Very Basic
Geographical Information System & Remote Sensing Applications for the Environment

earthobservation.wordpress.com

Stuart Green

Teagasc

Stuart.Green@Teagasc.ie

Purpose

Give you a very basic skill set and software training so you can:

- find free image and mapping data.
- process and understand the data.
- produce a digital map

Just enough that knowledge so you are dangerous, but hopefully show you how little you do know!

31/2 weeks

Week 1

- **Monday 10-12** Lecture Introduction
- **Monday 1-4** Practical Finding data & making 1st Map

Week 2

- **Monday 10-12** How to interpret Images
- **Monday 1-4.** Digitising boundaries & Editing
- Processing Images for use and digitising

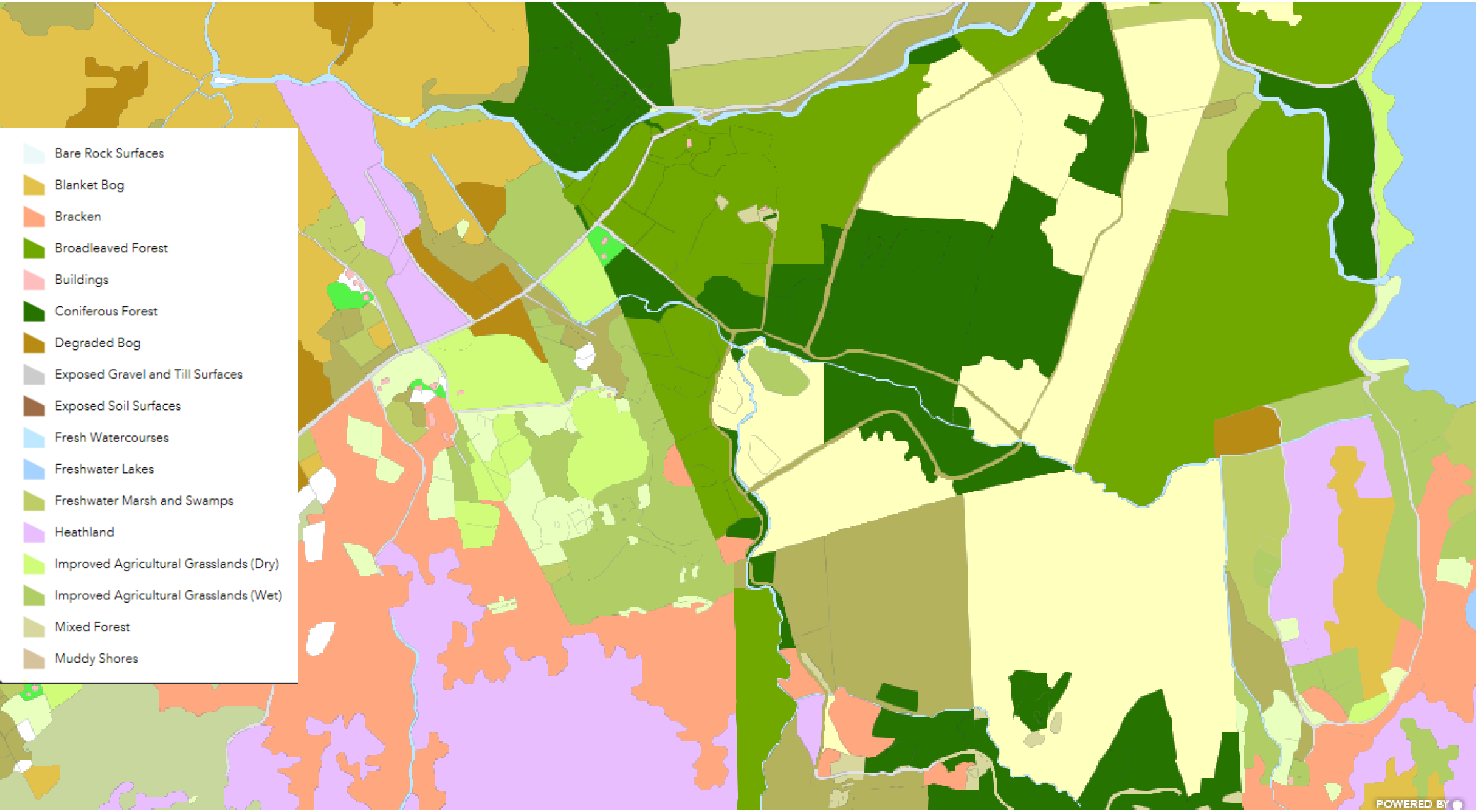
Week 3

- **Monday 10 -12** Lecture: Automatic Classification How to classify an image to make a map 2
- **Monday 1-4** Classifying

Week 4

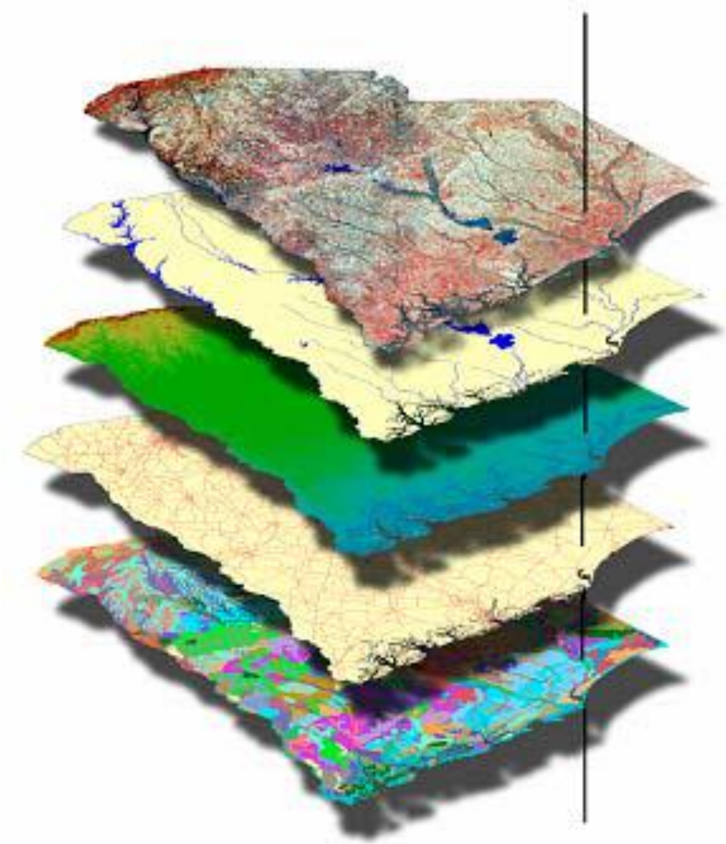
- **Tuesday 10-1pm-** Validating

Use GIS&RS to turn images into maps



http://www.arcgis.com/apps/webappviewer/index.html?id=32cb36ee28584e3b86e921f0af57036f&extent=-1100183.9743,6798892.9563,-1095960.8285,6801049.9137,102100

What is geospatial data?



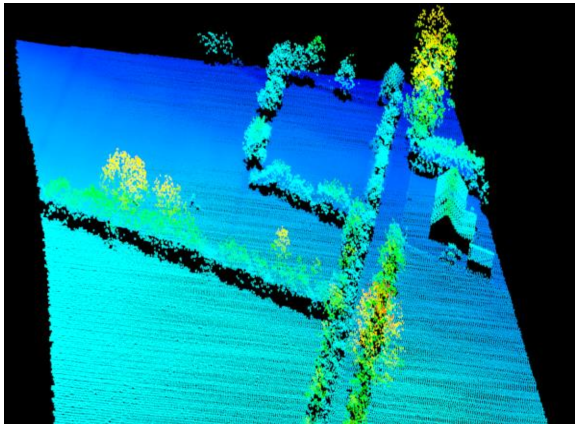
- Any data that can be ascribed to a place.
- Maps, GPS coordinates, addresses.
- Any sort of place- town, street, region, exact millimetre co-ordinates- The earth!

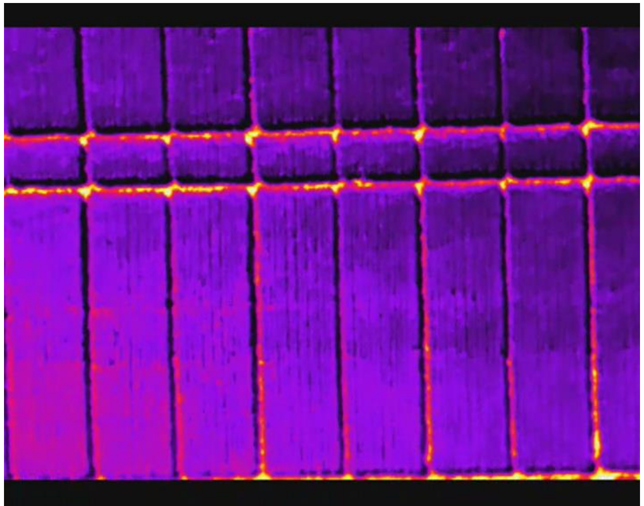
Remote Sensing is what?

"The science of telling something about an object without touching it"

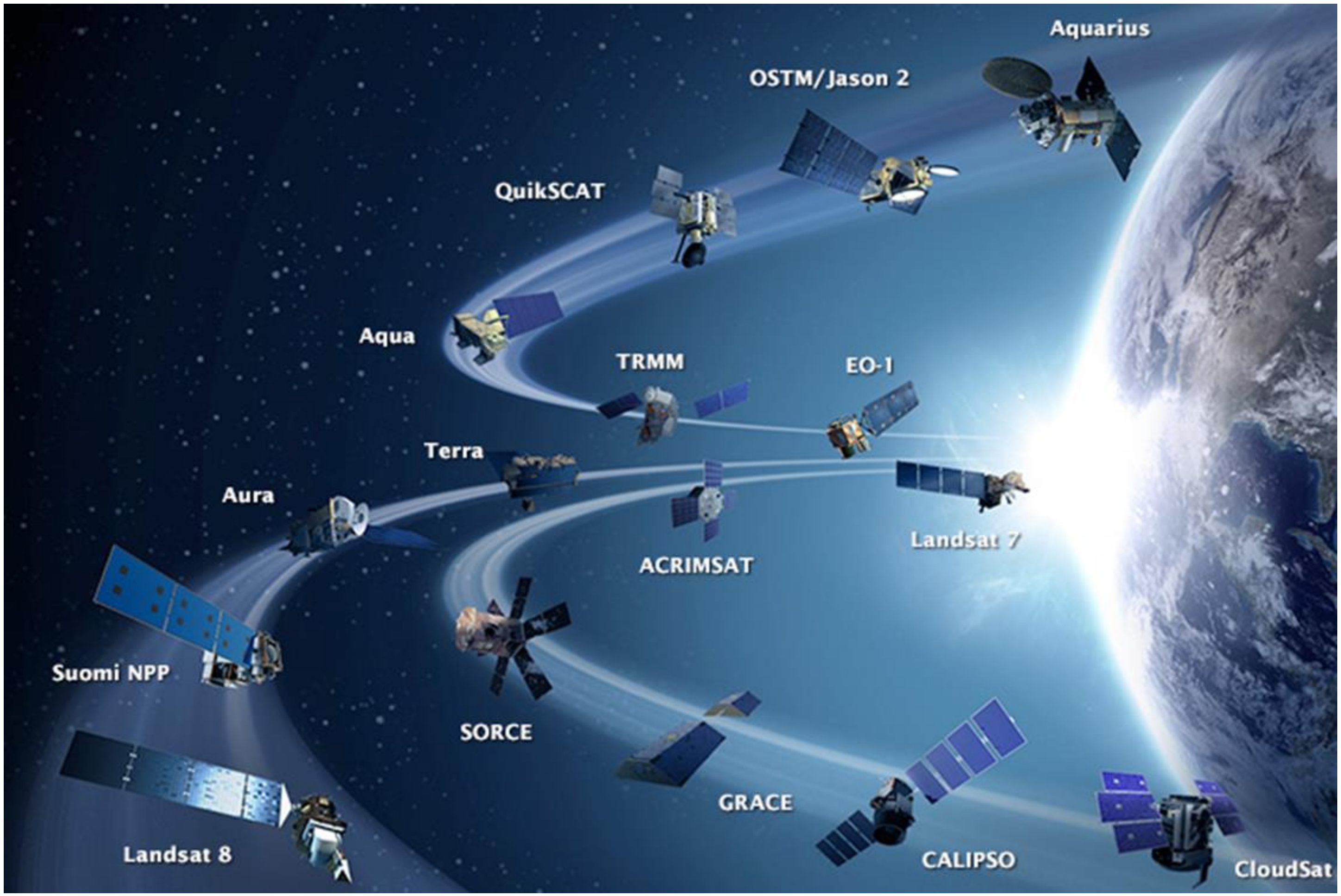
http://gisgeography.com/remote-sensing-earth-observation-guide/

