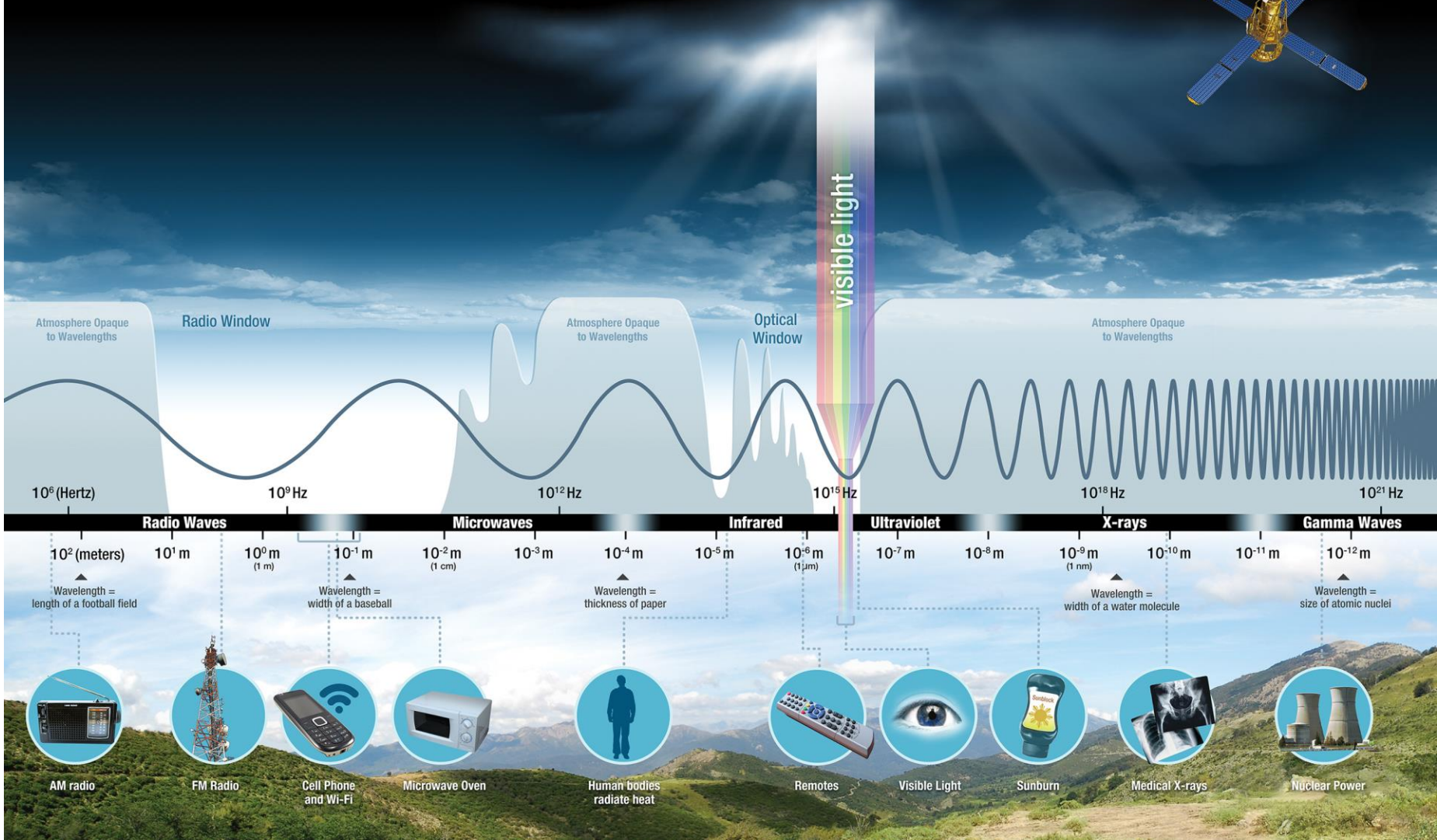# Remote sensing and the electromagnetic spectrum
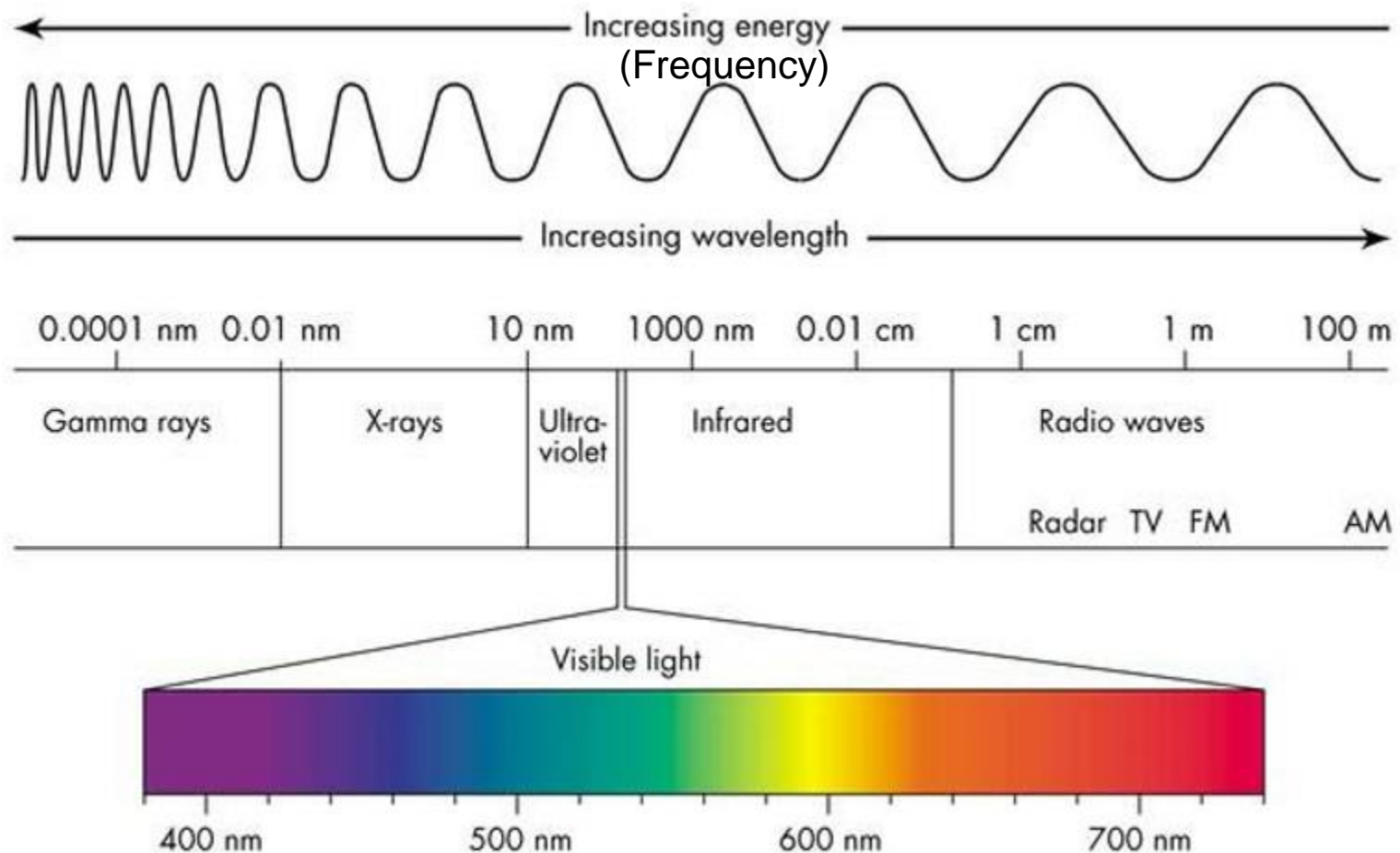
Units of wavelength measurement

