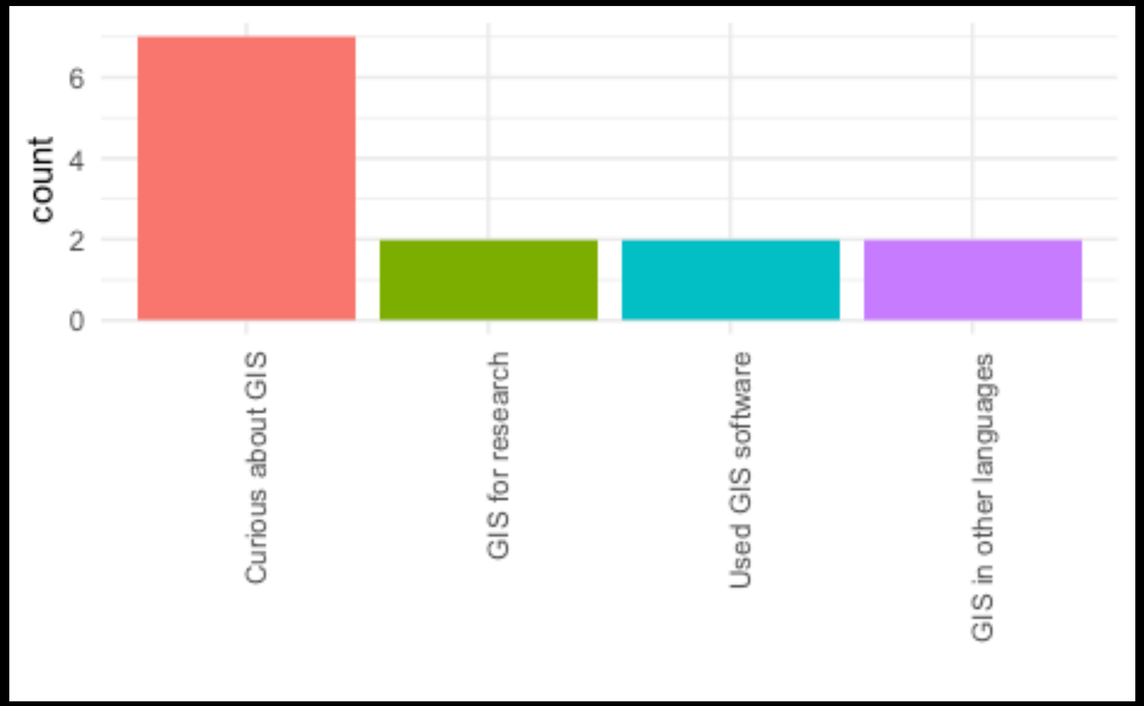
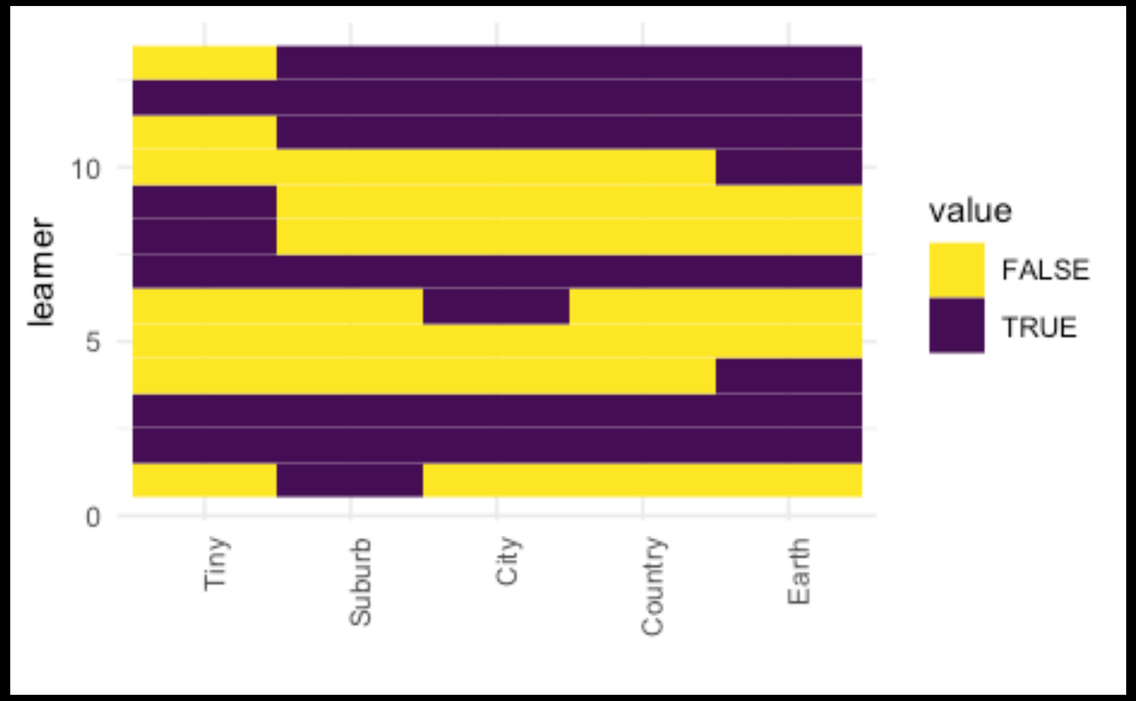
Geospatial concepts

A brief introduction by Darya Vanichkina

(Adapted from Data Carpentry, using additional material from sources listed in References/Further Resources)

