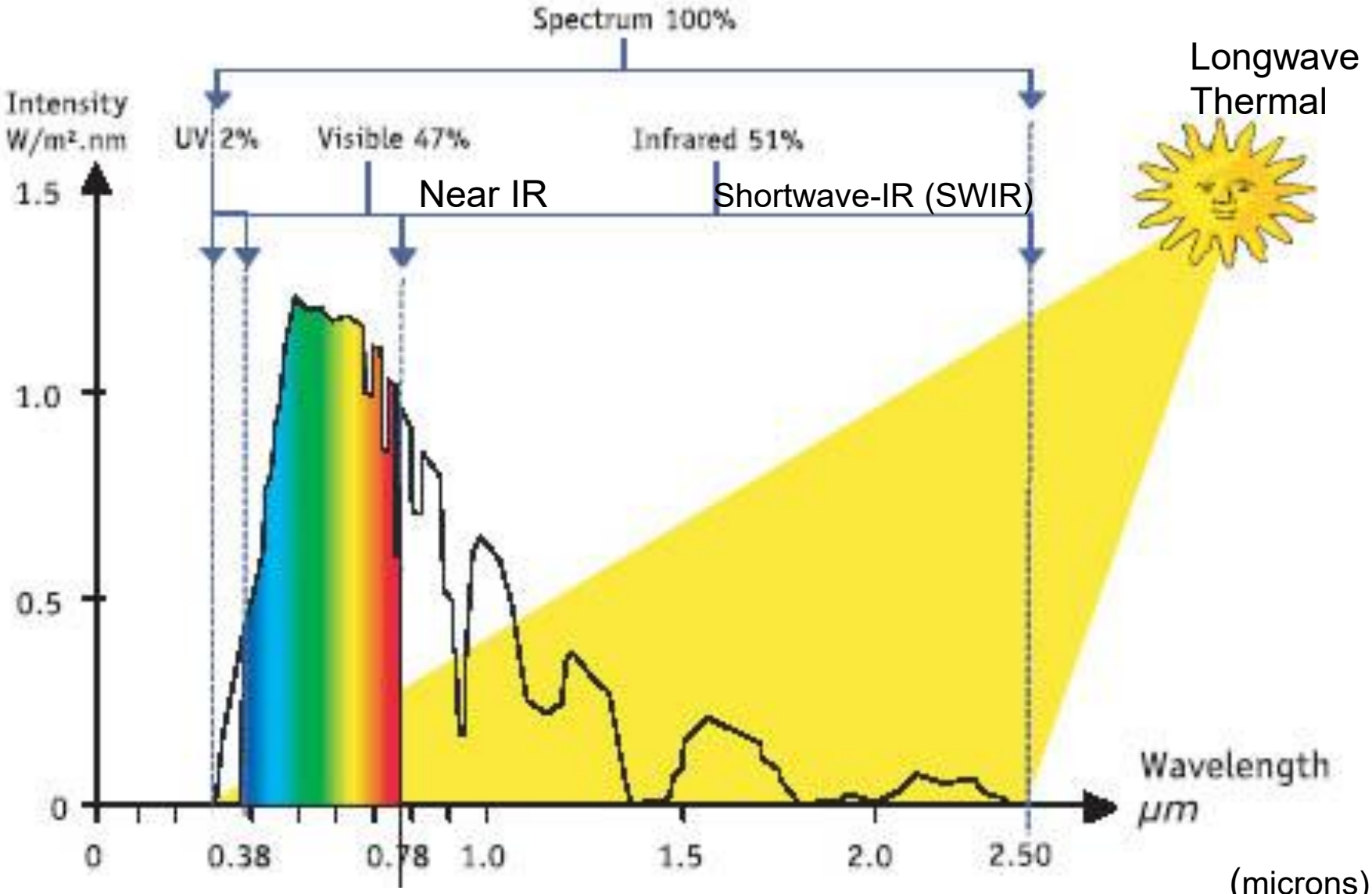
PGmap spring 2014 Near-IR:



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

1. Vegetation differences are enhanced e.g. coniferous v deciduous etc..
2. Land-water distinctions are enhanced (but shadows are deeper)
3. Blue –the most susceptible to haze / atmospheric refraction - is removed

SOLAR SPECTRUM



The Infra-red portion of the EM spectrum

0.7 - 1.5 microns: near IR –> **vegetation biomass / health**

1.3 - 3.0 microns: SWIR -> **moisture content** (inverse= dryness)
SWIR= ShortWave IR
*Visible, Near and SWIR are **reflected** energy from the Sun*