- It's the use of images taken from above to tell us about the world. There are lots of ways to take pictures
  - Drones
  - Laser Scanning (LIDAR)
  - RADAR satellite images
  - Aircraft





But we will look at Orbiting Satellites used for **Earth Observation (EO).**

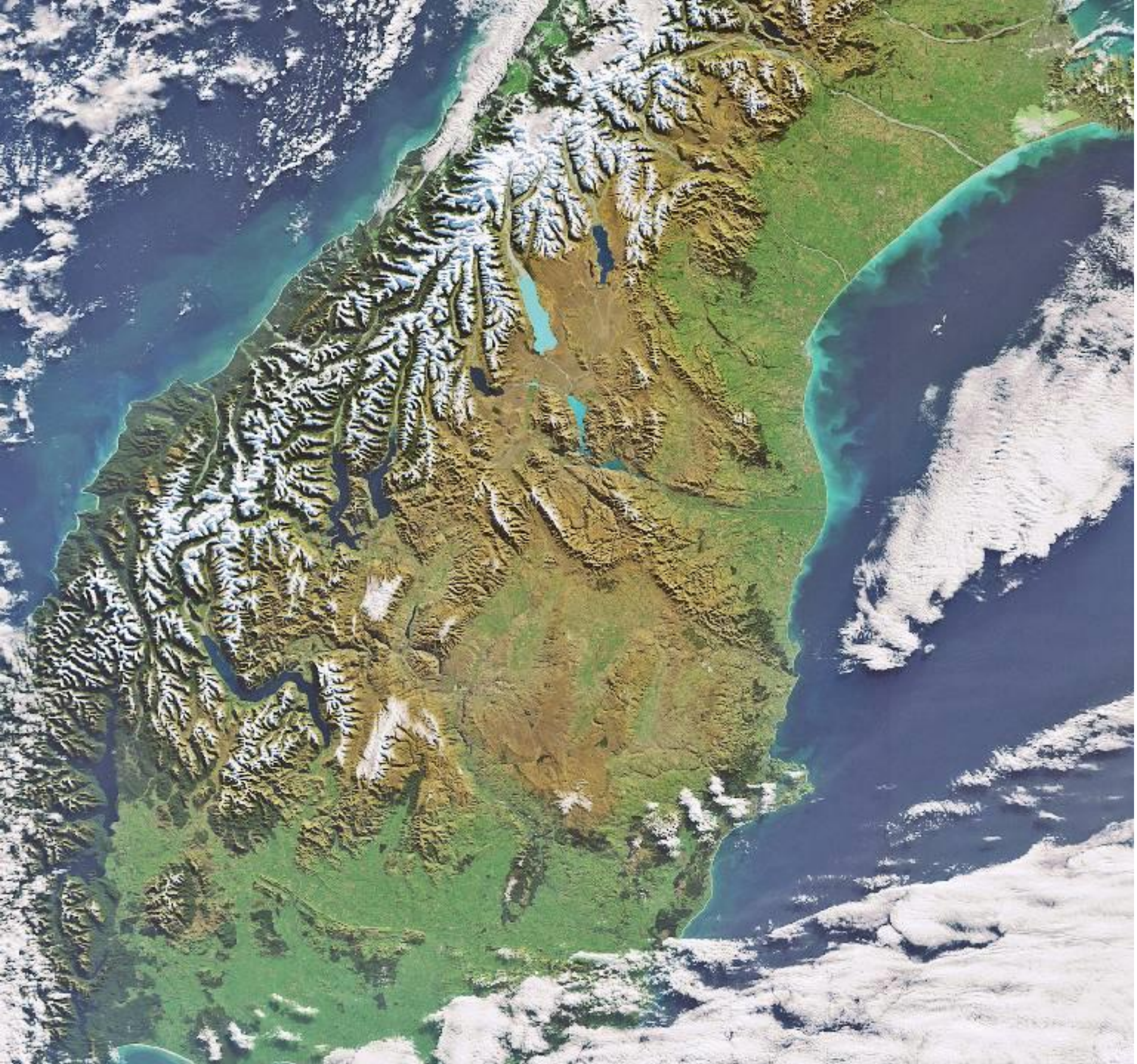


and specifically Multispectral Optical Imaging Sensors

What usefulness does EO bring?

- Wide overview
- Complete access
- Repeatability
- A different perspective

http://gisgeography.com/100-earth-remote-sensing-applications-uses/



What benefits does RS bring

- Wide overview
- Complete access
- Repeatability
- A different perspective

- http://staff.aub.edu.lb/~webeco/rs%20lectures.htm



What benefits does RS bring

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- Complete access
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30 July 2015

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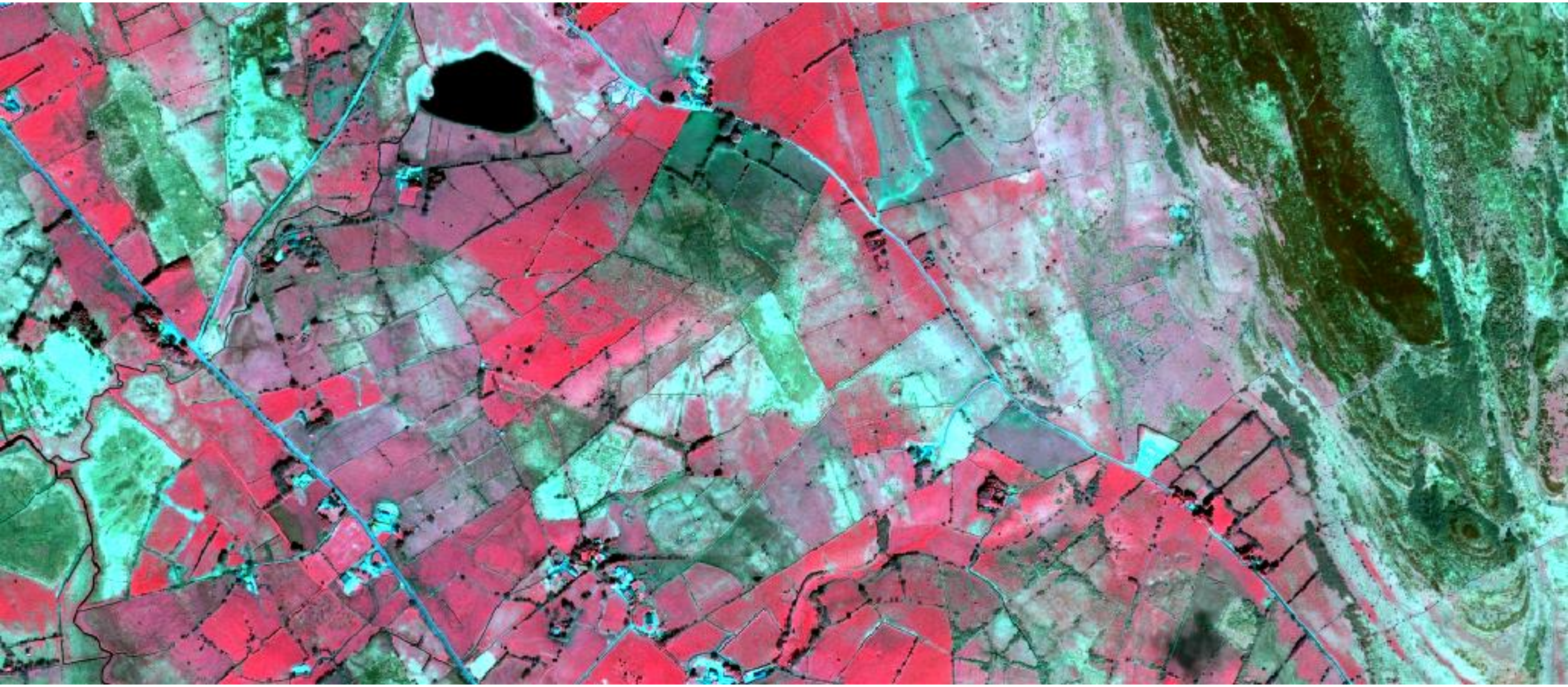
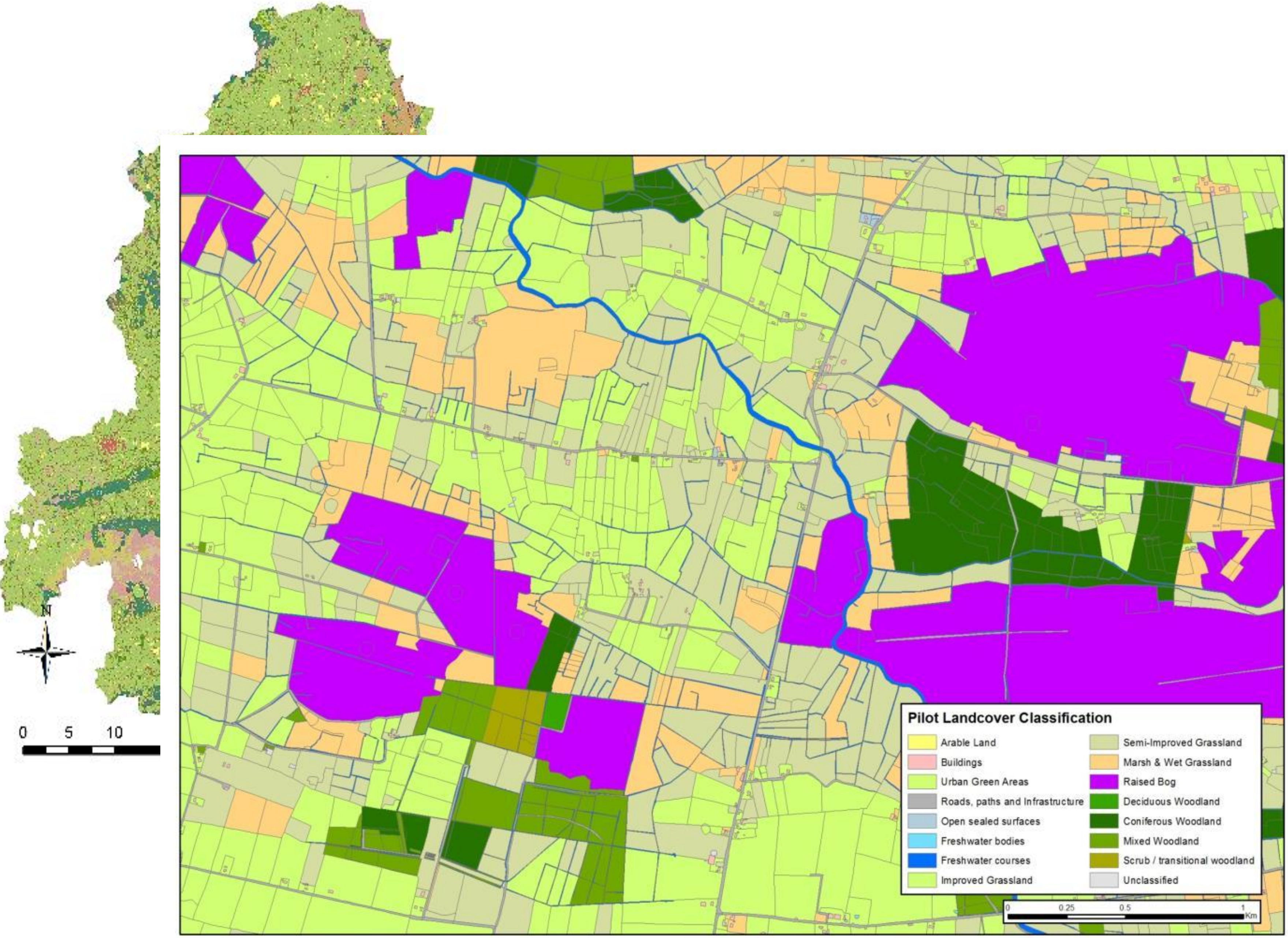