Survey results





GIS

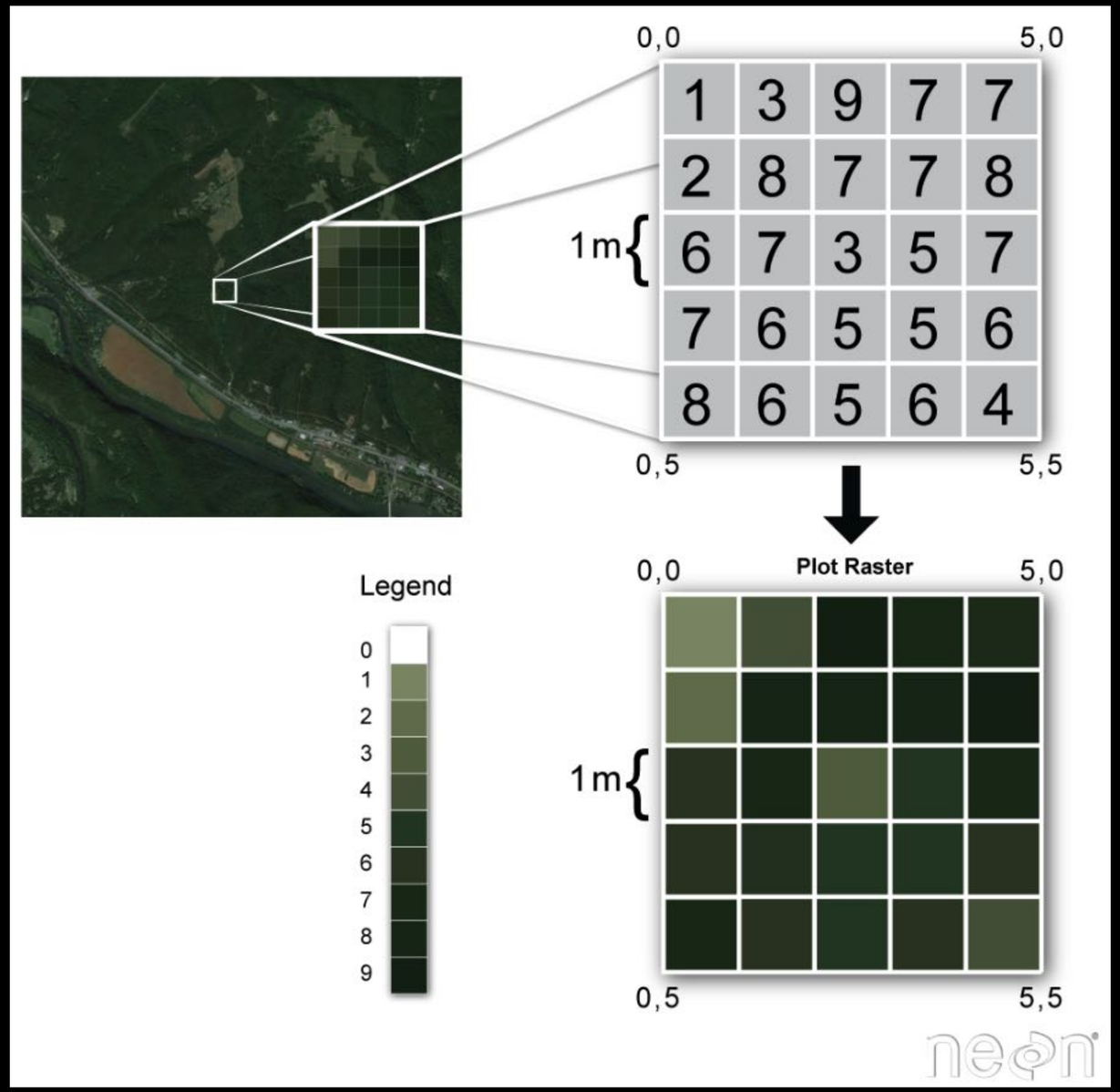
- A Geographic Information System is a multi-component environment used to create, manage, visualize and analyze data and its spatial counterpart
- The core of a GIS environment is a spatial database that facilitates the storage and retrieval of data that define the spatial boundaries, lines or points of the entities we are studying