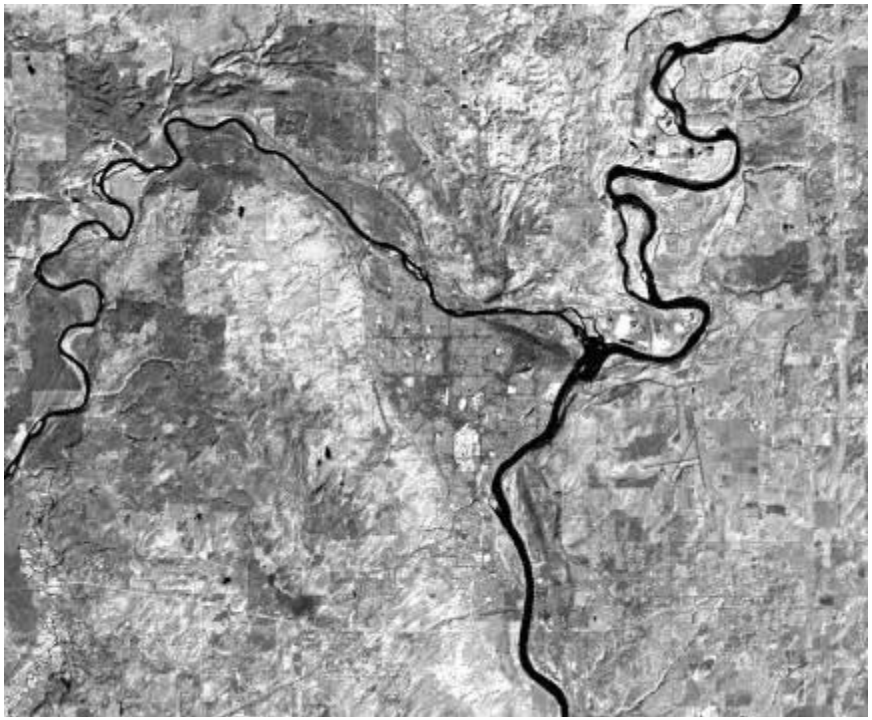
Far IR 3.0- 15.0 microns: far IR = thermal /temperature
Some sources extend far IR to 1000 microns (1 mm)

*Note: most of this energy is not reflected solar energy, but is **emitted** terrestrial energy (see previous slide)*

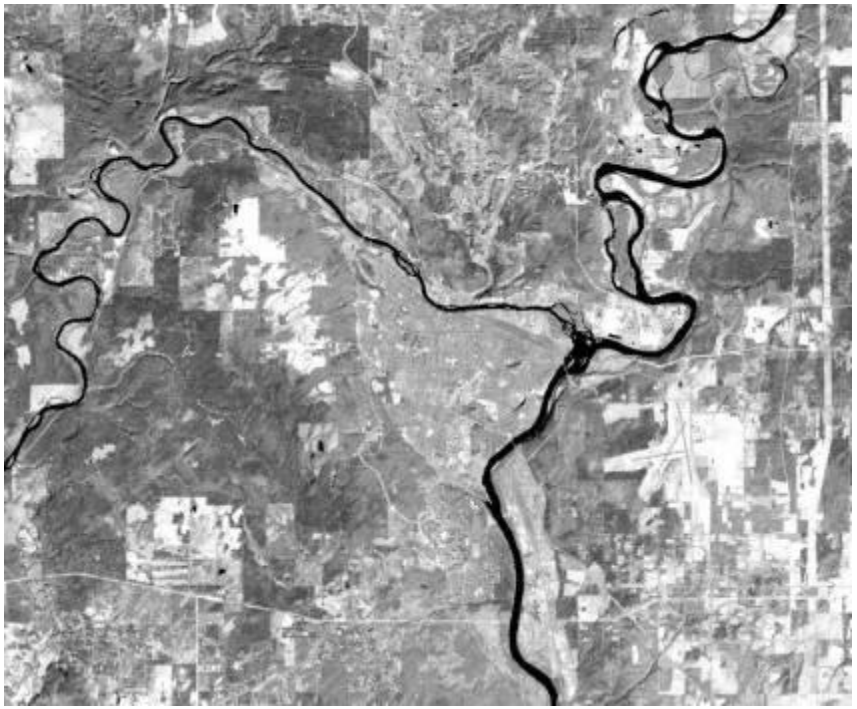
The **near IR** (0.7-1.3 microns) records energy related to **vegetation vigour** (health); the **SWIR** (1.3-3.0 microns) is (soil/veg) **moisture**.
- actually recorded as the lack of moisture = dryness

Neither have to do with temperature (or not much) ….