Metres: thousandths of a km

Millimetres: thousandths of a metre

micrometres: millionths of a metre (microns)

nanometres: billionths of a metre

Increasing energy (Frequency)

Increasing wavelength

| 0.0001 nm | 0.01 nm | 10 nm | 1000 nm | 0.01 cm | 1 cm | 1 m | 100 m |

Gamma rays | X-rays | Ultra-violet | Infrared | Radio waves

Radar   TV   FM   AM

Visible light

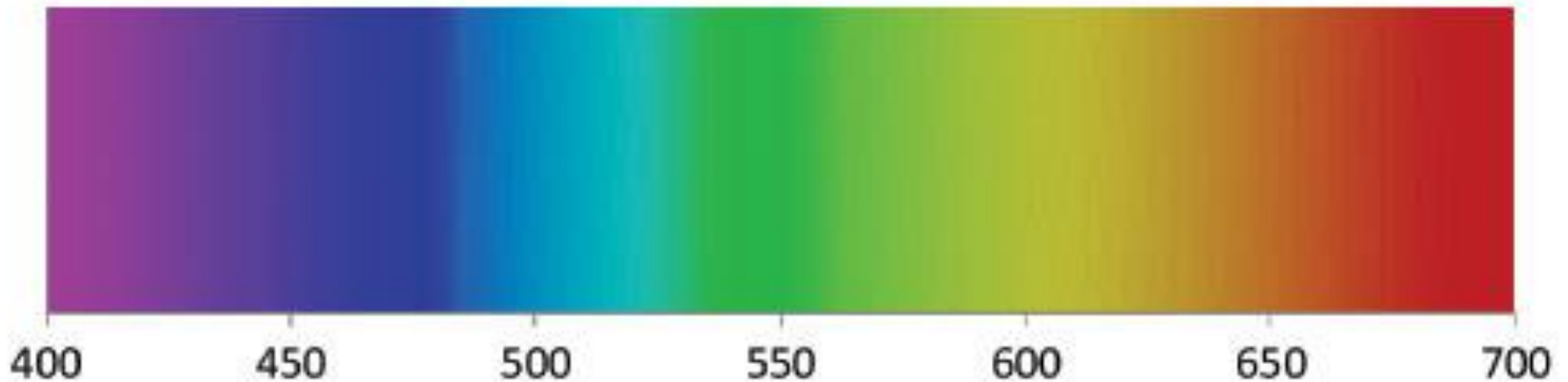400 nm   500 nm   600 nm   700 nm

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

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

PINK FLOYD

DARK SIDE OF THE MOON
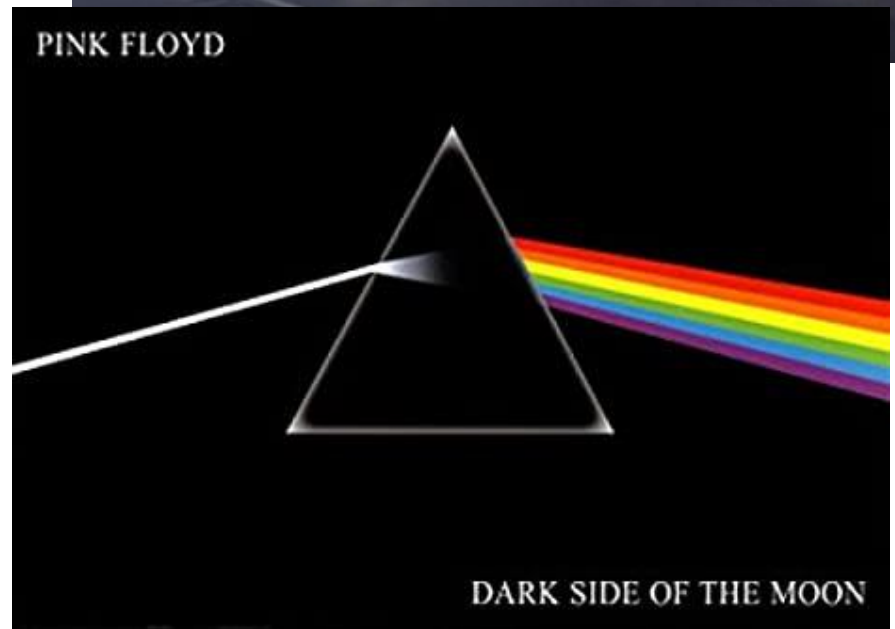
Wavelength (nm)

← ——— Visible Spectrum ———→

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)