Two main types of data

- Raster
- Vector

RASTER

Raster

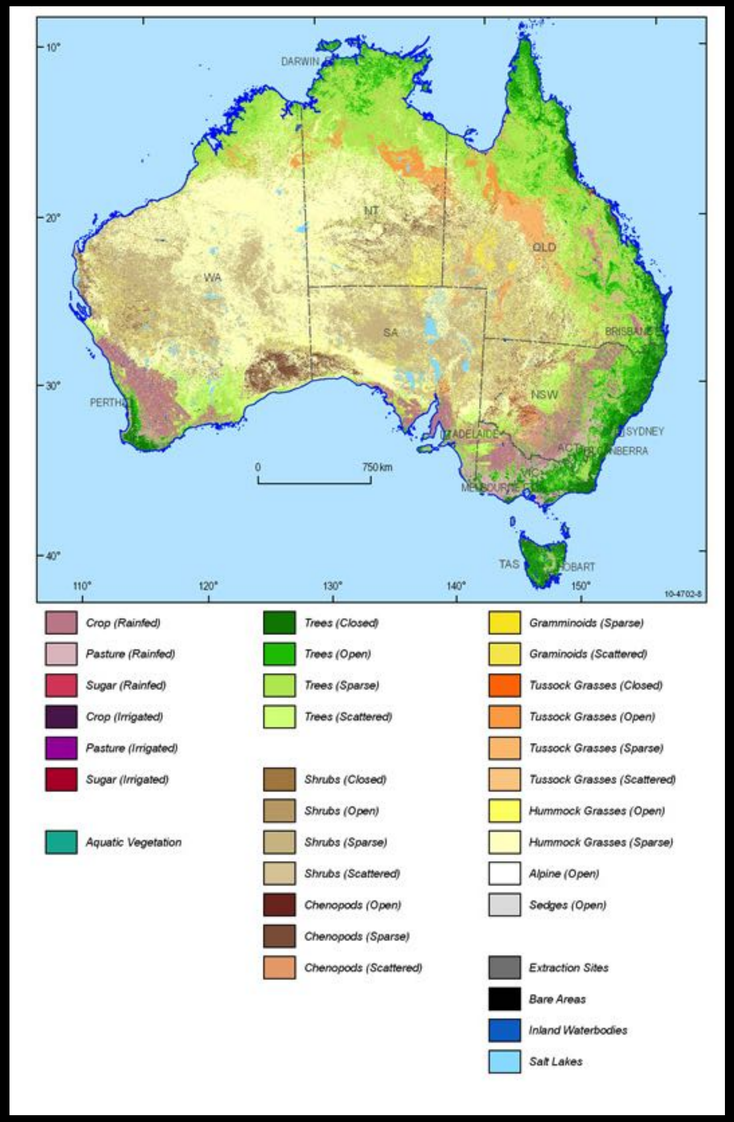


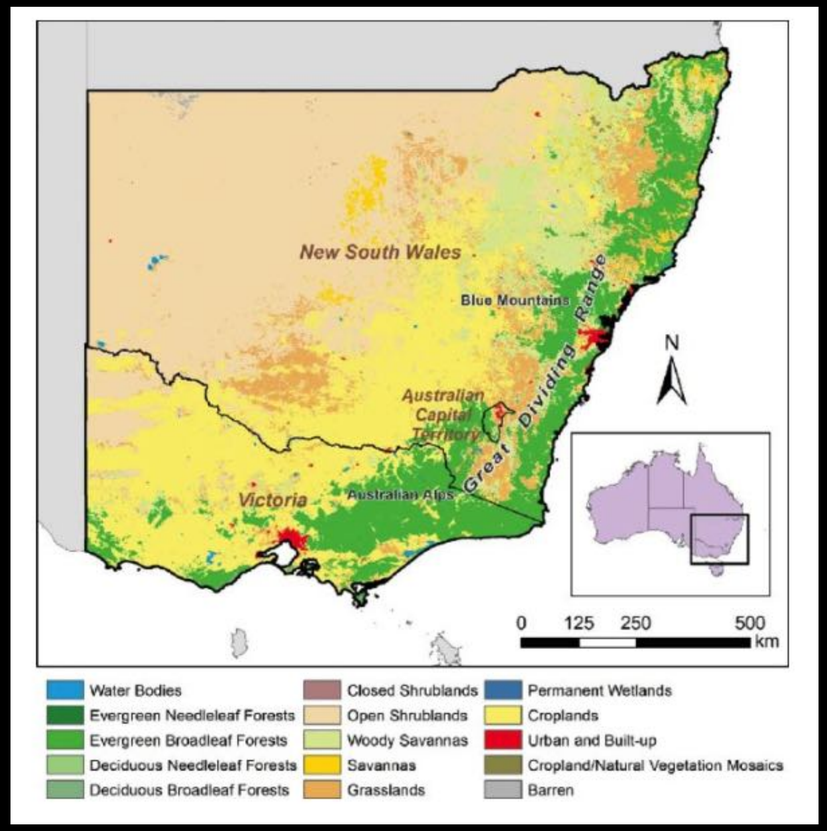
- Each pixel - an AREA on the Earth's surface, i.e. associated with a specific geographical location.
- Value of a pixel can be continuous (e.g. elevation) or categorical (e.g. land use)
- A geospatial raster is only different from a digital photo in that it is accompanied by spatial information that connects the data to a particular location, including:
  - the raster's extent and cell size
  - the number of rows and columns
  - its coordinate reference system (or CRS).

Raster

- Continuous rasters include:
  - Precipitation maps.
  - Maps of tree height derived from LiDAR data.
  - Elevation values for a region
  - Hillshade - a raster that maps the shadows and texture that you would see from above when viewing terrain
- Classified maps aka categorical rasters include:
  - Landcover / land-use maps.
  - Tree height maps classified as short, medium, and tall trees.
  - Elevation maps classified as low, medium, and high elevation.

Categorical raster examples





https://www.researchgate.net/publication/297599886_Modelling_spatial_patterns_of_wildfire_occurrence_in_South-Eastern_Australia/figures?lo=1
http://www.ga.gov.au/scientific-topics/earth-obs/accessing-satellite-imagery/landcover