Near-IR



SWIR



Landsat band combinations: Visible versus IR combination

RGB are not too different

Visible wavelengths

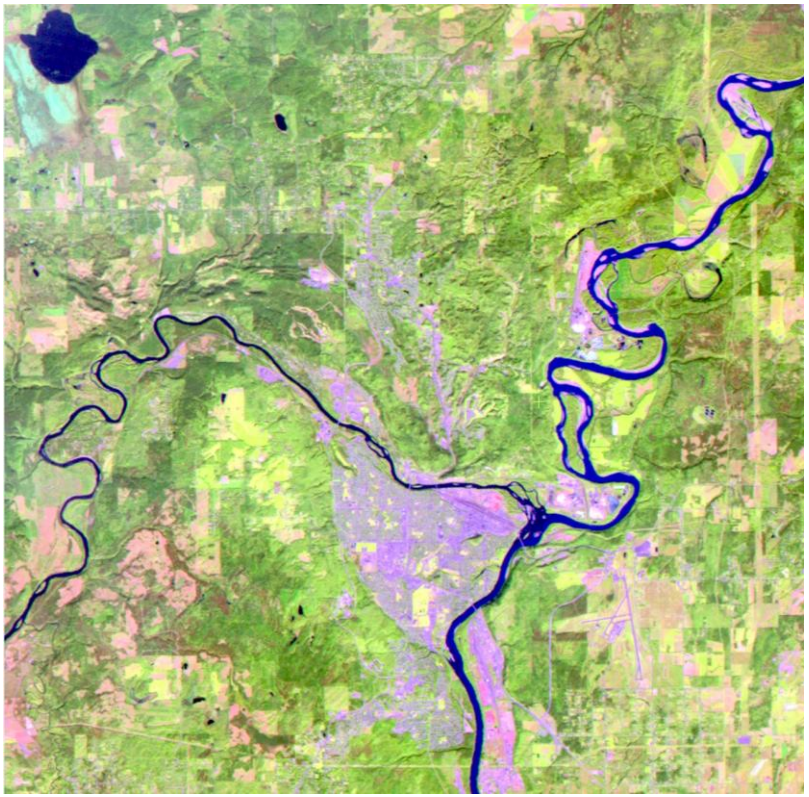
e.g. Google maps, earth (TM3-2-1)

Poor distinction of land/water

Including Infrared (NIR / SWIR)

e.g. BC imap / GEOG357 labs (TM5-4-3)