In short

- A new perspective
- Information that's not available in other ways
- A synoptic view
- The data is directly useable in GIS mapping systems

- Importantly EO mapping can be much cheaper than conventional field mapping.
- But its at its best when combined with field mapping to produce large scale, highly detailed maps of the environment quickly and cheaply


N
0 5 10
Pilot Landcover Classification
Arable Land
Buildings
Urban Green Areas
Roads, paths and Infrastructure
Open sealed surfaces
Freshwater bodies
Freshwater courses
Improved Grassland
Semi-Improved Grassland
Marsh & Wet Grassland
Raised Bog
Deciduous Woodland
Coniferous Woodland
Mixed Woodland
Scrub / transitional woodland
Unclassified
0 0.25 0.5 1
Km

Current Teagasc Capabilities with Remote Sensing

- Classify grass type (Improved. Semi-improved, wet, dry etc.) at field scale.
- Estimate grassland intensification.
- Estimate total Biomass (kg/DM/ha) at field/farm scale.
- Estimate Current grass growth rate (kg/DM/Ha/day) at farm scale.
- National estimates of relative grass performance to a benchmark – 1km scale.
- Delineate flooded areas with Sentinel 1A data.

Classify grass use at field scale.

Estimate total Biomass (kg/DM/ha) at 100m scale using sentinel 2 data.

Estimate Current grass growth rate (kg/DM/Ha/day) at 100m scale sentinel 2 data.

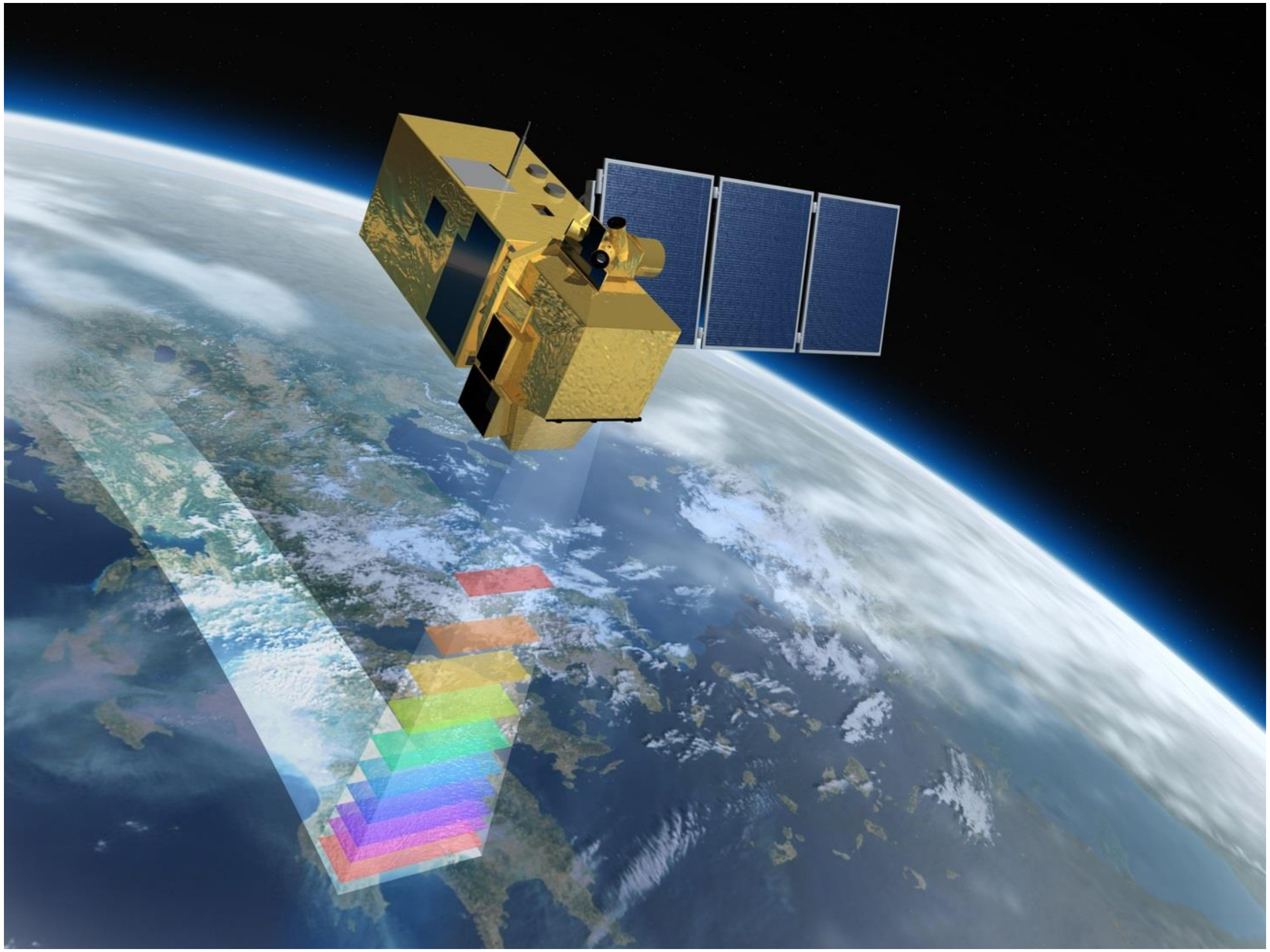
Calculate National Fodder Harvest at farm scale using Sentinel 2 and 1A.

Detect drained land using sentinel 2 and 1A.

- We will look at different remote sensing technologies over the coming weeks but, for now, just image all we will be doing for the next few lectures is looking at photographs!

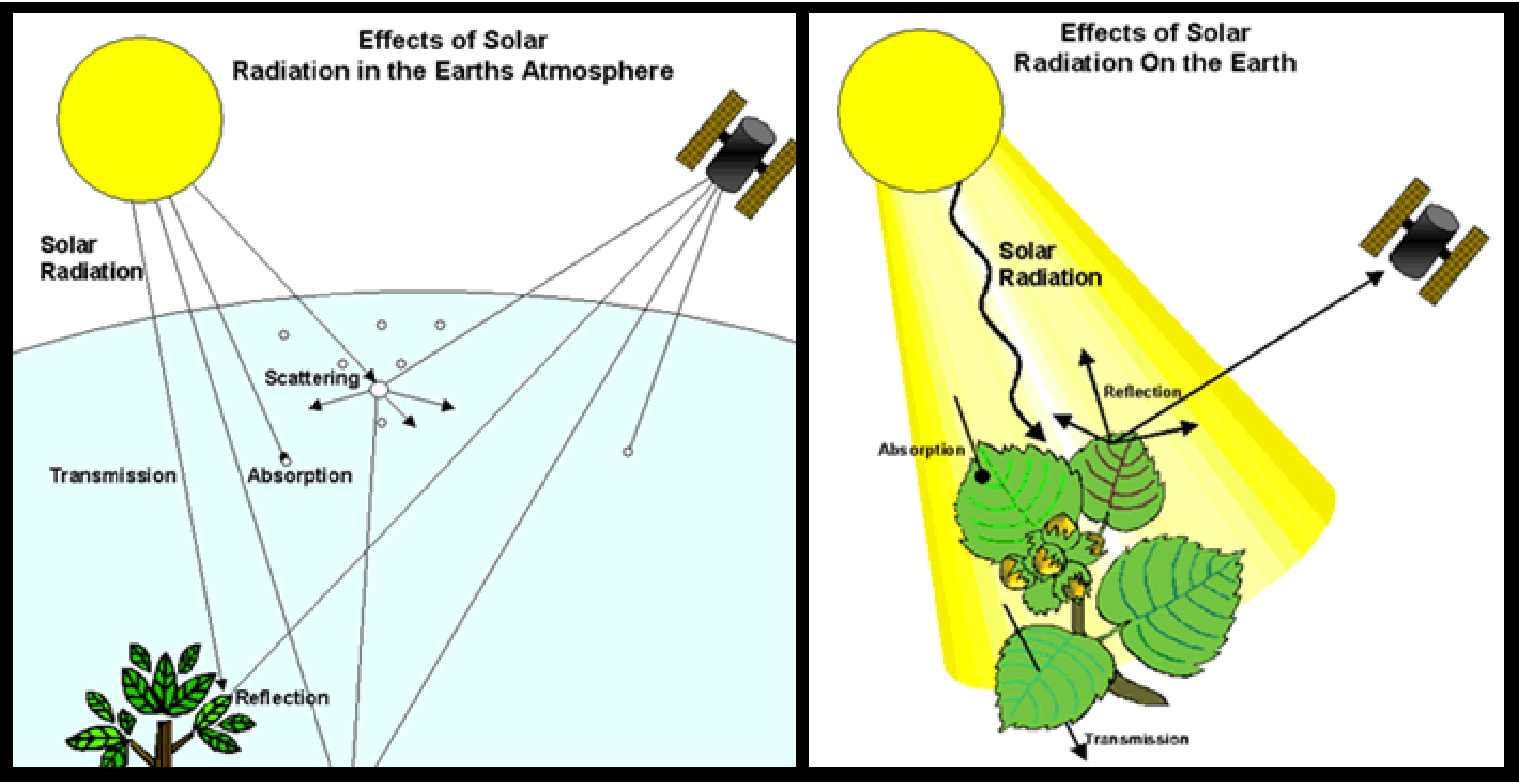
- But how are photographs, either film or digital, formed?