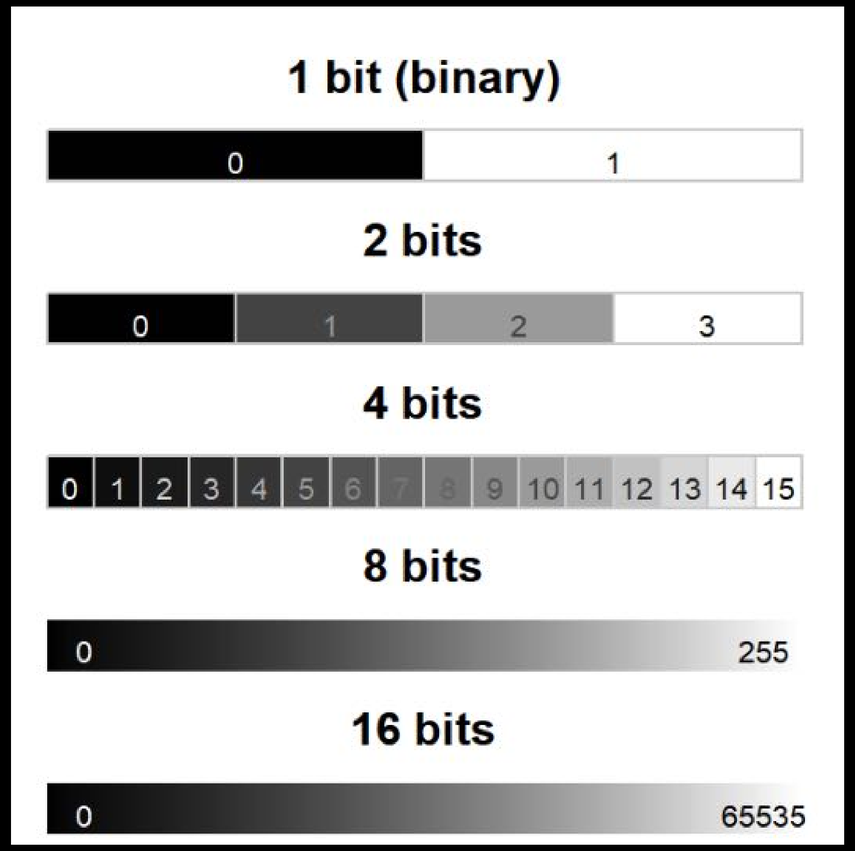
Raster

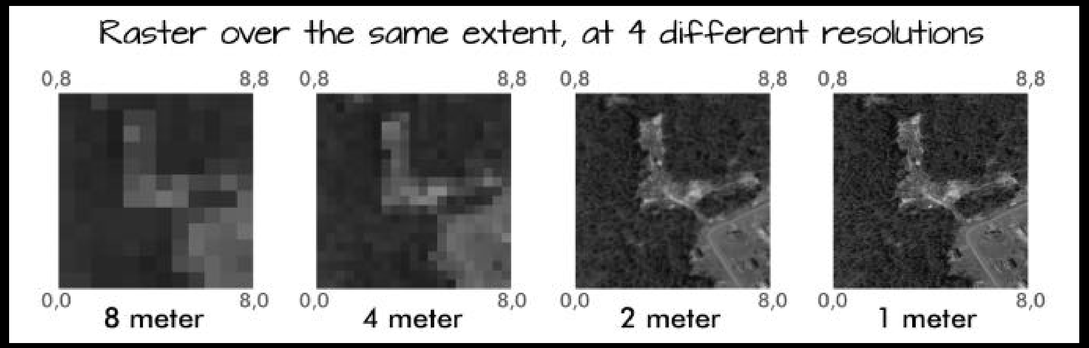
- In your group, brainstorm potential advantages and disadvantages of storing data in raster format.
- Add your ideas to the Etherpad.
- The Instructor will discuss and add any points that weren’t brought up in the small group discussions.

Raster

- Raster data has some important advantages:
  - representation of continuous surfaces
  - potentially very high levels of detail
  - data is ‘unweighted’ across its extent - the geometry doesn’t implicitly highlight features
  - cell-by-cell calculations can be very fast and efficient
  - …
- The downsides of raster data are:
  - very large file sizes as cell size gets smaller
  - currently popular formats don’t embed metadata well (more on this later!)
  - can be difficult to represent complex information
  - …