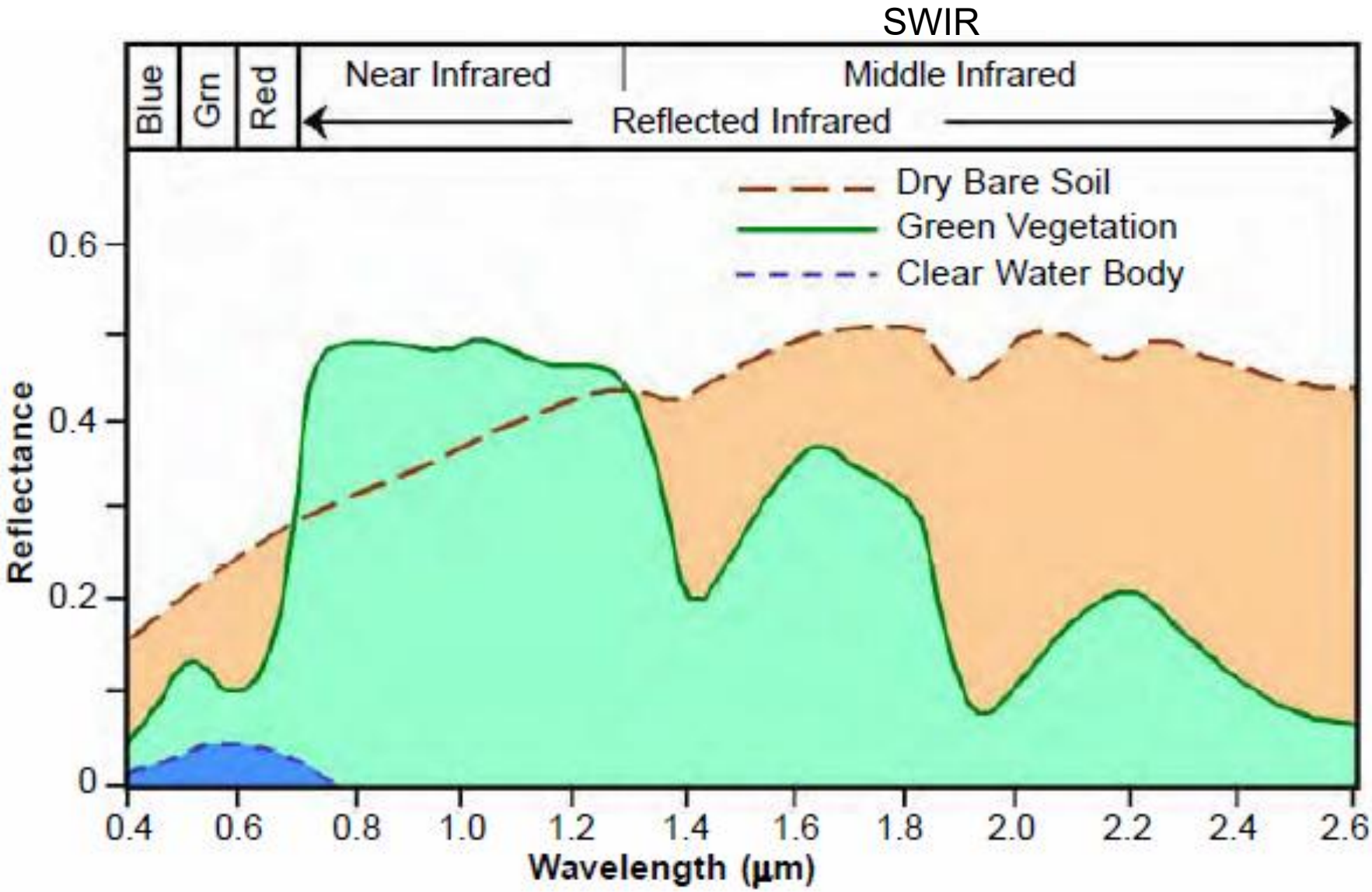
Good distinction plus vegetation types



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

advantages of Infra-Red wavelengths: contrast

Spectral Reflectance Curves

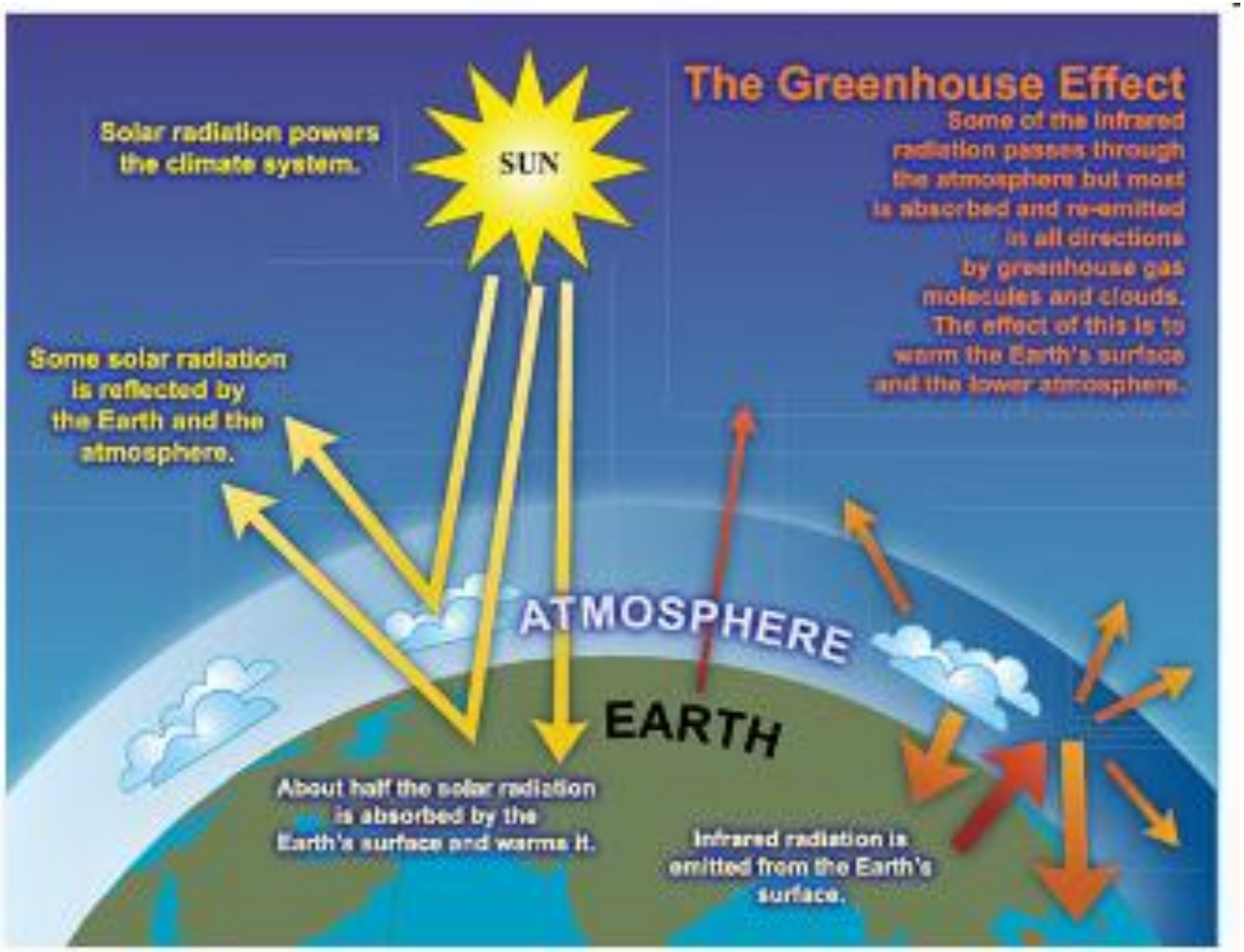


The various wavelengths are captured as ‘bands’ or layers e.g. Landsat satellites 4, 5 and 7 (below) – 1982-2011

Band	Wavelength	Useful for mapping
Band 1 - blue	0.45-0.52	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
Band 2 - green	0.52-0.60	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 3 - red	0.63-0.69	Discriminates vegetation slopes
Band 4 - Near Infrared	0.77-0.90	Emphasizes biomass content and shorelines
Band 5 - Short-wave Infrared	1.55-1.75	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 6 - Thermal Infrared	10.40-12.50	Thermal mapping and estimated soil moisture
Band 7 - Short-wave Infrared	2.09-2.35	Hydrothermally altered rocks associated with mineral deposits ‘Geology’
Band 8 - Panchromatic (Landsat 7 only)	.52-.90	15 meter resolution, sharper image definition Why does it not include blue wavelengths ?