For now think of a satellite, like the new Sentinel 2 from ESA as a Giant Camera in Space orbiting the planet every 75mins



http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2

Taking a Picture from Space



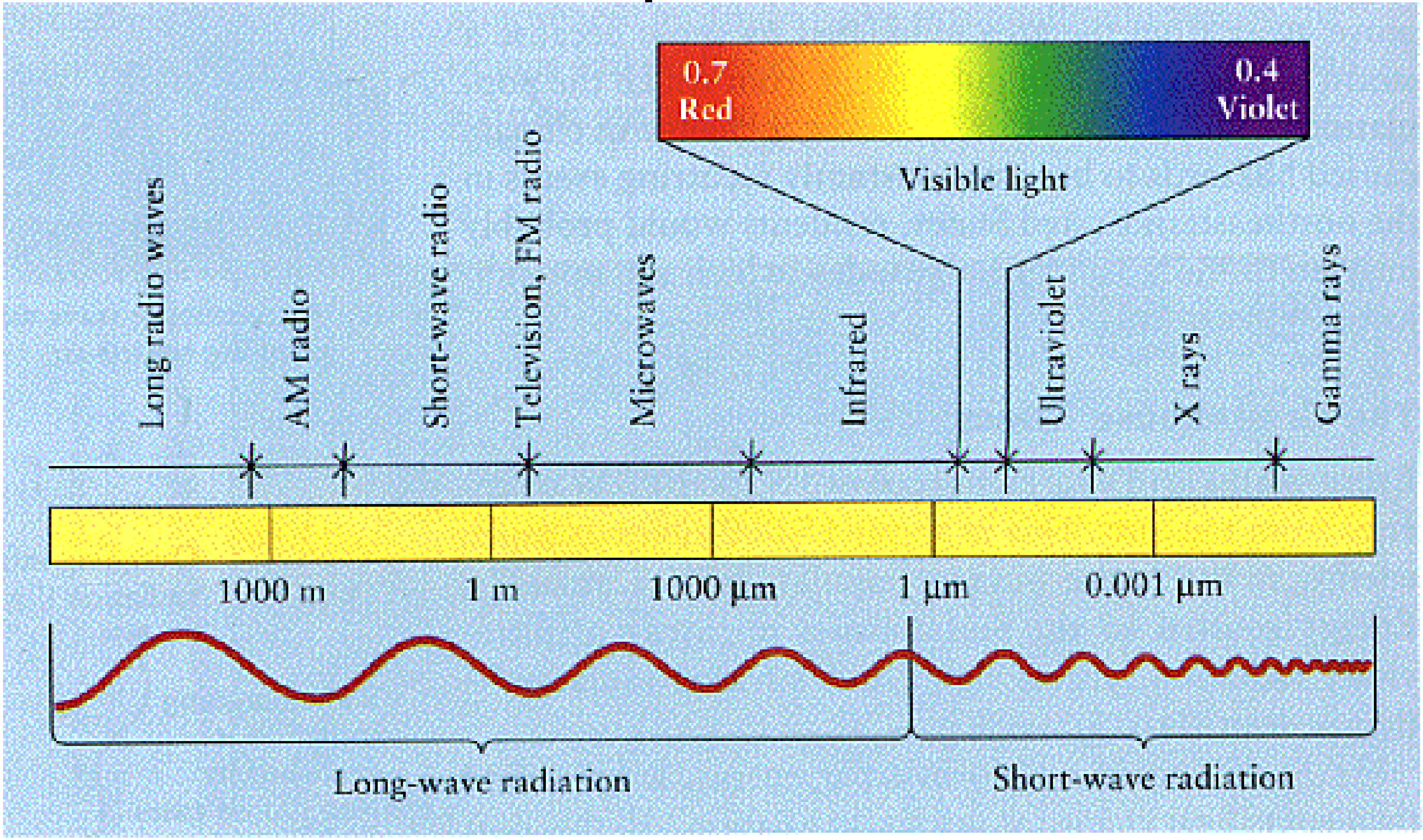
Kazakhstan's Alakol Lake in this Copernicus Sentinel-2 image from 5 April 2016.

We Rely upon

Electromagnetic Energy

- We are all familiar with EMR (even if we don't realise it!)
- Light, radio, microwaves – are all EMR and part of the Electromagnetic Spectrum

The spectrum



Properties of EMR

EMR can be thought of as little packets, or quanta, or Energy called *Photons*

Or as energy propagating as a wave

You can chose to think of light as either model:

- The machine gun model: Image the sun (or a laser pointer or a lamp) firing out little packets of energy that shoot through the sky and bounce of, or through or are scattered by objects

Or

- The radio model: Imagine the sun broadcasting waves of energy like a radio antenna that reflect, or transmit or are diffracted by objects

In both cases the amount of energy is determined by the wavelength
of the light involved and we can only see stuff because some of that
energy is bounced or reflected of an object into our eyes (or our
camera or our satellite imaging device)

All Electromagnetic radiation **(EMR)** travels at the speed of light

$$\mathbf{C=\lambda.\nu}$$

C speed measured in meters per second

n frequency measured in Hertz

λ wavelength measured in meters

$$E \propto \frac{1}{\lambda}$$

E is energy, measured in Joules and **λ** is wavelength measured in meters

$$\mathbf{E=\nu.h}$$

E is energy, measured in Joules and **h** is Planks constant

- Wave length is measured in nanometers *nm*

- *Blue light has a wave length of ~450nm*
- *Green ~550nm*
- *Red ~700nm*

What happens when a photon meets an object?

Absorption (A) occurs when radiation (energy) is absorbed into the target while transmission (T) occurs when radiation passes through a target. Reflection (R) occurs when radiation "bounces" off the target and is redirected. In remote sensing, we are most interested in measuring the radiation reflected from targets.

Absorption

- Absorption of radiation occurs when the atmosphere prevents, or strongly attenuates, transmission of radiation energy through the atmosphere. (Energy acquired by the atmosphere is subsequently re-radiated at longer wavelengths). Three gases are responsible for most absorption of solar radiation.
- O_3 High Atmosphere high energy short wavelength (ultra violet)
- Co_2 energy in the mid and far infrared regions of the spectrum
- H_2O extremely effective in several bands between 5.5– 7.0μm and above 27μm.

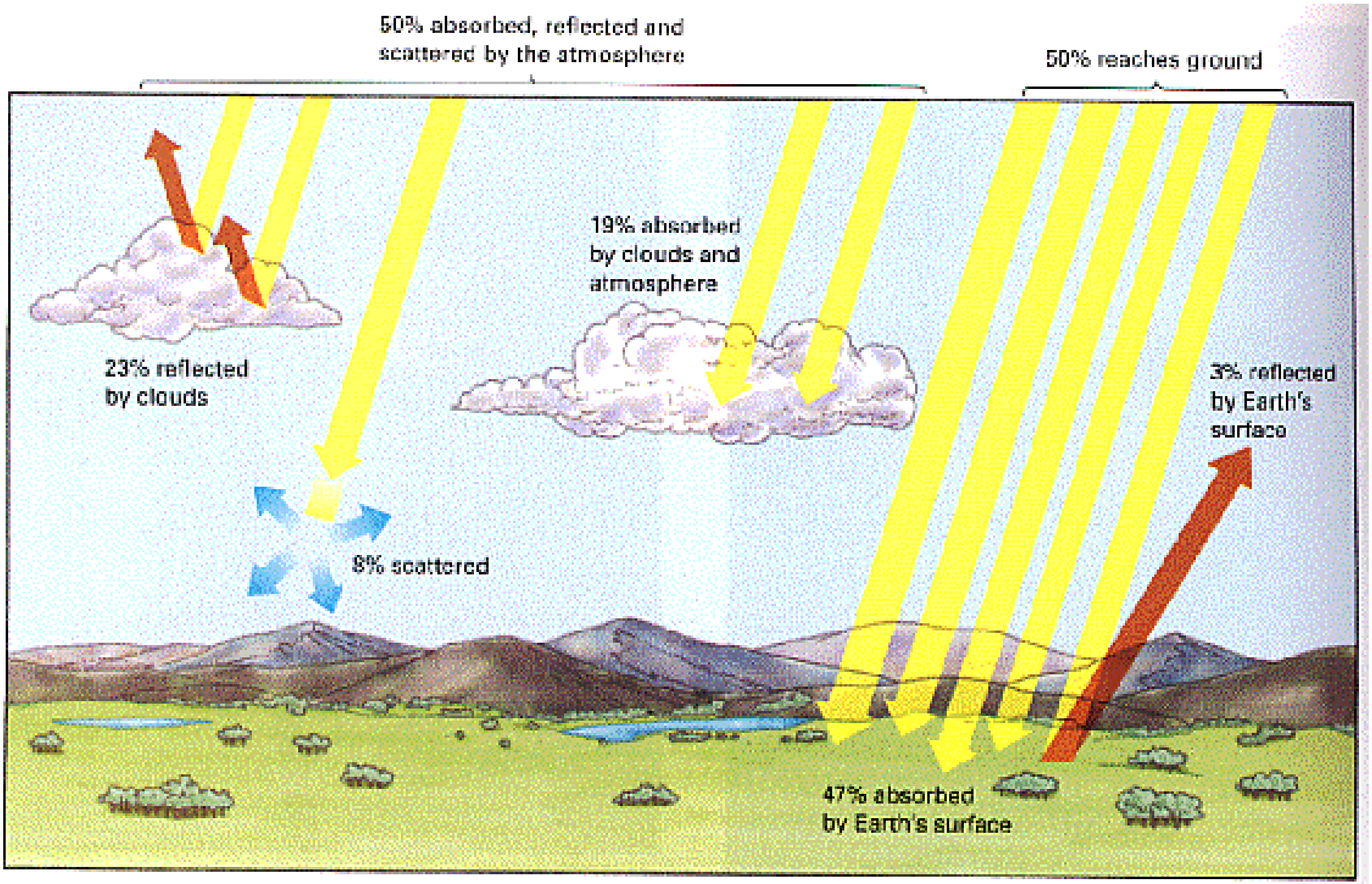
Scattering

- Rayleigh scattering occurs when atmospheric particles have diameters that are small relative to the wavelength of the radiation.
- Mie Scattering This is caused by particles larger than those responsible for Rayleigh scattering.
- Non Selective Scattering. Nonselective means that scattering is not wavelength dependent, so we observe it as whitish or greyish haze-all visible wavelengths are scattered equally.

Transmission

- Transmission of radiation occurs when radiation passes through a substance without significant attenuation.
- From a given thickness or depth of a substance, the ability of a medium to transmit energy is measured as the transmittance (*t*)

(t) = Transmitted radiation / Incident radiation


50% absorbed, reflected and scattered by the atmosphere
50% reaches ground
19% absorbed by clouds and atmosphere
23% reflected by clouds
3% reflected by Earth's surface
8% scattered
47% absorbed by Earth's surface

Spectral Properties of Objects

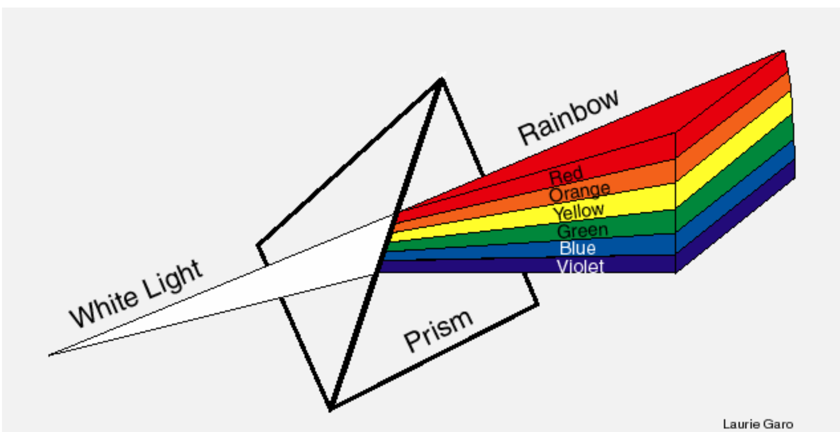
- *"Everything in nature has it's own unique distribution of reflected, emitted and absorbed radiation. These spectral characteristics can – if ingeniously exploited- be used to distinguish one thing from another or to obtain information about shape, size, and other physical and chemical properties"*

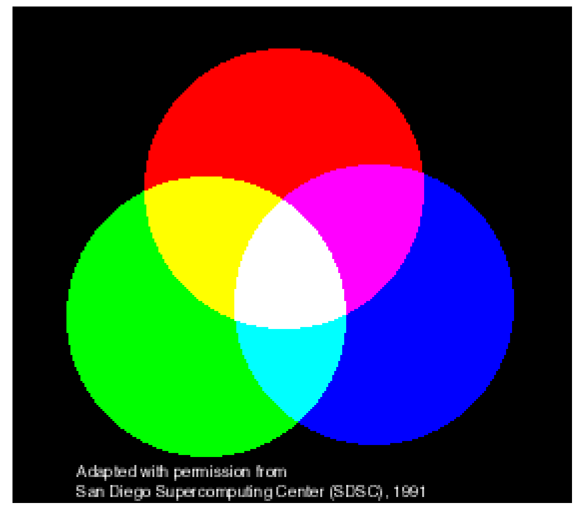
(Parker and Wolf, 1965, p21).

Colour!