Raster attributes: pixel depth and resolution



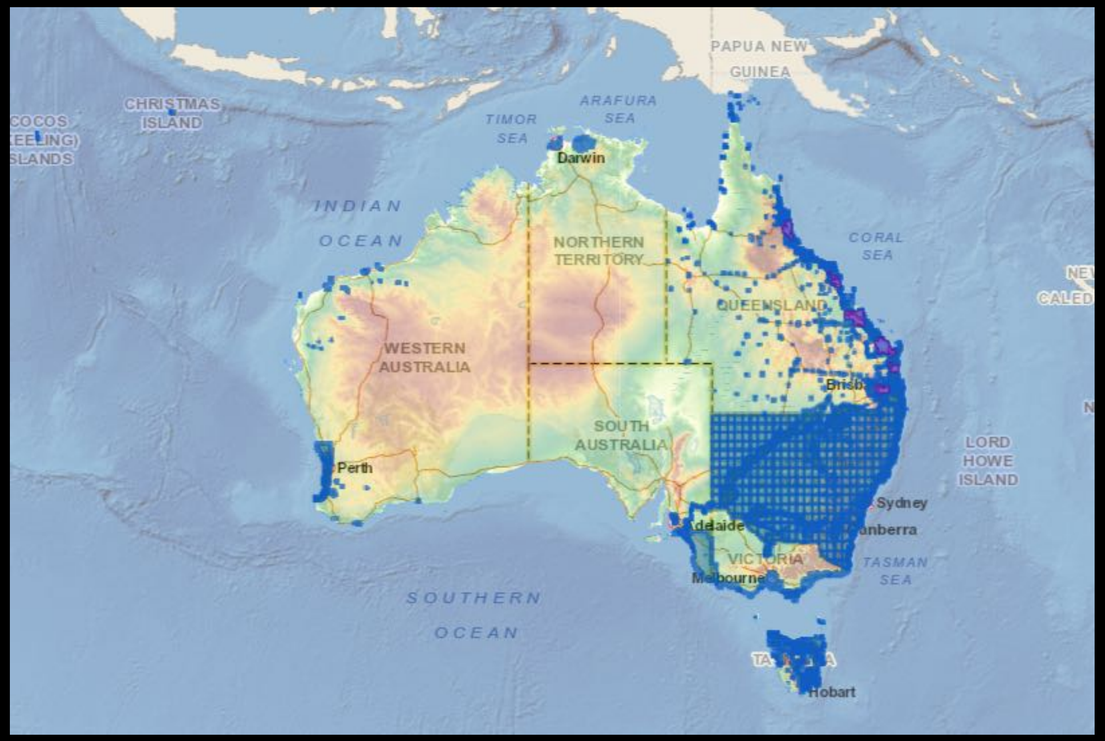


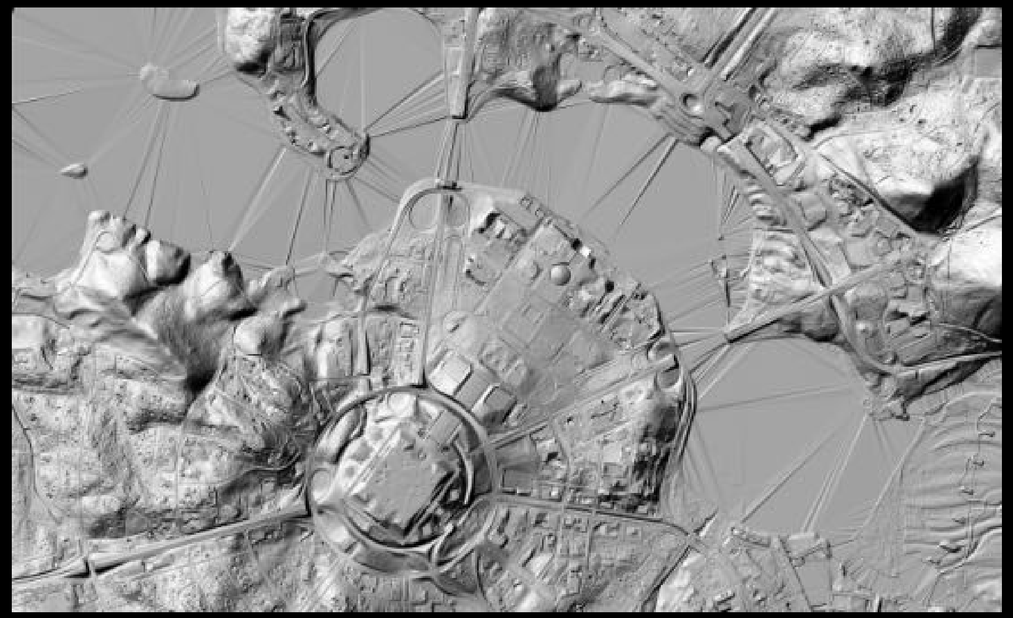
Resolution: the area on the ground that each pixel of the raster covers.

(Interlude) LiDAR

- https://youtu.be/EYbhNSUnIdU

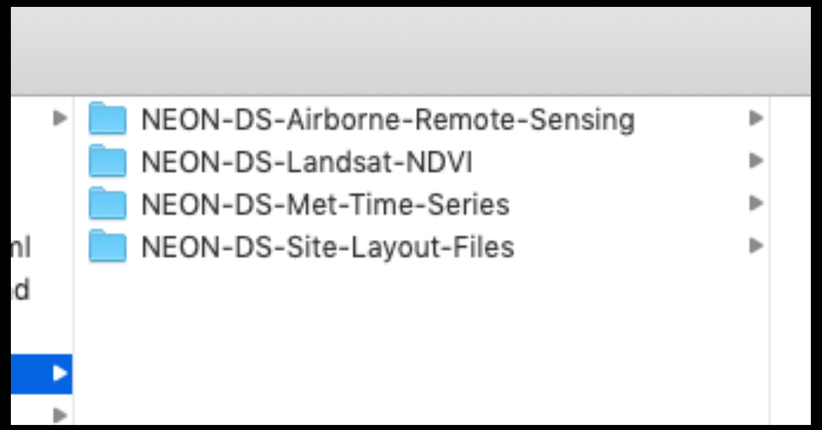
(Interlude2) LiDAR Au





- http://elevation.fsdf.org.au/ 15Gb limit per request
- https://data.gov.au/dataset/digital-elevation-model-dem-of-australia-derived-from-lidar-5-metre-grid
- http://www.ga.gov.au/scientific-topics/national-location-information/digital-elevation-data