Layers or bands in colour film / digital / scanners

0.4 μm   0.7 μm   Microns

Black & White Film

Blue+Green+Red
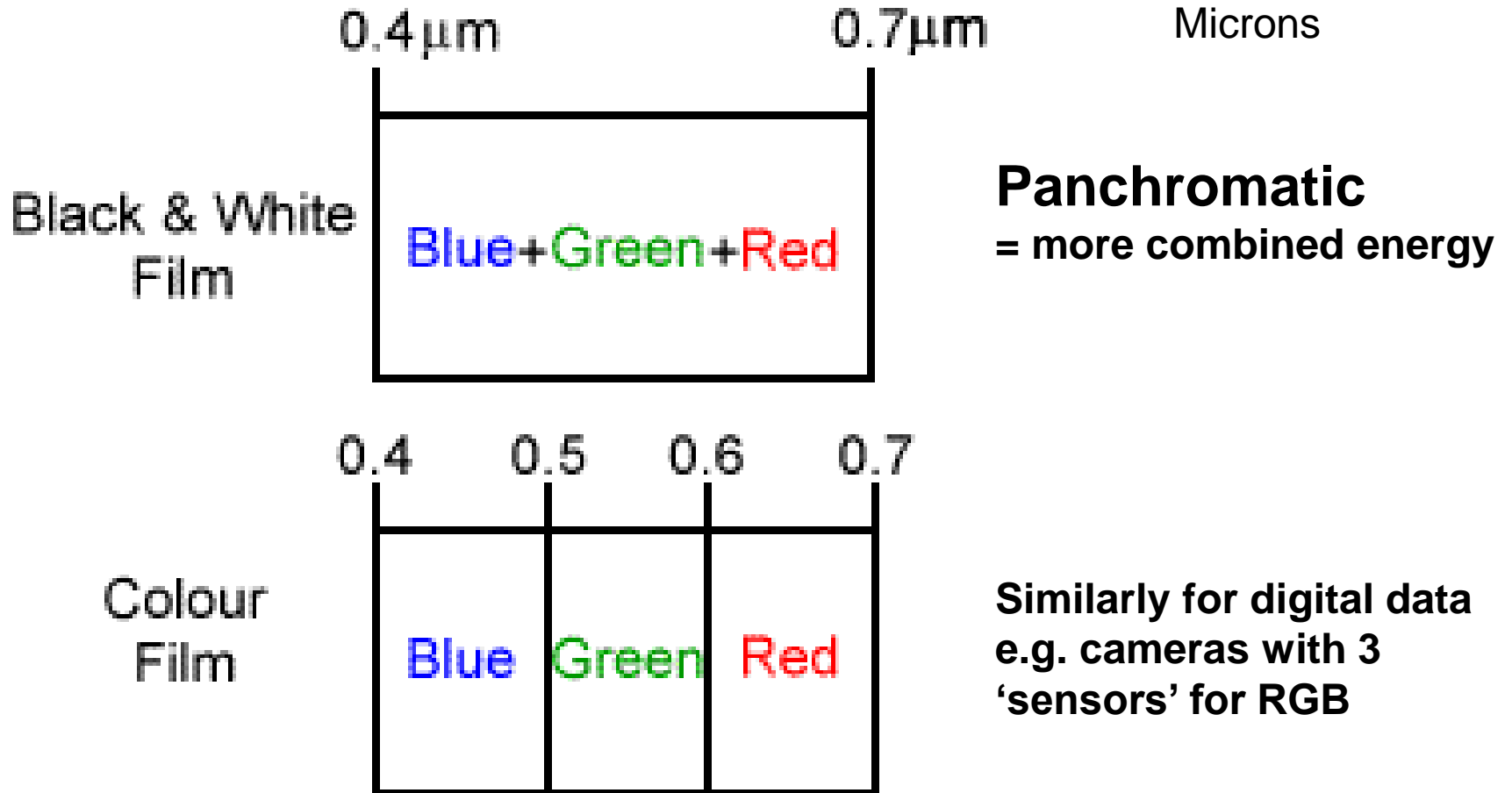
Panchromatic
= more combined energy

0.4   0.5   0.6   0.7

Colour Film

Blue   Green   Red

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

© CCRS / CCT

Panchromatic air photo: 15ᵗʰ / University Way

# Colour air photo: 15th / University Way

There is limited 'extra information' compared to PAN

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		

Human vision   Bird vision
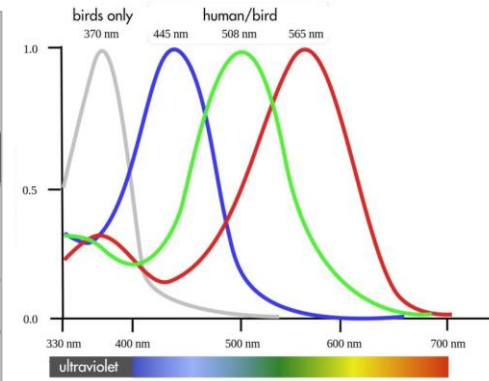
Colors That Humans See