Color as Light (Spectral Color)

The Electromagnetic spectrum consists of the spectral hues of light. Hue is the specific color, identified by a name, (e.g., red, blue, green, etc.) as they are the component wavelengths of white light. When combined together in equal amounts, they form white light. Color as Light is translucent, that is, we can see through the colors and can project colors over one another to form other colors





Reflected Color

Most surfaces are opaque (not transparent). These surfaces absorb and reflect different amounts of color from white light. Most of the colored objects we see on earth are made up of combinations of reflected wavelengths. Surfaces or objects illuminated by white light absorb differing proportions of visible wavelengths and reflect the remainder.

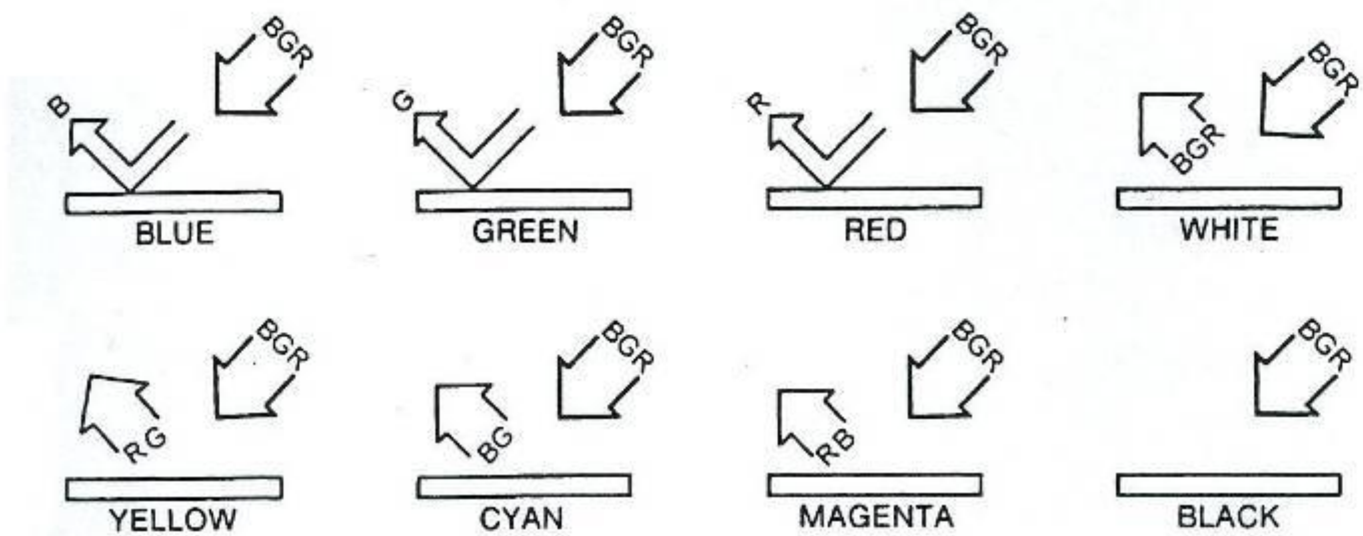


FIGURE 5 Colors.

Bet you didn't realise you'd be doing quantum mechanics...

Before we go any further we need to mention that these processes are generally **quantised** (not always so in the case of scattering).

What this means is that the processes occur a fixed discrete energy levels. In the macro world we live in filling a jug with water is a non-quantised process. If you need to fill a litre jug, then you can poor 100ml, then 50 then 600 and then the rest in order to fill the jug or if you have a 2l Jug you can poor half in to fill your 1l jug.

In a quantised world you can only fill a 1l jug with water from another 1 l jug in one go – you can't use small amounts to make up the total and you can't use just some of a bigger amount.

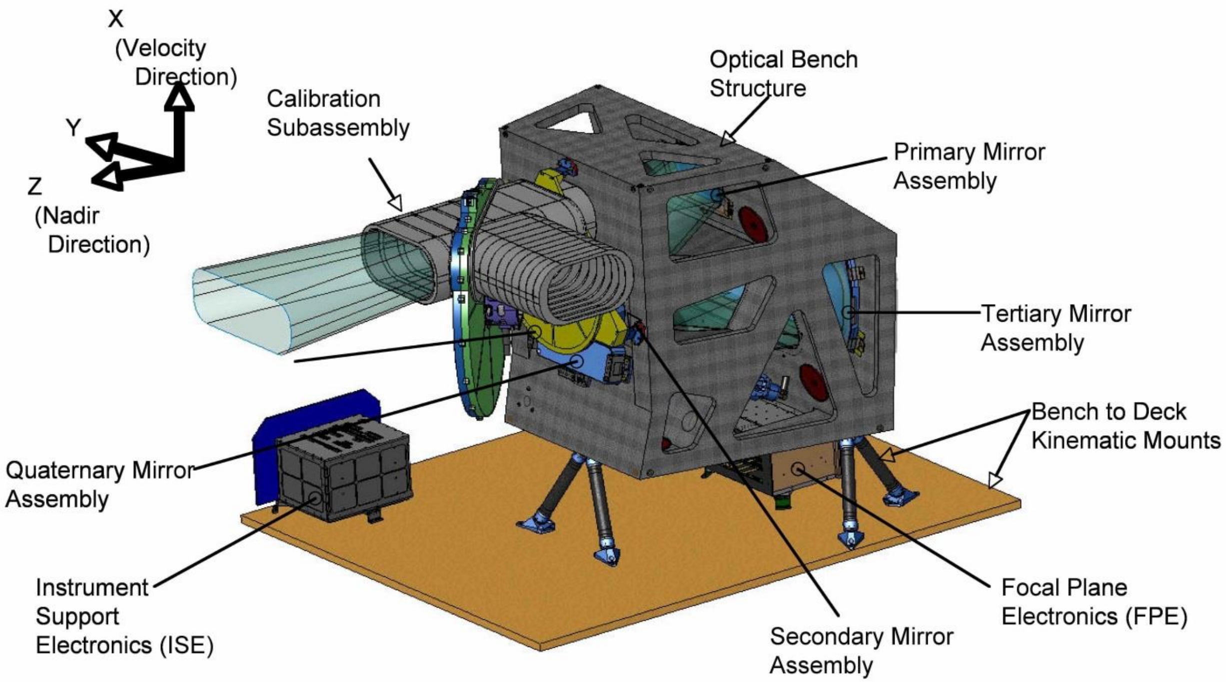
KEY CONCEPTS OF REMOTE SENSING.

- Spectral Differentiation.
- Remote sensing depends on observed spectral differences in the energy reflected or emitted from features of interest.
- Radiometric Differentiation.
- Remote sensing also depends on the ability to determine differences in the brightness of objects and features..
- Spatial Differentiation.
- Every sensor is limited in respect to the size of the smallest area that can be separately recorded as an entity on an image.
- Geometric Transformation.
- Remote sensing does not immediately produce images with accurate, consistent geometric relationships between points on the ground and their corresponding representations on the image.
- Role of the Atmosphere.

All energy reaching the remote sensing instrument must pass through a portion of the earth's atmosphere. In doing so, the sun's energy is altered in intensity and wavelength by particles and gases in the earth's atmosphere. These changes appear on the image in ways that degrade image quality or influence the accuracy of interpretations.

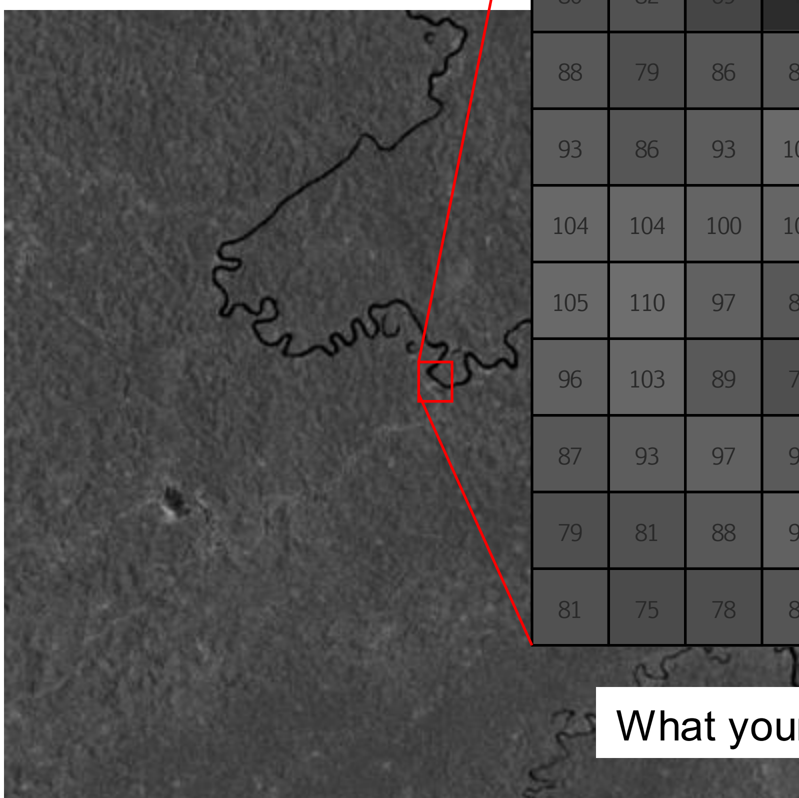
So sun light is reflected form the earths surface, interacts with the atmosphere and is then “Captured” by the satellite sensor as an image.

OLI Instrument Overview



What Is A Digital Image?

Digital Number (DN)