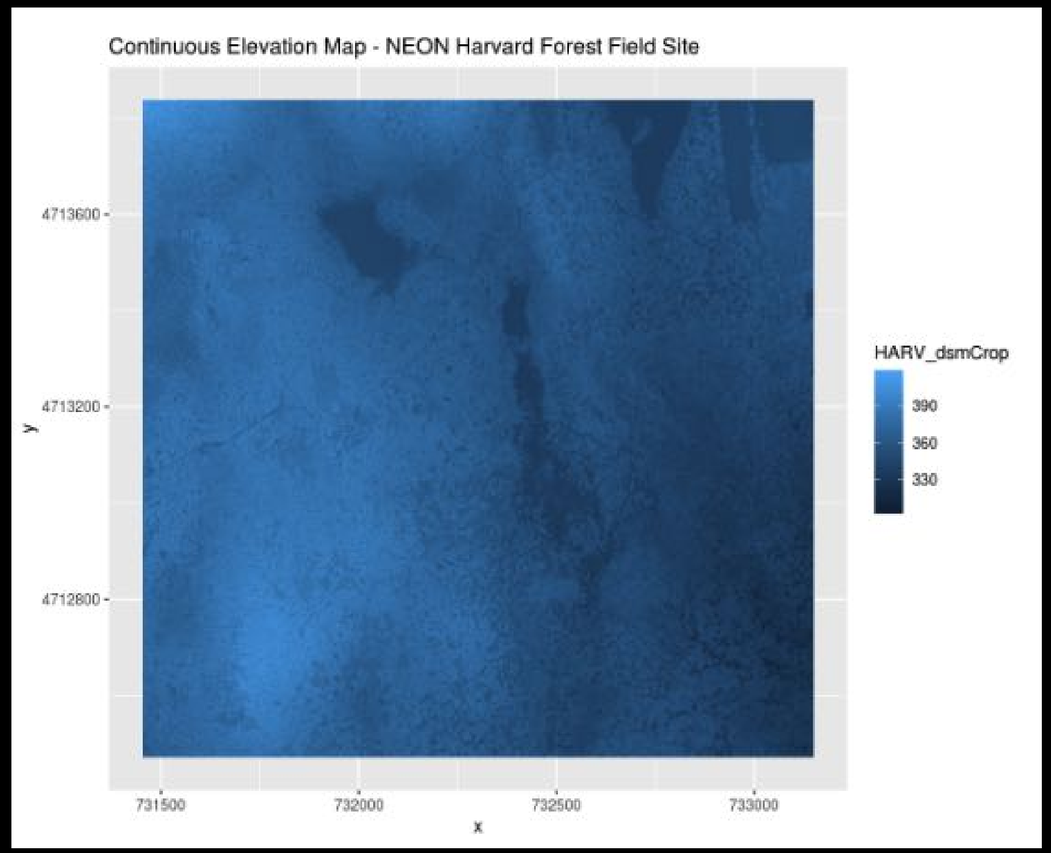
LiDAR data today

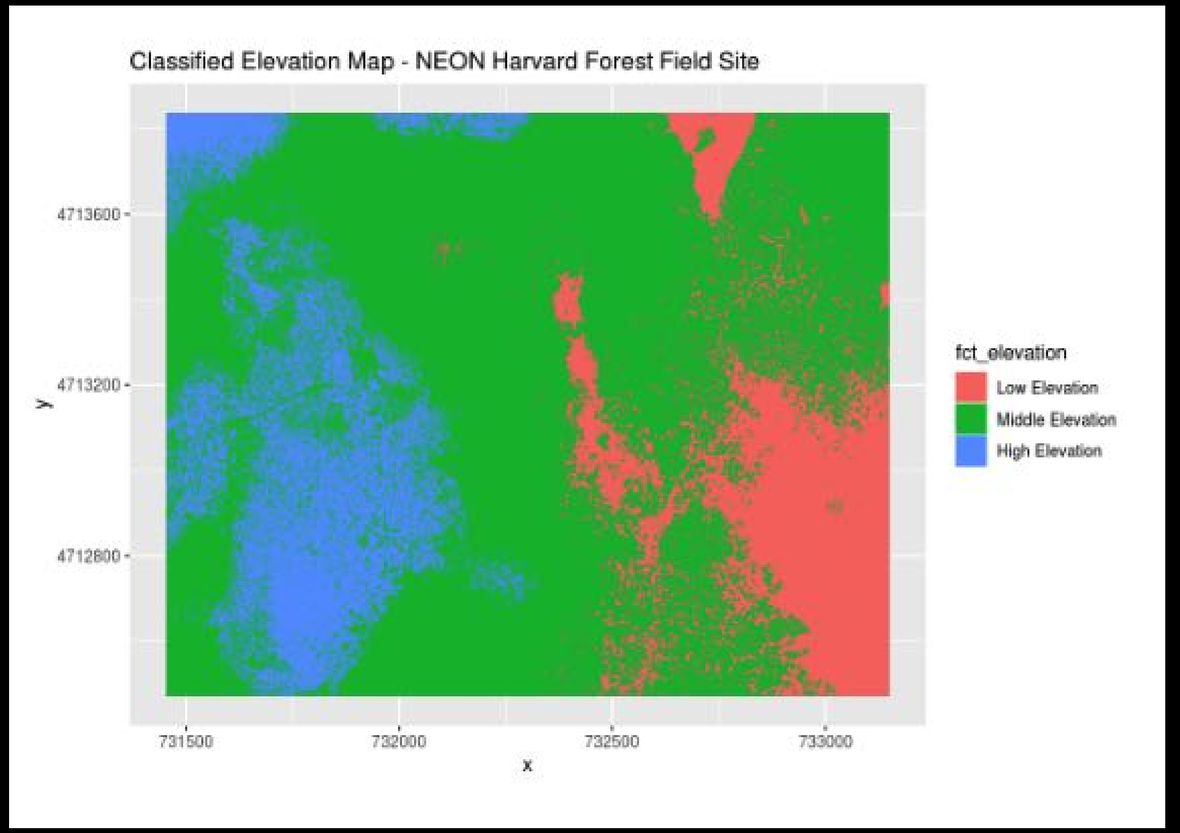


Harvard Forest (HARV) - Massachusetts, USA
San Joaquin Experimental Range (SJER) - California, USA