Colors The Dogs See

Reptiles can see into the IR

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

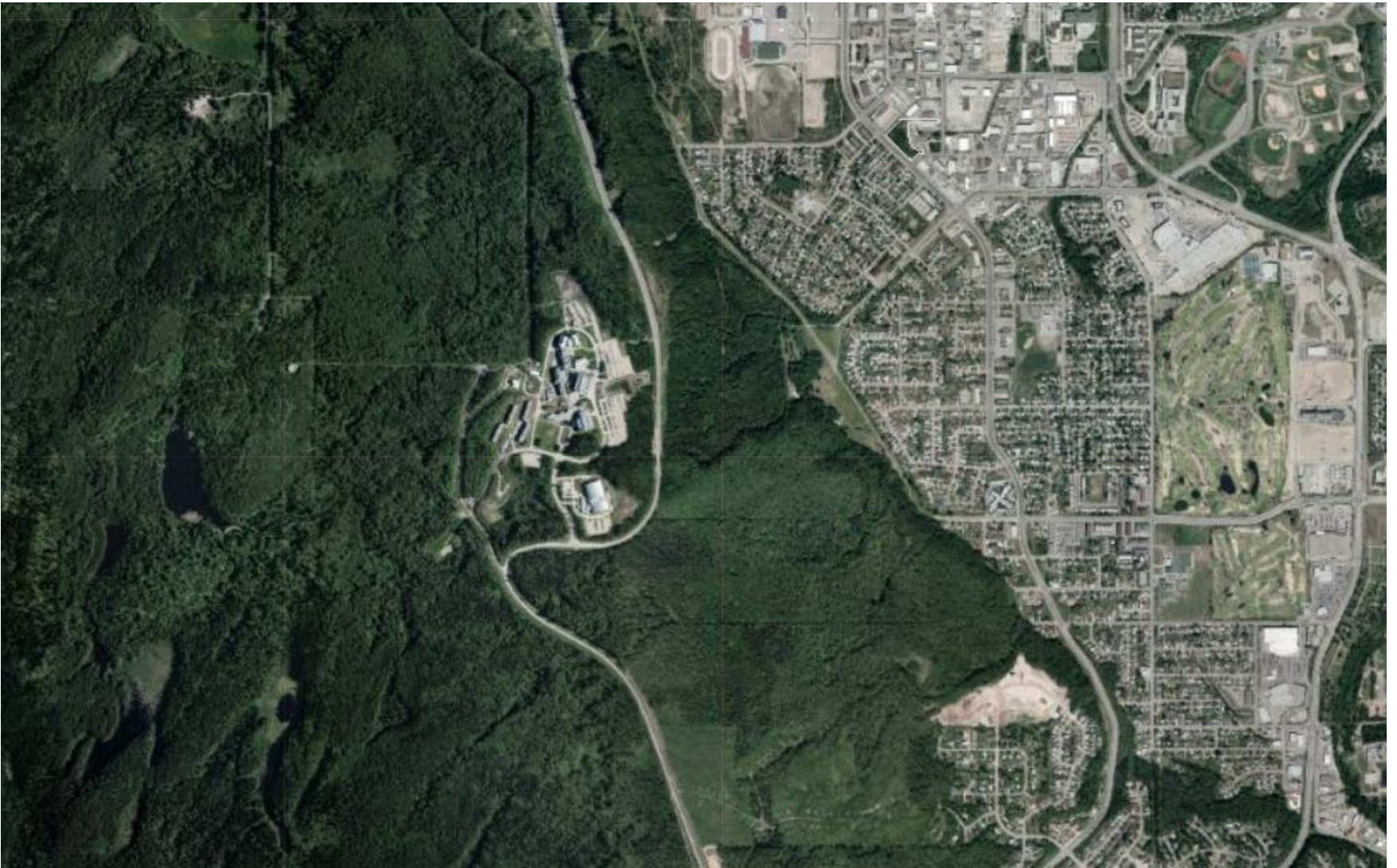| Normal colour film (Energy captured by film)	IR film (Energy captured by film)	Colour that results on film
B	G	Blue
G	R	Green
R	IR	Red

/ screen display

B

G

R

Healthy vegetation:

Red (IR) overwhelms Blue
or Red = (Green /Blue)