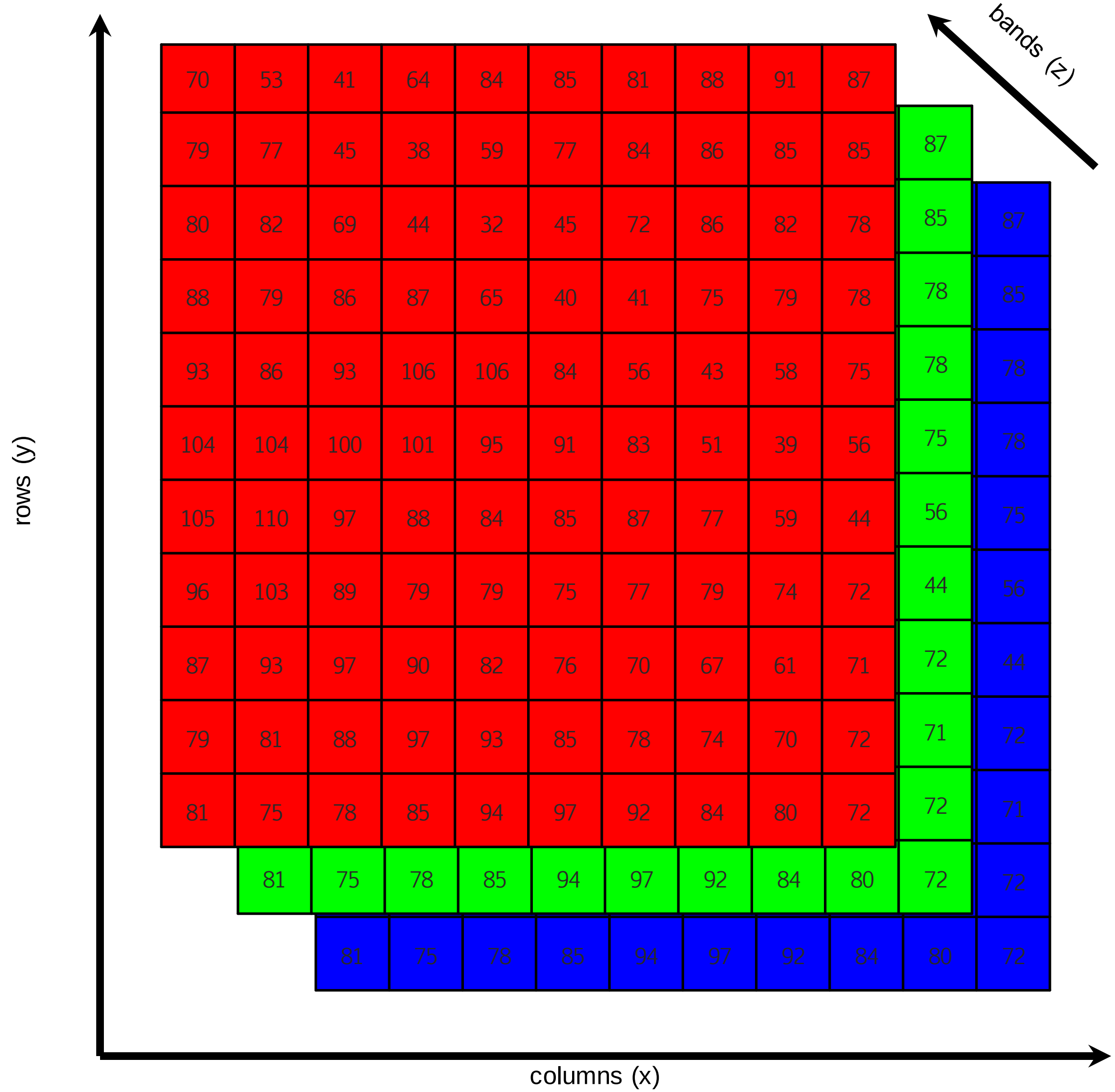


70	53	[illegible]	64	84	85	81	88	91	87
79	77	45	38	59	77	84	86	85	85
80	82	69	44	32	45	72	86	82	78
88	79	86	87	65	[illegible]	[illegible]	75	79	78
93	86	93	106	106	84	56	43	58	75
104	104	100	101	95	91	83	51	39	56
105	110	97	88	84	85	87	77	59	44
96	103	89	79	79	75	77	79	74	72
87	93	97	90	82	76	70	67	61	71
79	81	88	97	93	85	78	74	70	72
81	75	78	85	94	97	92	84	80	72

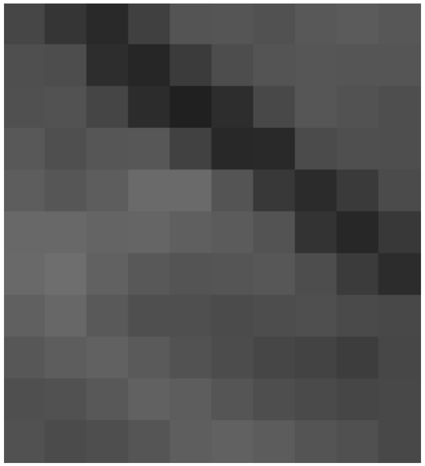
What your computer sees…

Digital numbers (DNs) typically range from 0 to 255; 0 to 511; 0 to 1023, etc. These ranges are binary scales: 2^8=256; 2^9=512; 2^{10}=1024.

What Is A Digital Image?

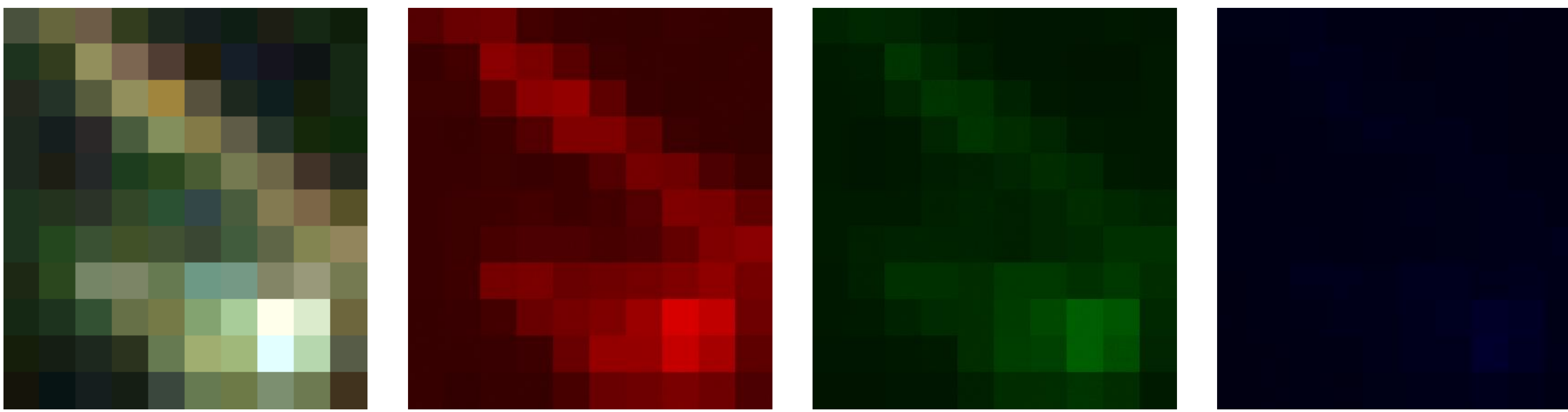


Greyscale vs. RGB

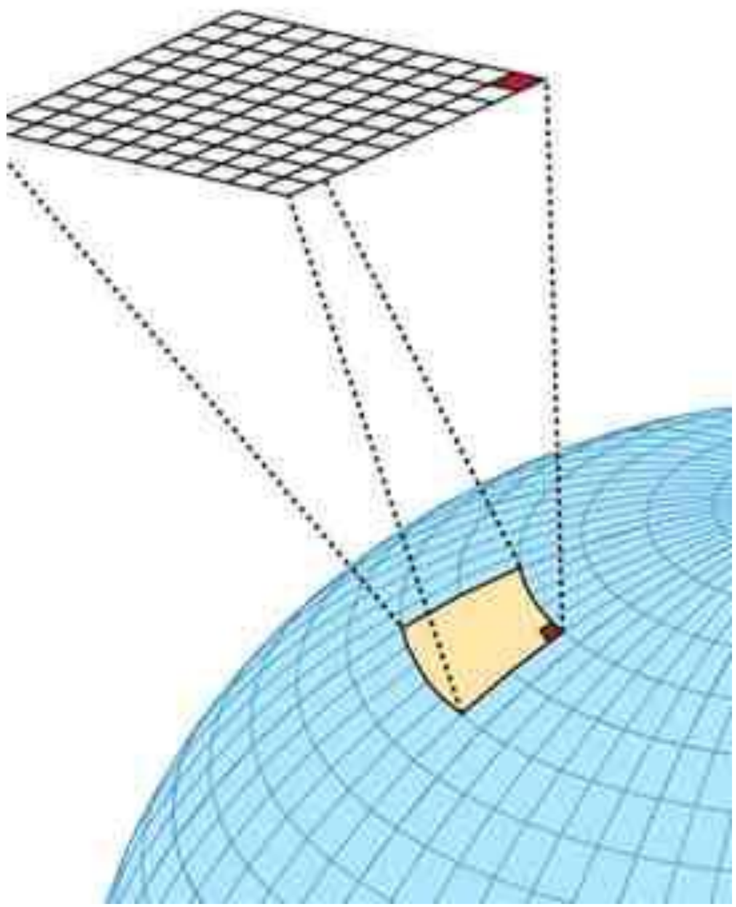


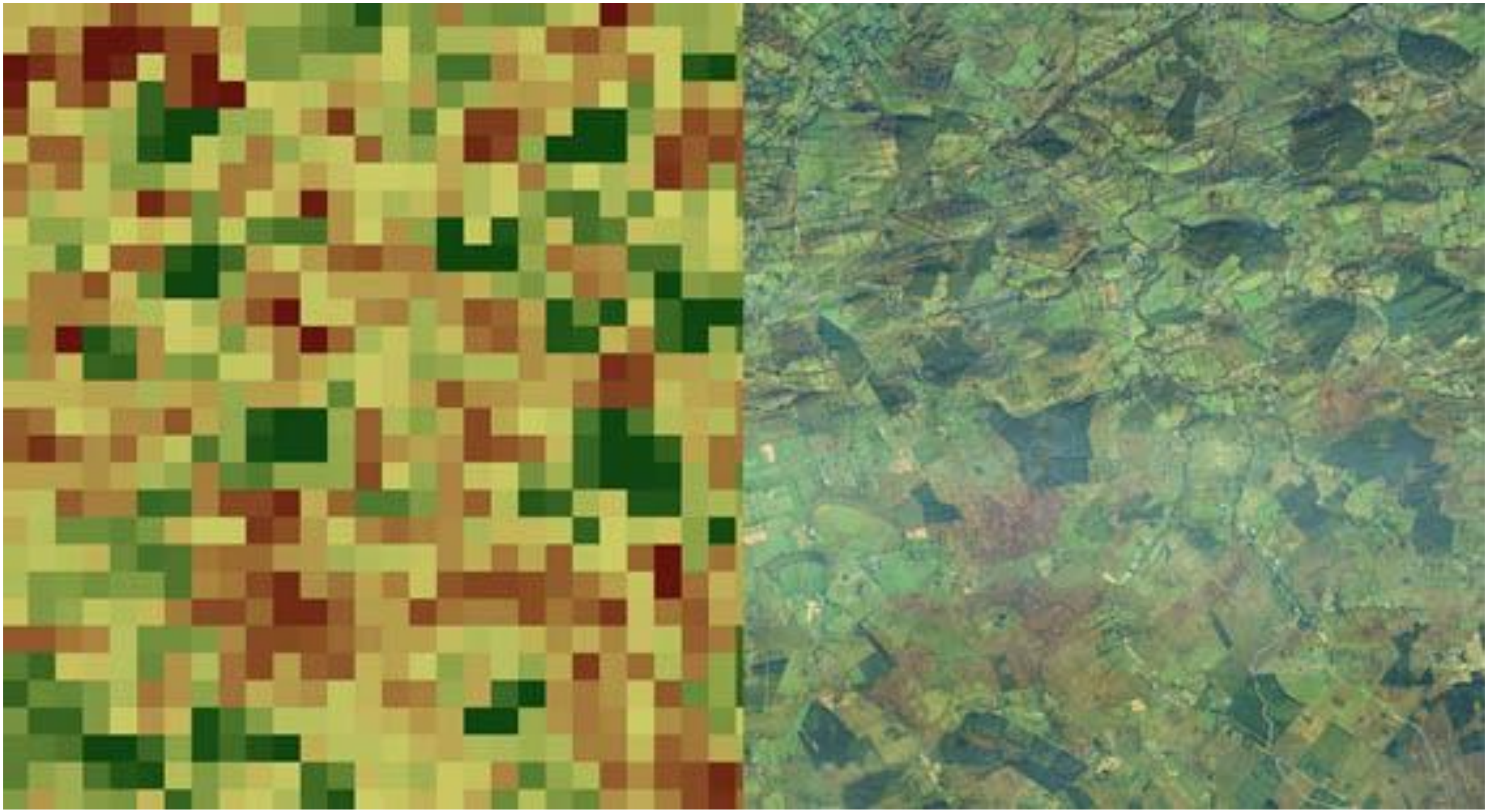
Greyscale is typically used to display a *single band*…