Dataset	File name	Description
Site layout shapefiles	NEON-DS-Site-Layout-Files.zip	A set of shapefiles for the NEON's Harvard Forest field site and US and (some) state boundary layers.
Meteorological data	NEON-DS-Met-Time-Series.zip	Precipitation, temperature and other variables collected from a flux tower at the NEON Harvard Forest site
Airborne remote sensing data	NEON-DS-Airborne-RemoteSensing.zip	LiDAR data collected by the NEON Airborne Observation Platform (AOP) and processed at NEON including a canopy height model, digital elevation model and digital surface model for NEON's Harvard Forest and San Joaquin Experimental Range field sites.
Landsat 7 NDVI raster data	NEON-DS-Landsat-NDVI.zip	2011 NDVI data product derived from Landsat 7 and processed by USGS cropped to NEON's Harvard Forest and San Joaquin Experimental Range field sites

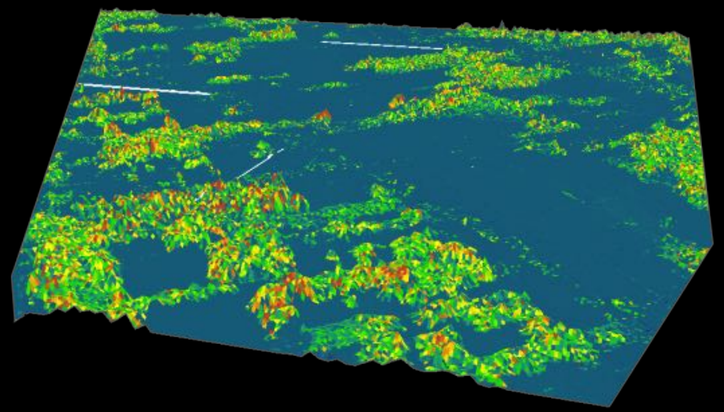
LiDAR data today

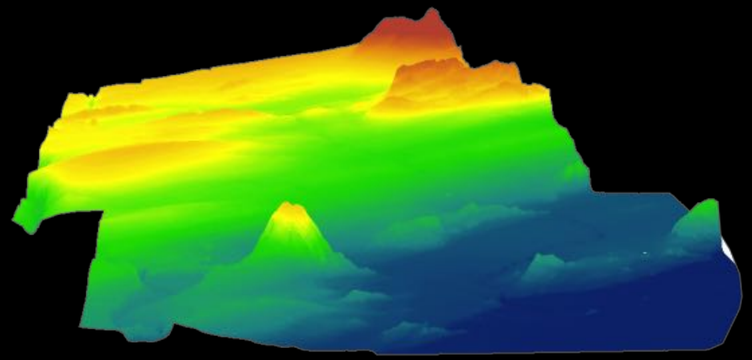


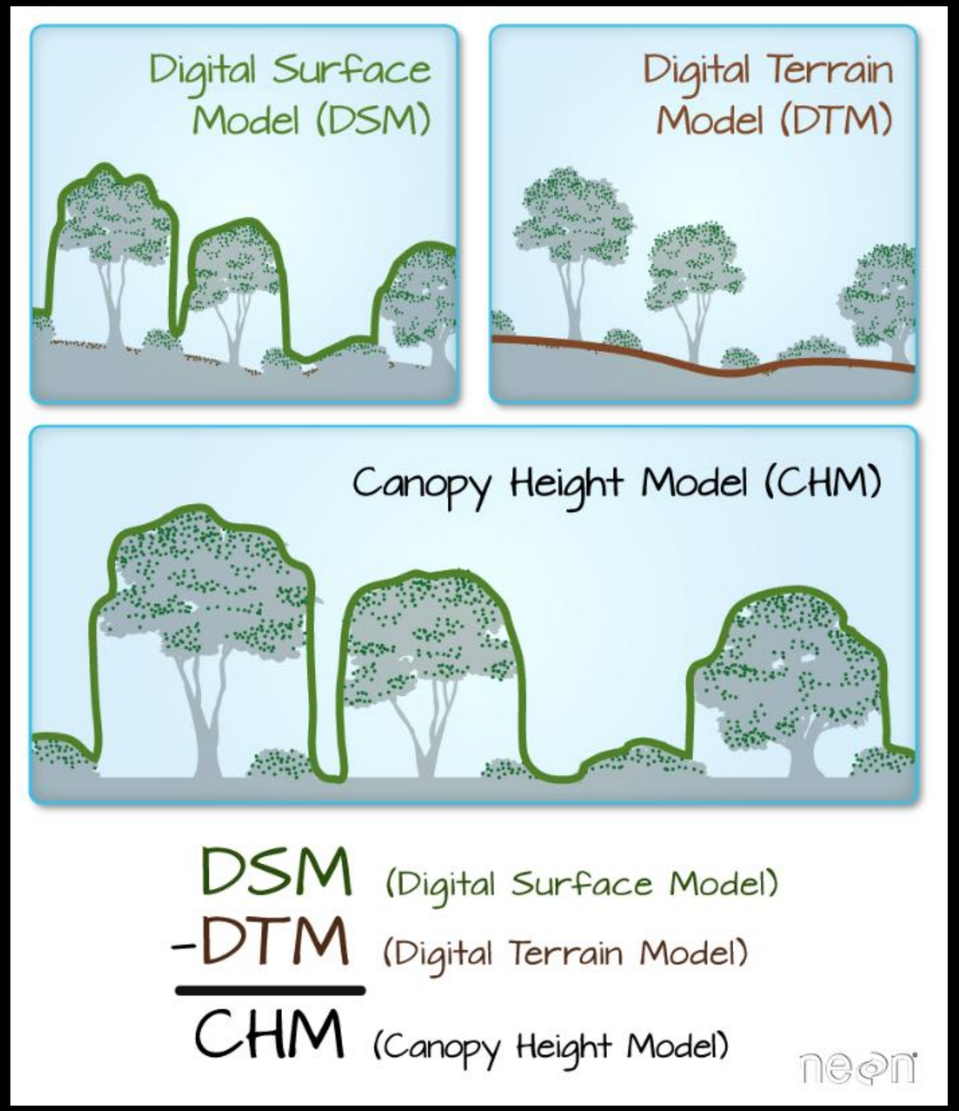


LiDAR data today

- Canopy height model
- Digital elevation = terrain model
- Digital surface model