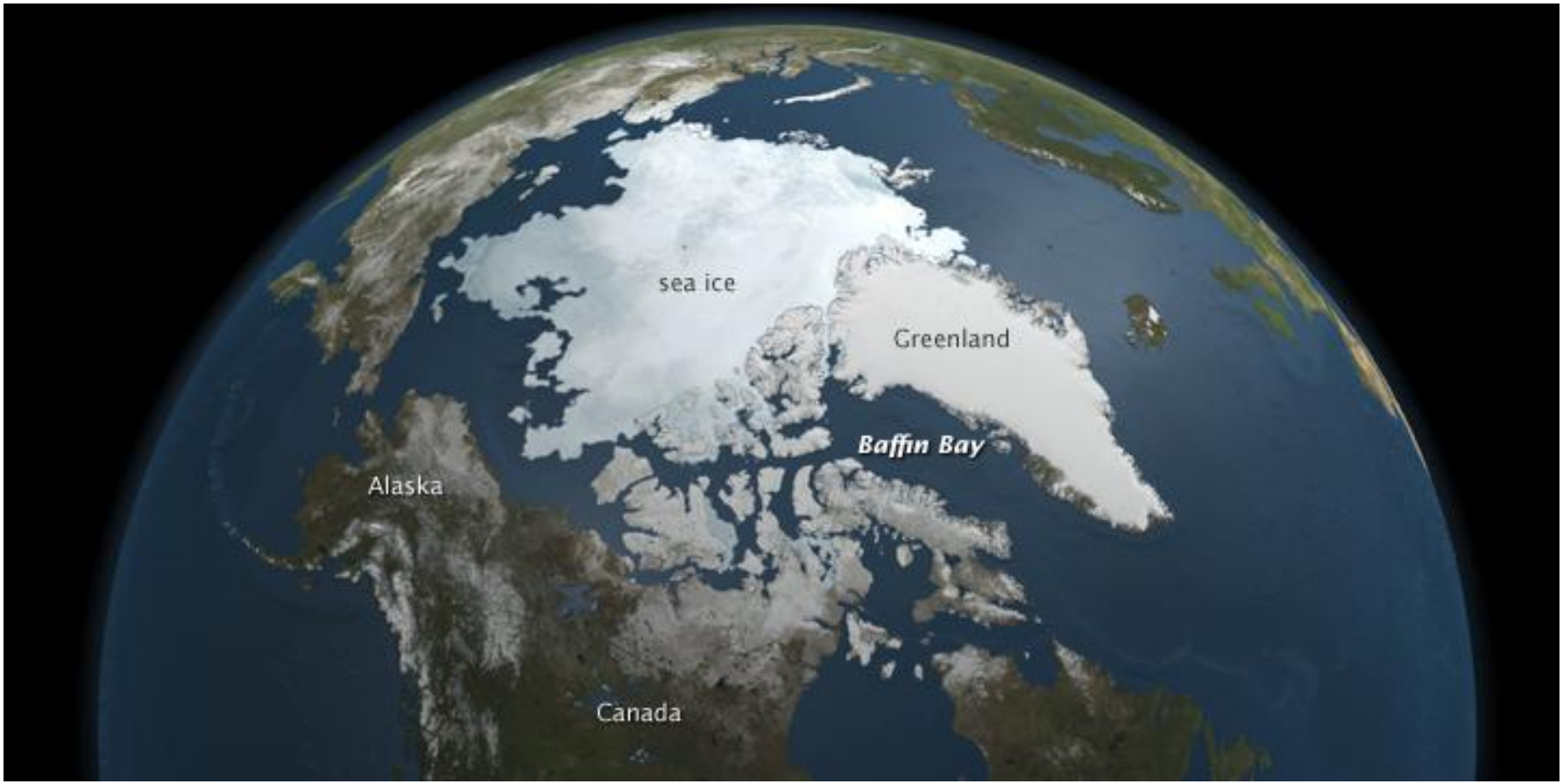
Thermal Infrared (3-15 microns)

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



Microwave: 1mm – 1 metre wavelength

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



As wavelength increases, so does atmospheric penetration ….

Gamma rays: most don't reach earth (phew!)

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

(some)

Summary

RS is classified into three main groups based on the spectral wavelengths used, and their inherent type/source of data:

1. Visible and Near/Shortwave Infrared: VNIR + SWIR (reflected) = 'optical'

2. Thermal Infrared - emitted from earth - TIR

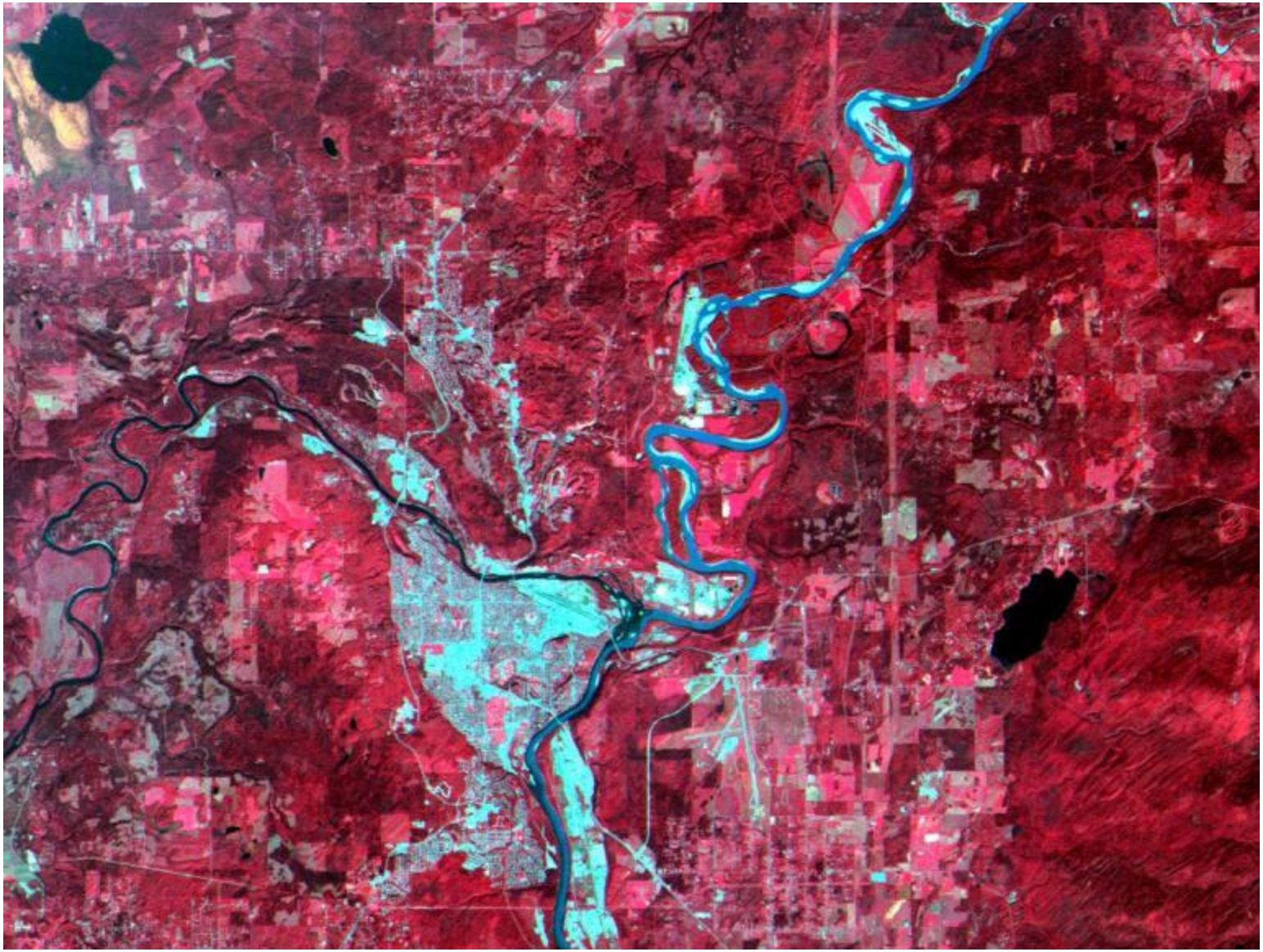
3. Microwave - emitted and cloud-free

These describe 'passive' remote sensing (most of the course), but we will also learn about 'active' RS (RADAR ?LiDAR)

Image Unstretched – low contrast due to limited range of digital numbers: more on this in the next lecture and the lab

Note: most images would not be this extreme

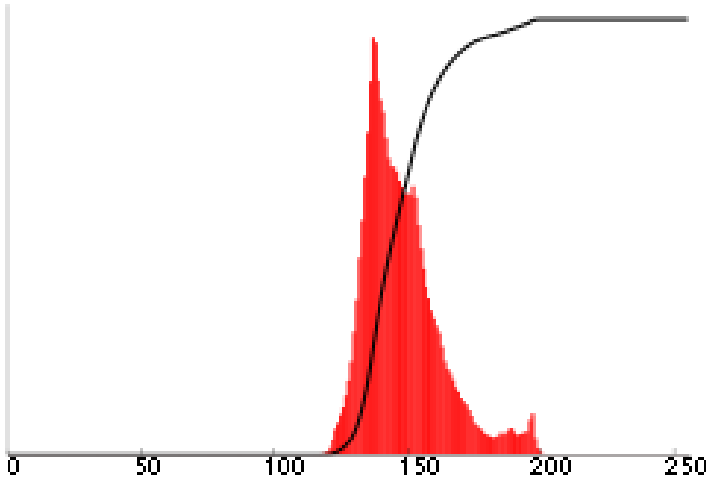
‘False’ colour enhanced / stretched for display

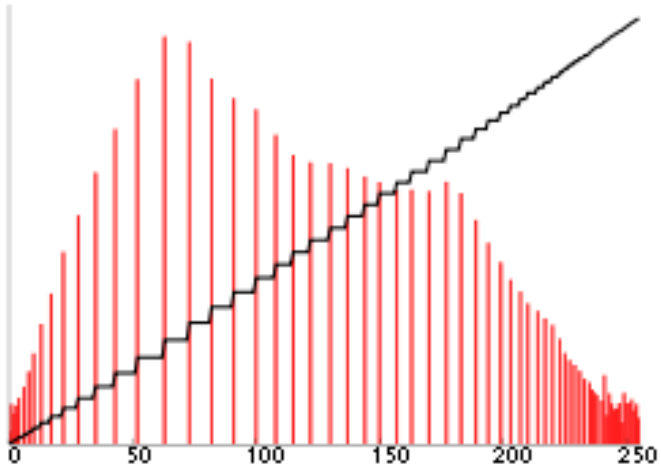


Data histogram equalization / contrast stretching / image enhancement

A histogram plots the Digital Numbers (DN) on the x-axis against the frequency of values with those DNs.