…while **RGB** (“Red”, “Green”, “Blue”) images can display *3 bands*



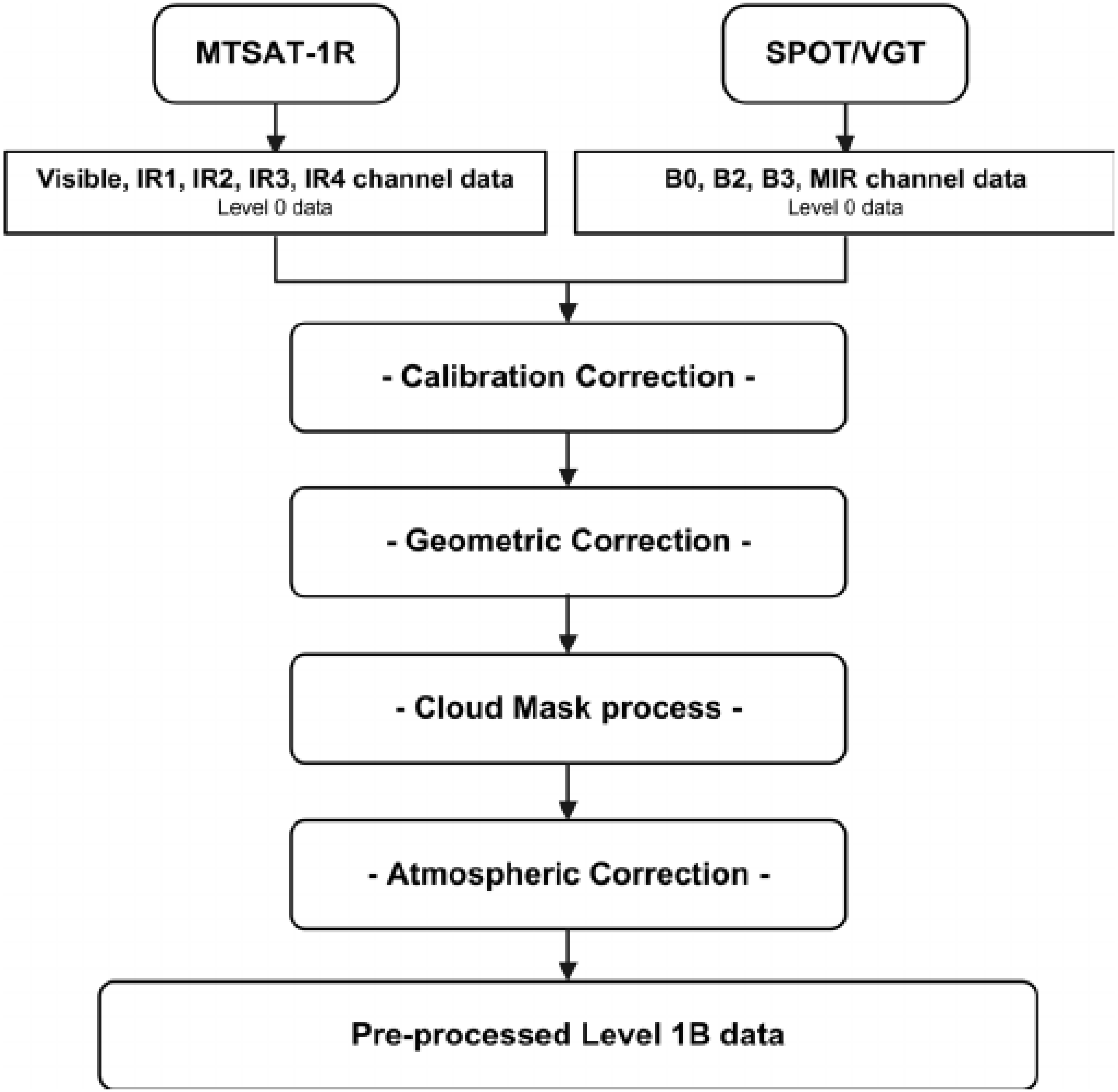
Its best to think of the satellite output not as a “image” but as a square array of samples (the pixels) of the reflected surface light.





Data Visualization

- A digital number in a satellite image has no intrinsic visual display meaning to the computer.
- Based on some predefined algorithm, the computer adjusts the brightness on the screenas a function of the pixel value. This function can take a wide range of forms.
- Typically, lower pixel values are displayed as “dark” and higher pixel values are displayed as “bright”.
- Important to remember: while there is no limit to the number of image bands, there is a limit to the number a monitor can display at once.

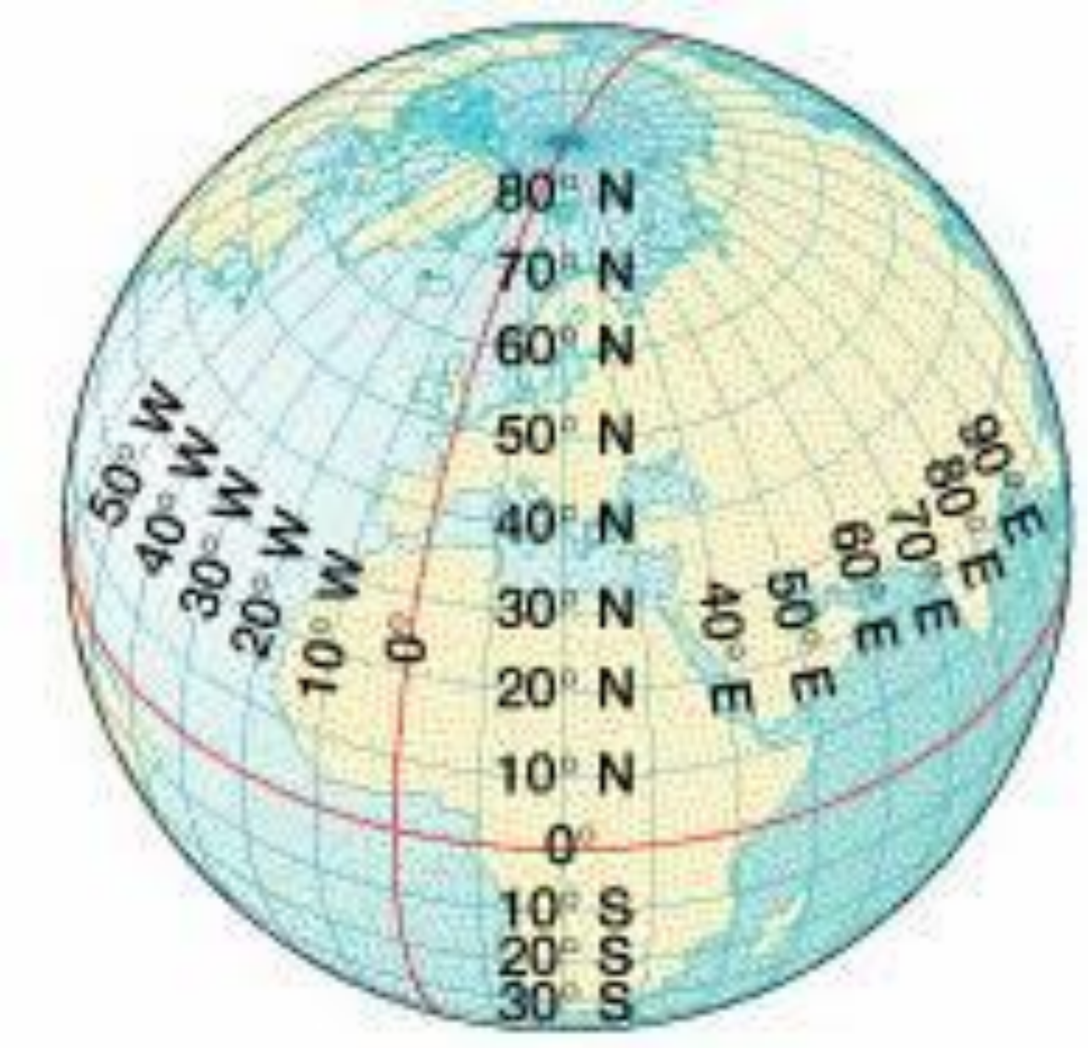


https://geospatialworldforumorg/2011/proceeding/pdf/sreenivas.pdf

Taking a “photo” from above always introduces distortions.

Making a 2D map of the world always creates distortions.

Latitude and Longitude.



http://www.physicalgeography.net/fundamentals/2a.html

Latitude.

- Halfway between the poles, at the earth's fattest we imagine a line round the earth, the equator, which divides it exactly into two halves.

- A series of equidistant circles drawn round the globe with the poles as centre decreasing in size from the largest circle (equator) towards the pole, provide a system of reference lines to establish the distance of any point north or south of the equator.

- These **lines** are parallel to each other and to the equator; they are, therefore, called **parallels**.

- **Angular distance** north or south of the equator is called **latitude**. For reference the parallels of latitude are numbered from 0-90 on each side of the equator, the equator being 0 and the poles being 90 on each side.

Longitude.

- Another set of lines around the globe can be constructed to intersect the parallels of latitude at right angles; these lines run north and south.

- They are semi-circles, all of them the same size, with the centre of the earth as their centres.

- These semi-circles converge at the poles and divide up the earth rather like the segments of an orange. These **lines** are called **meridians**. If we look down on the globe from the poles, they appear to radiate out from each pole to the equator.

- If one meridian is chosen and numbered zero, and the others are then consecutively to the left and right (west and east), it is possible to determine how round the world a place is from the zero meridian by quoting the meridian reference. **Angular distance east and west** of the zero meridian is called **longitude**.

Latitude and Longitude.

- Before considering how this system of reference works, the units of measurement must be understood.
- We are dealing with a globe and distance along the circumference of circles, we use angular measurement, the basic unit of which is the degree. A circle is made up of 360 degrees; a degree is divided into 60 minutes (') each minute into 60 seconds (").
- Parallels of latitude are numbered according to their angular distance from a line drawn from the centre of the globe to the equator. Thus a parallel of 40° latitude means that a line drawn from that parallel (north or south of the equator) to the centre of the earth will form an angle of 40° with the line from the centre of the earth to the equator.
- As the distance from either pole to the equator is one quarter of a full circle, the angular distance from equator to pole is nowhere greater than 90°. The parallels of latitude are, therefore numbered from 0-90 both north and south. The north pole is 90° north latitude, the south pole is 90 ° south latitude. Because latitude can have the same value north and south of the equator, the direction N or S must be given with the degree of latitude, viz: 45 ° N or 45 °S.

Latitude and Longitude.

- A full reference to the location of any place in the world can be given by stating the degree values of the parallel and the meridian which intersect at that point; in other words, by giving the latitude and longitude of the place. The map reference for each place on the earth's surface is unique. The indexes of most atlases give the location of places shown in the maps by latitude and longitude references.
- .

That's all well and good when dealing with a globe

Transforming this 3D object into 2D **ALWAYS** introduces errors. Imagine trying to tear and squash a tennis ball so that it lies
perfectly flat - cant be done. And all our images are Flat! .

What is a Datum?

The Earth is shaped like a flattened sphere. This shape is called an ellipsoid.

A datum, or *reference ellipsoid*, is a mathematical model of the earth that is used in mapping.

The datum consists of a series of numbers that define the shape and size of the ellipsoid and it's orientation in space.

A datum is chosen to give the best possible fit to the true shape of the Earth often for a particular location

Projections

A method by which the curved surface of the earth is portrayed on a flat surface. This generally requires a systematic mathematical *transformation* of the earth's graticule of lines of longitude and latitude onto a plane.

It can be visualized as a transparent globe with a light bulb at its center (though not all projections emanate from the globe's center) casting lines of latitude and longitude onto a sheet of paper. Generally, the paper is either flat and placed tangent to the globe (a planar or azimuthal projection) or formed into a cone or cylinder and placed over the globe (cylindrical and conical projections).

Every map projection distorts distance, area, shape, direction, or some combination thereof. This is sort of like taking a tennis ball and cutting it up so it will lay flat on a table. There are many different ways to this and all will leave some distortion as they will not all lay perfectly flat and still align up with each other

http://www.city-sheridan-wy.com/info/pwd-pd-gis/intro.php

Any map projection must be based on some geometrical and/or mathematical model or representation of the Earth's surface.

The Earth is often thought of as a ***sphere***. In reality, there is a slight flattening of the Earth at the poles, and a slight bulging of the Earth at the Equator. Technically, the Earth is an ***ellipsoid***.

Ellipsoids which approximate a sphere, such as the Earth, are also called *spheriods*.

Datums are simply a reference for modeling the Earth's surface based on some definition of the spheroid.