… and Pan IR

PGmap spring 2014 natural colour
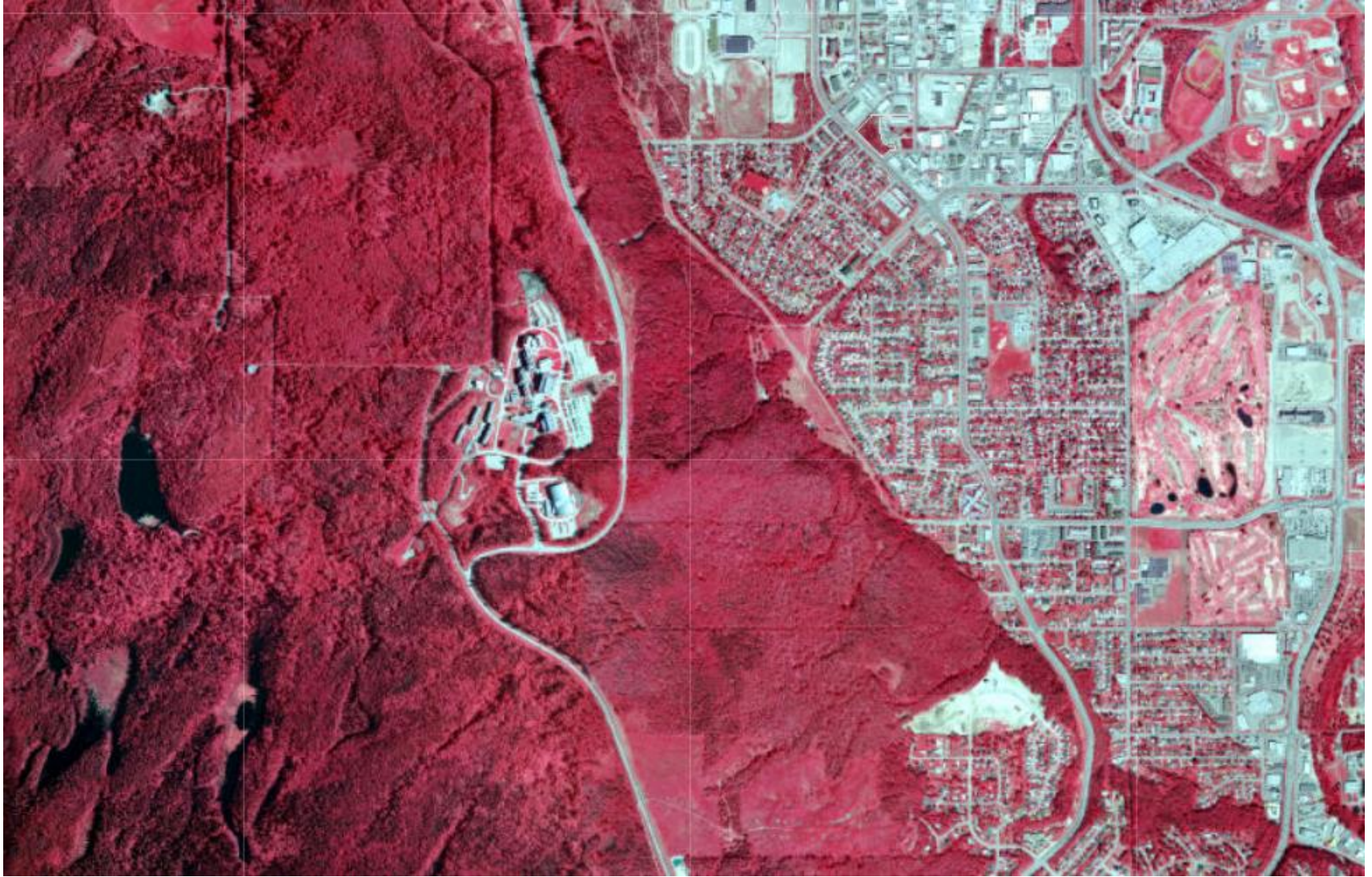

https://pgmap.princegeorge.ca/Html5Viewer/index.html?viewer=PGMap
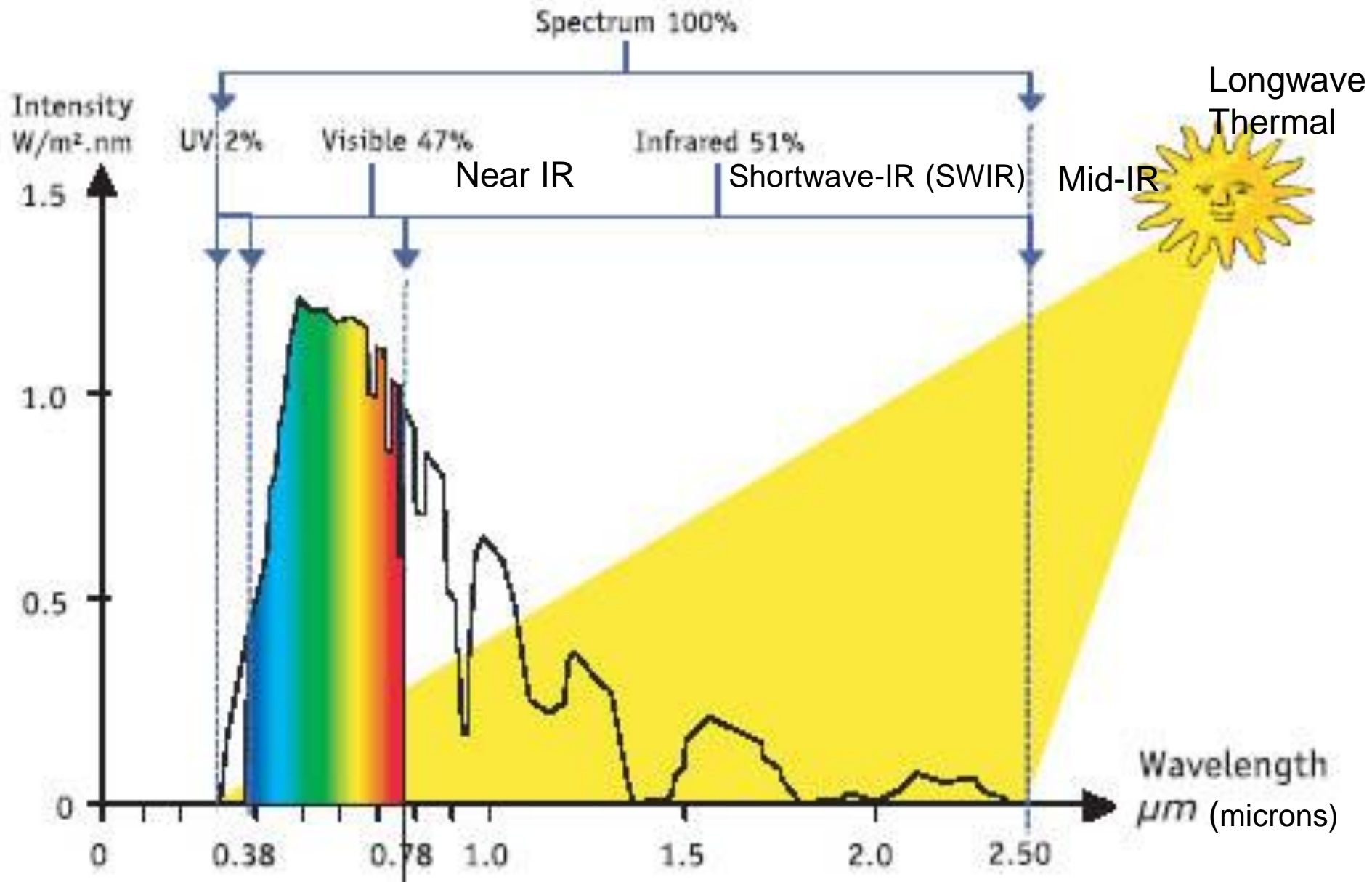
PGmap spring 2014 Near-IR image:

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 - 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
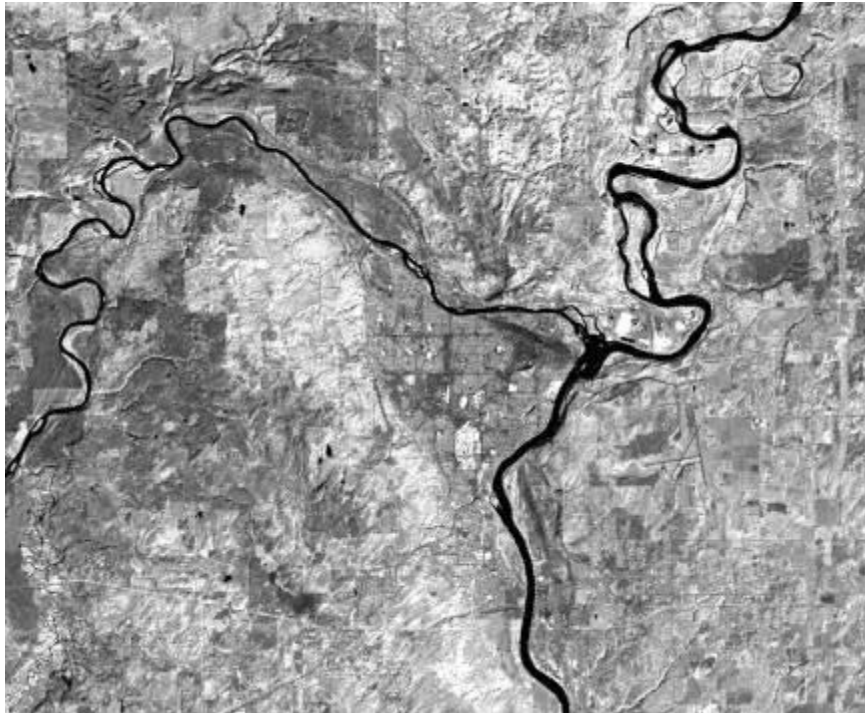(includes 'mid-IR' 3-5 microns)

Some sources extend far IR to 1000 microns (1 mm)

*Note: most of this energy is <u>not </u>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**.