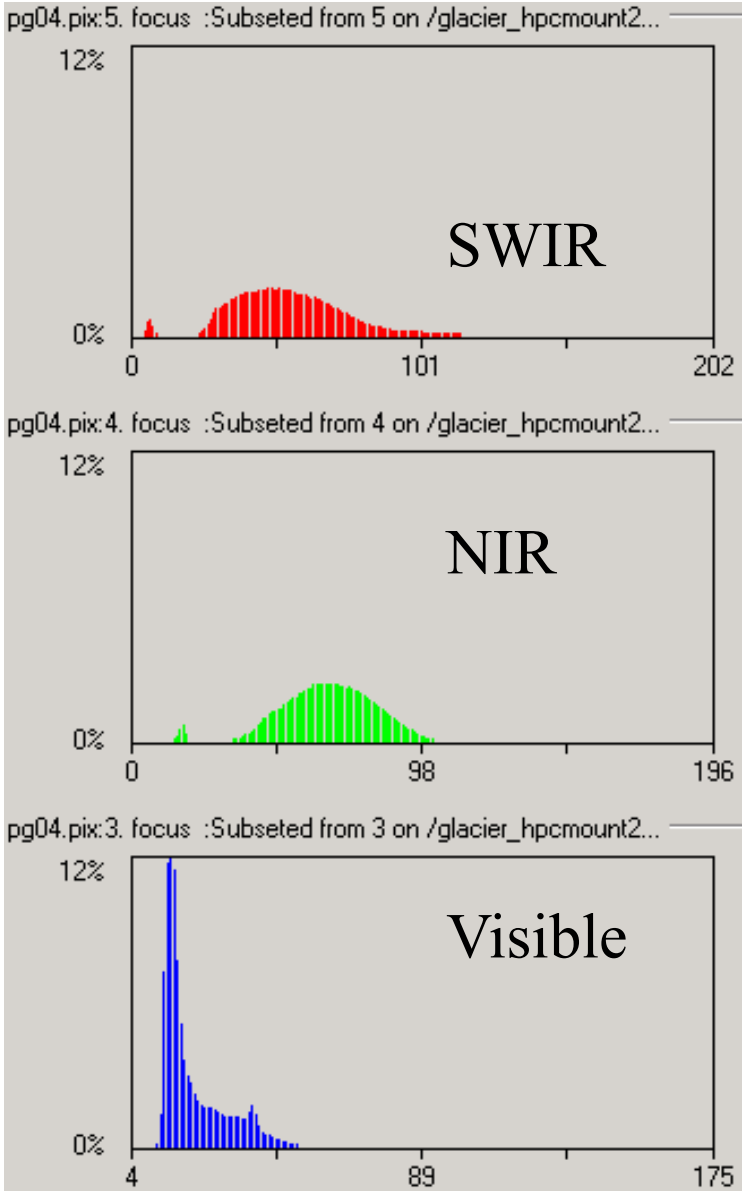
From Wikipedia



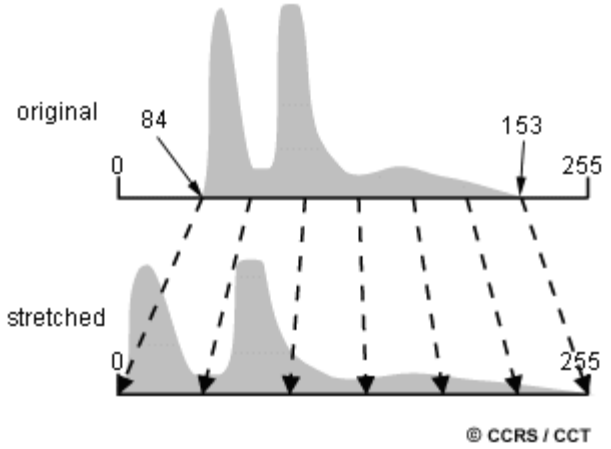


https://natural-resources.canada.ca/maps-tools-publications/satellite-elevation-air-photos/image-enhancement

Contrast stretch / enhancement as DNs do not fill the display range



Linear stretch



Root stretch