The new national mapping system: Irish Transverse Mercator

	IG	ITM
Reference Ellipsoid	Airy (modified)	GRS80
Central Meridian	8° West	8° West
Scale on CM	1.000 035	0.999 820
True Origin ø λ	53° 30' North 8° West	53° 30' North 8° West
False Origin	200 000 W 250 000 S	600 000 West 750 000 South

https://en.wikipedia.org/wiki/Irish_Transverse_Mercator

Finding sources of satellite information

- https://scihub.copernicus.eu/dhus/
- http://earthexplorer.usgs.gov/
- http://www.class.ncdc.noaa.gov/saa/products/welcome
- https://earthdata.nasa.gov/
- http://landcover.org/

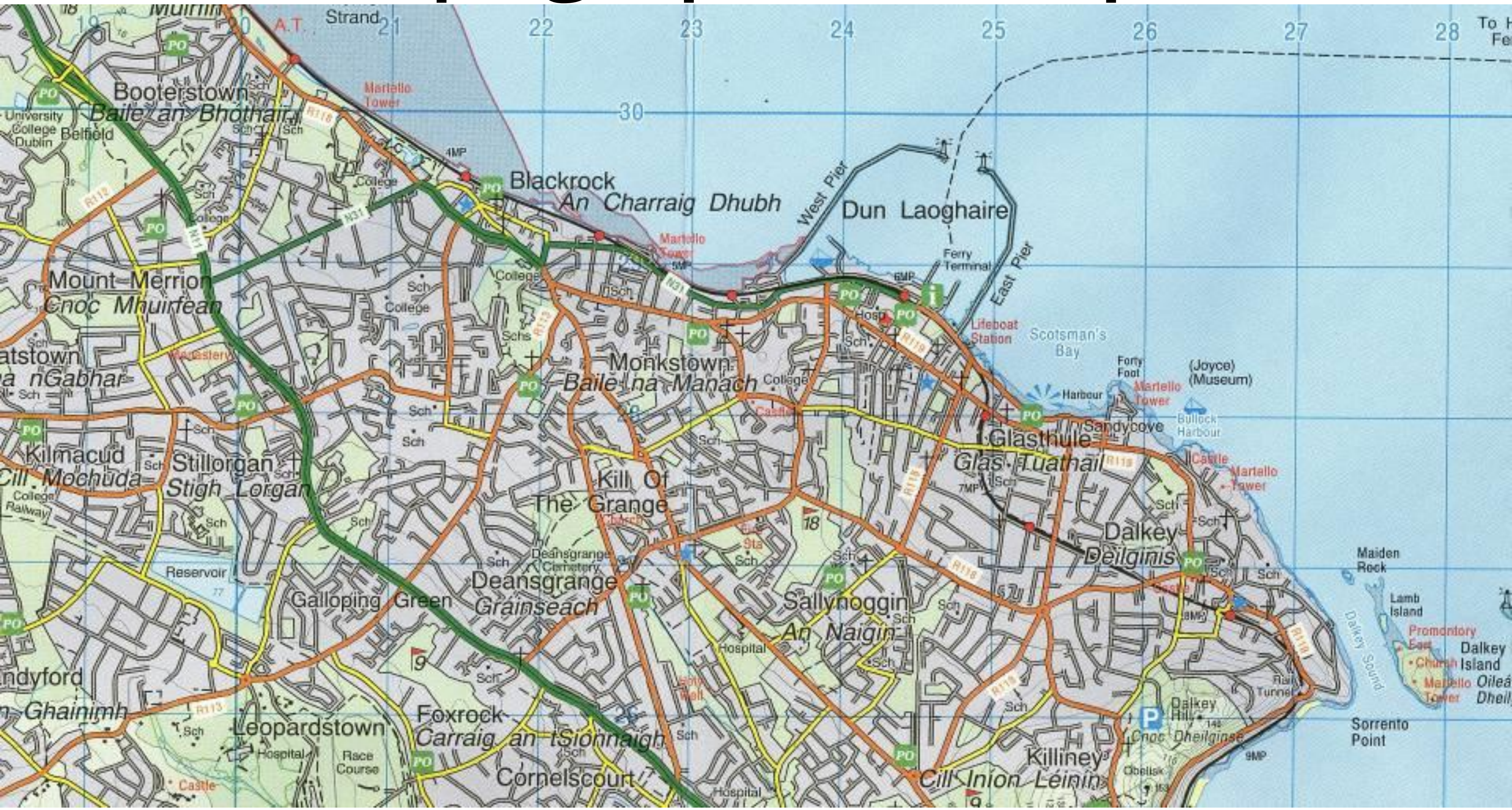
PHYSICAL AND CULTURAL MAPS

- Atlas Maps
- These are usually drawn to show only principal features such as the shape of landmasses, main mountain ranges, larger rivers, international boundaries, large towns and cities, main railways and roads. These maps usually portray large areas and, while useful when considering countries as a whole, provide little detailed information about the parts or regions of a country.

Topographical Maps

- Topographical maps are maps which depict in detail the surface features of an area, including relief (normally by means of contour lines) and physical features as forests, rivers and lakes. They also show man-made features such as towns, villages, roads, railways, canals, bridges and some aspects of land-use. These maps give much more detail than atlas maps because they are larger in scale.

Topographical Maps



Cadastral Maps

- Cadastral Maps are maps drawn to show an area in great detail. Because of this, the area shown on one sheet is usually much smaller than the area shown on a topographical sheet of the same size. There are hardly any features that cannot be shown on this type of map. They are therefore different from topographical maps, for on a topographical map much detail has to be omitted to avoid crowding and confusion and other detail has to be given in conventional form, i.e., by symbols.

- The term “cadastral” comes from the French word *cadastre meaning a* “register of survey of lands” and the main purpose of this kind of map is to show the boundaries of property and the plan and location of individual buildings. Cadastral maps are used by lawers when arranging sales of land or when dealing with disputes about land ownership. They are also used by surveyors and builders.

Cadastral Maps

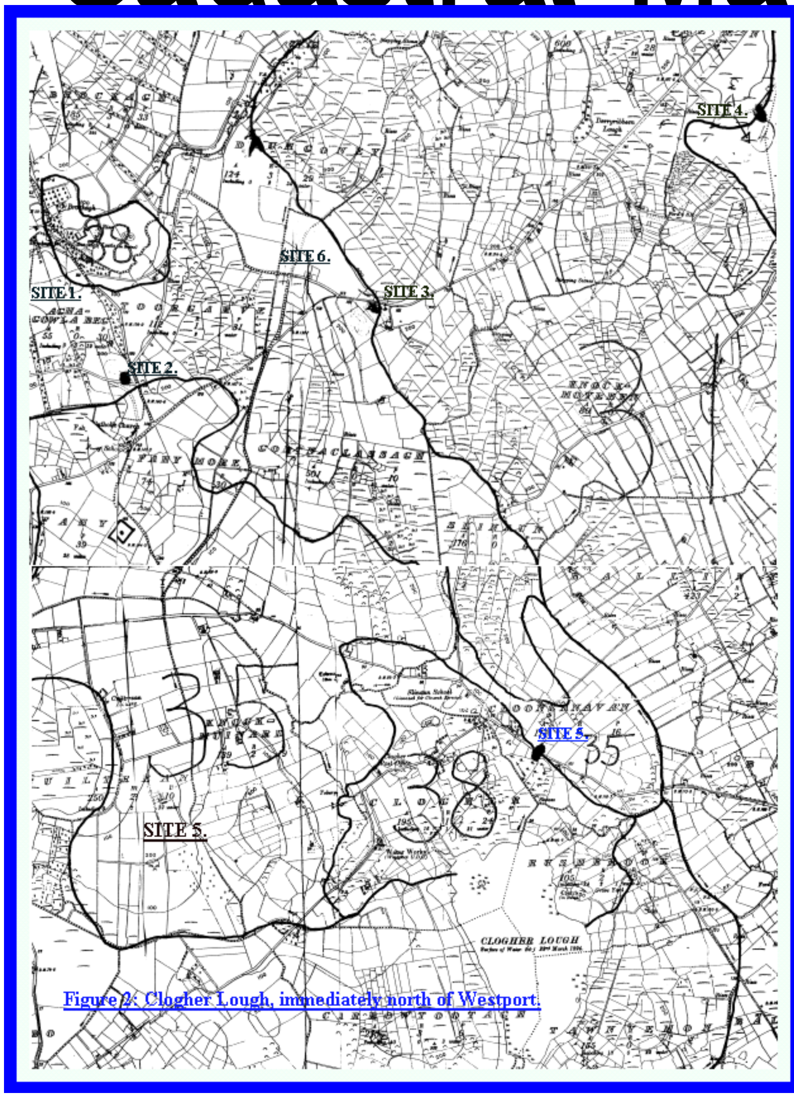
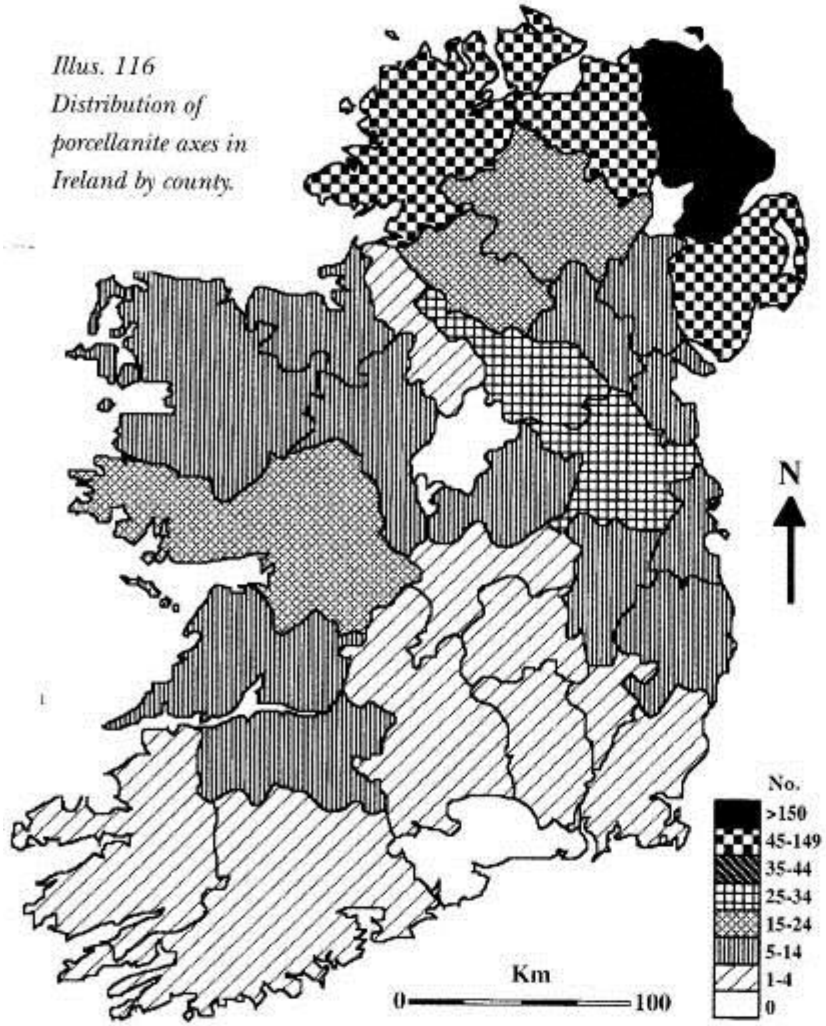


Figure 2: Clogher Lough, immediately north of Westport.

Distribution Maps

- These are based on statistics and enable us at a glance to identify regions of a country with different concentrations of people, livestock, crops and other features.

Distribution Maps



Specialised Maps.

- Specialised maps present specialised information, gathered by a range of institutions focusing on specific themes, namely; Geology, Soils and Habitats.

Habitat Maps. Teagasc.