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

Near-IR   SWIR

Landsat TM band combinations: Visible versus IR combination

RGB are not too different

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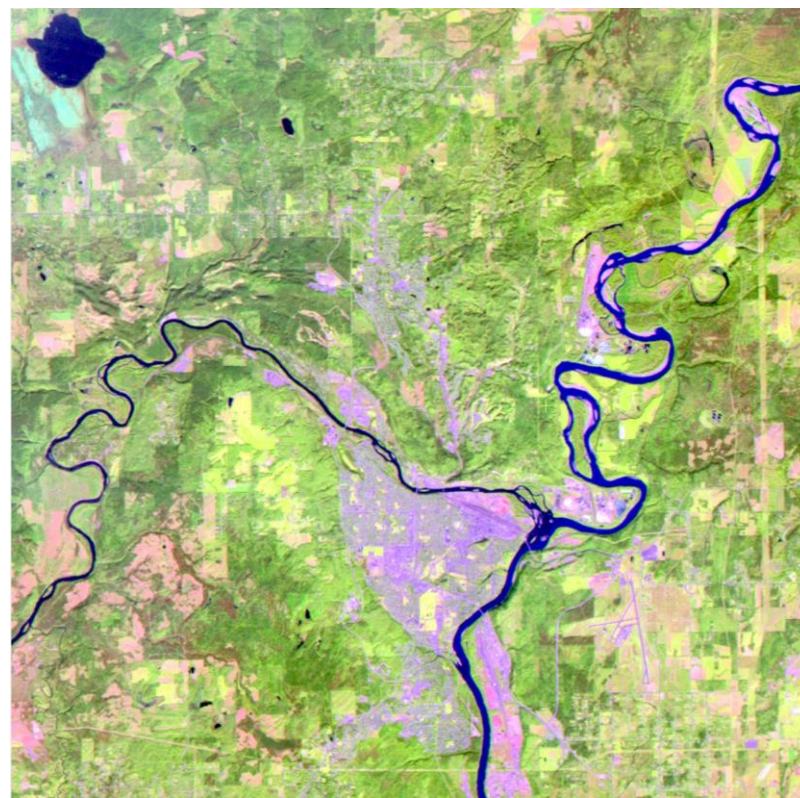
e.g. Google maps, earth (TM3-2-1)

Poor distinction of land/water

Including Infrared (NIR / SWIR)
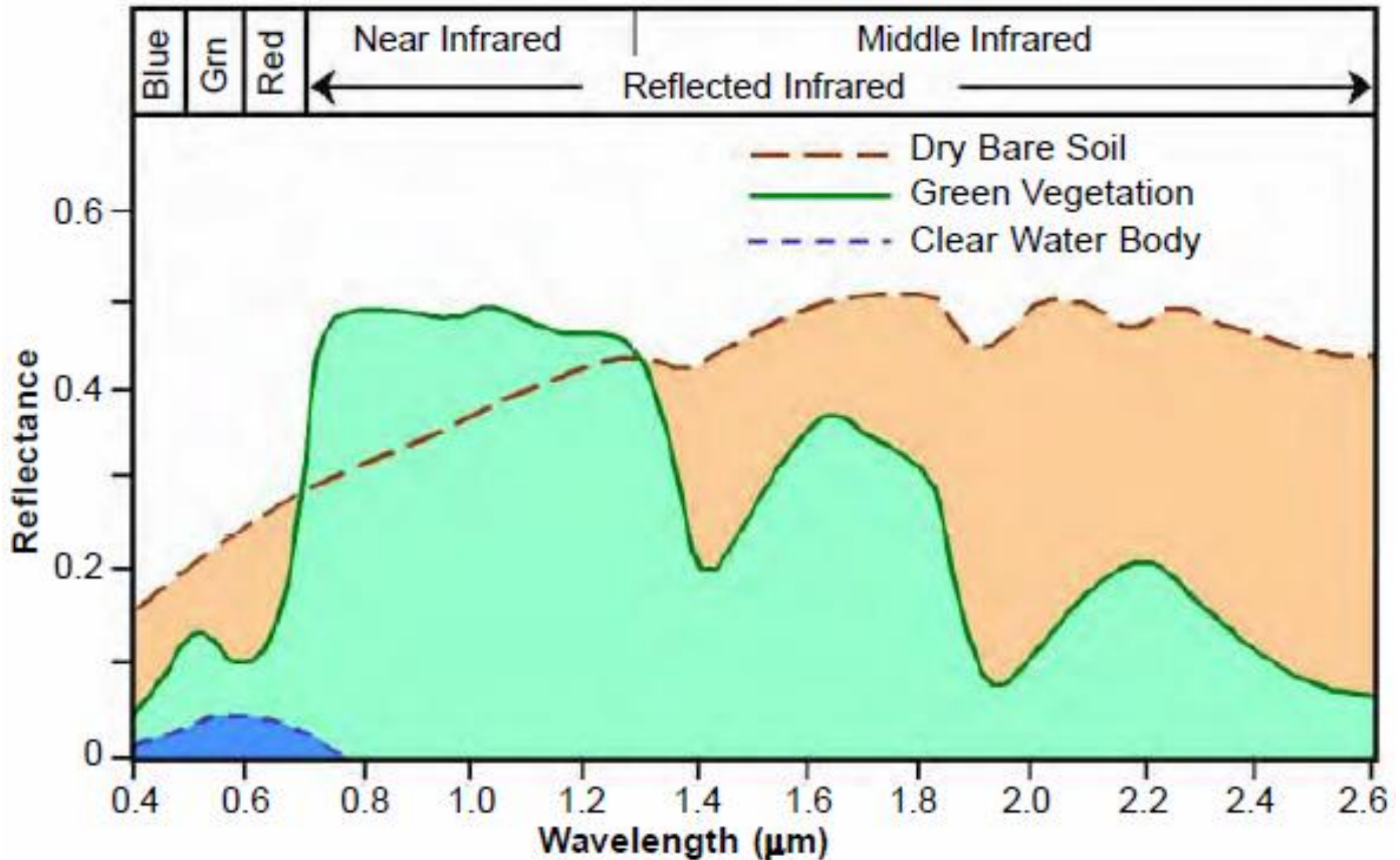
e.g. BC imap / GEOG357 labs (TM5-4-3)

Good distinction plus vegetation types

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

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
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

Prince George Landsat 5 (14 Sept 2011)   Band 6 - thermal-IR
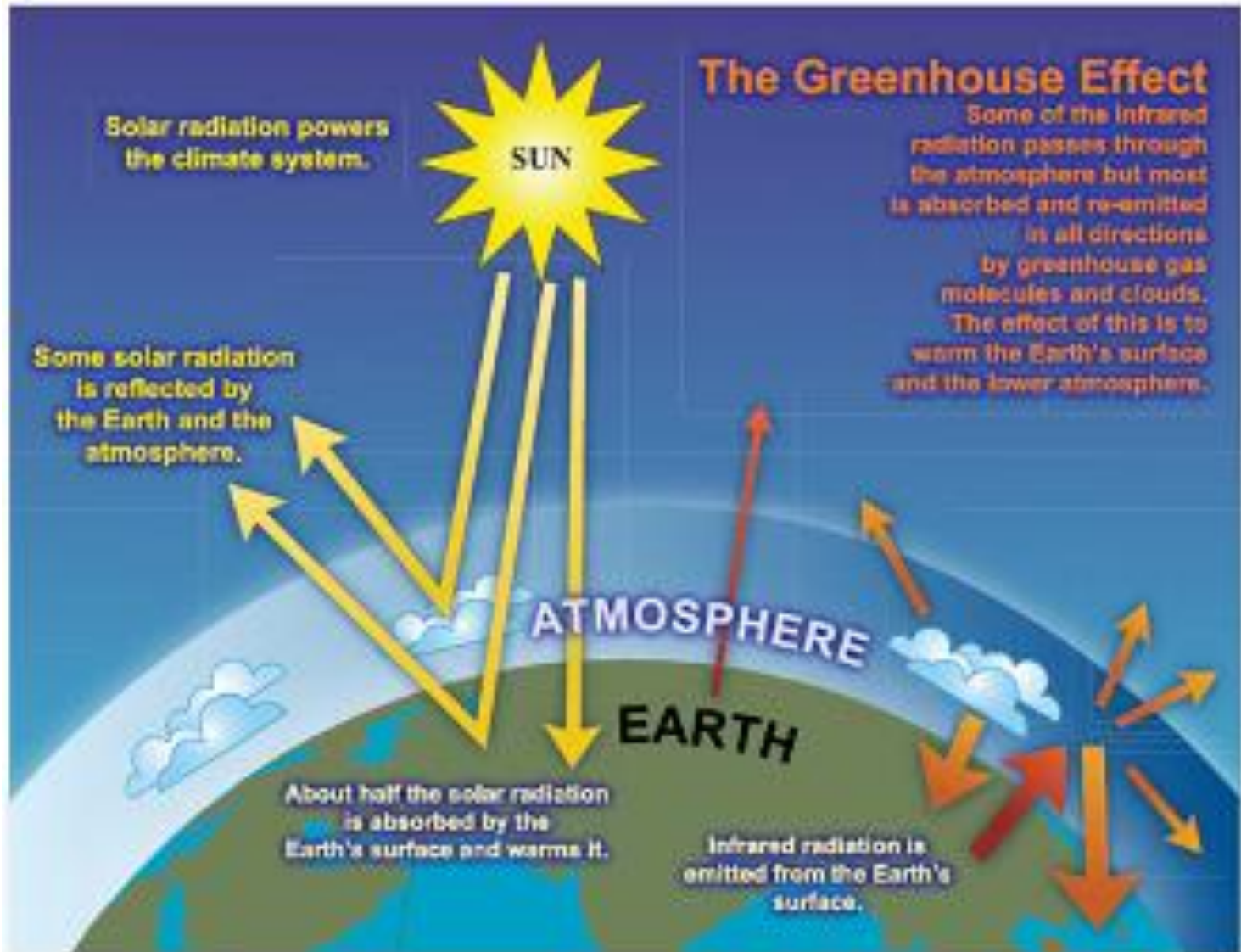
'Brightness temperature' – related to surface thermal qualities

Child found in cornfield, using thermal drone: https://www.bbc.com/news/videos/cwy4r1xn7l2o

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
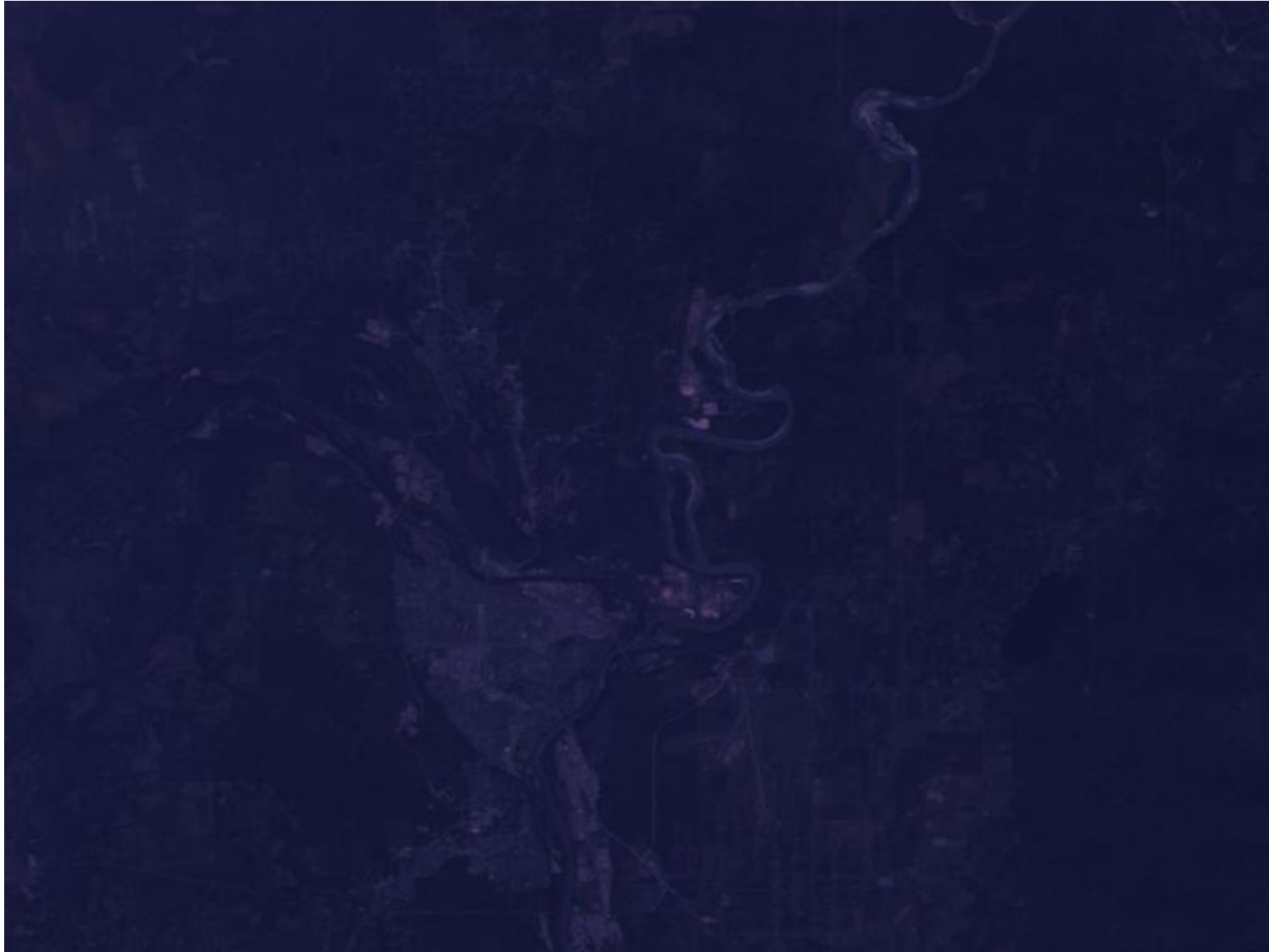   (reflected) = 'optical'

2. Thermal Infrared - emitted from earth - TIR
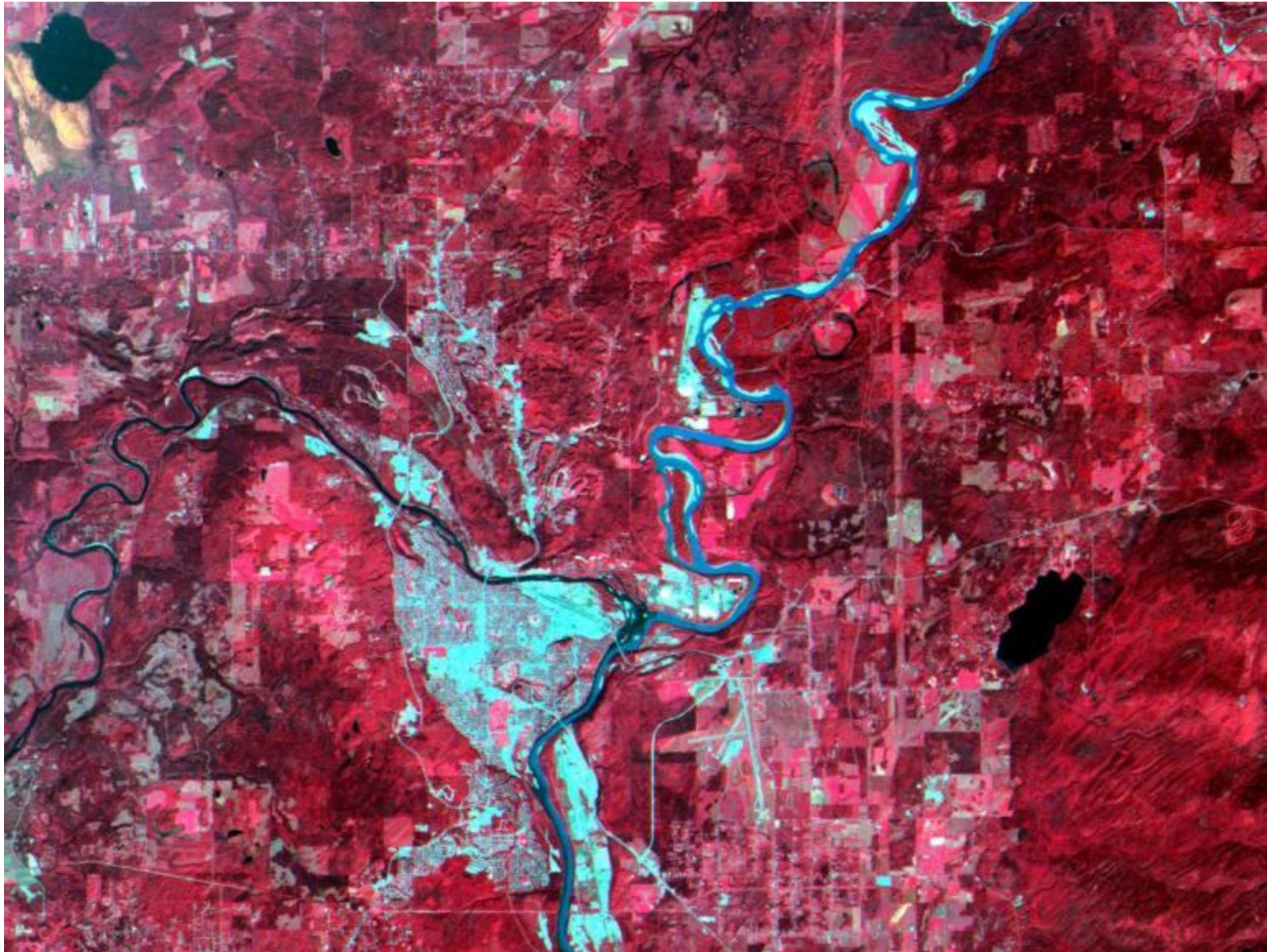
3. Microwave - emitted and cloud-free

These describe 'passive' remote sensing (most of the course),
but we will also learn about 'active' RS.
https://www.earthdata.nasa.gov/learn/backgrounders/remote-sensing

Image Unstretched – low contrast due to range of digital numbers

‘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