LiDAR data application

Figure 2: Digital surface model (DSM) of Caerau Camp, Cardiff, showing the distinctive triangular interior of the hillfort set amongst houses and trees and buildings (© Crown: All rights reserved. Environment Agency, 100026380, 2011, LD2012_01_06. Funded by the Royal Commission on the Ancient and Historic Monuments of Wales, Cadw, Welsh Government, and National Museum Wales. LiDAR view generated by RCAHMW).

LiDAR data application

Figure 2: Digital surface model (DSM) of Caerau Camp, Cardiff, showing the distinctive triangular interior of the hillfort set amongst houses and trees and buildings (© Crown: All rights reserved. Environment Agency, 100026380, 2011, LD2012_01_06. Funded by the Royal Commission on the Ancient and Historic Monuments of Wales, Cadw, Welsh Government, and National Museum Wales. LiDAR view generated by RCAHMW).

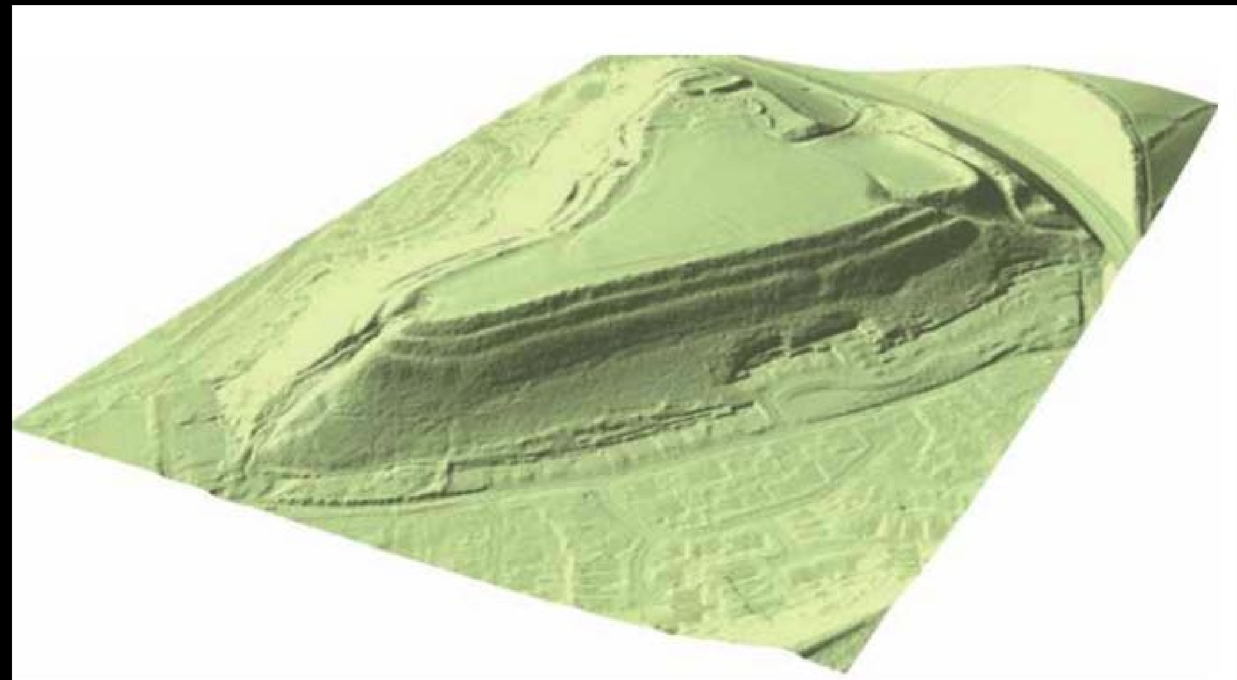
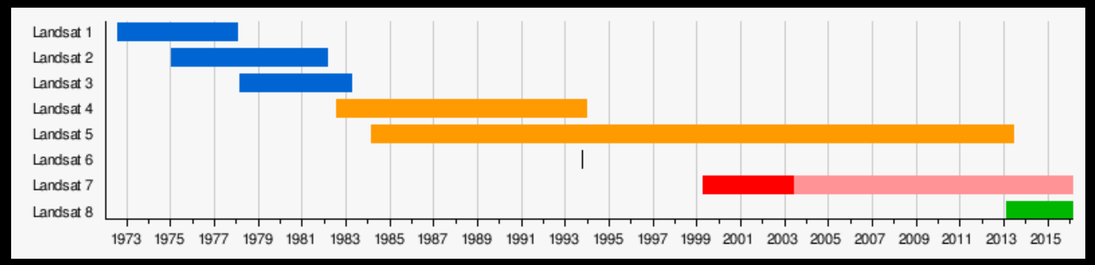


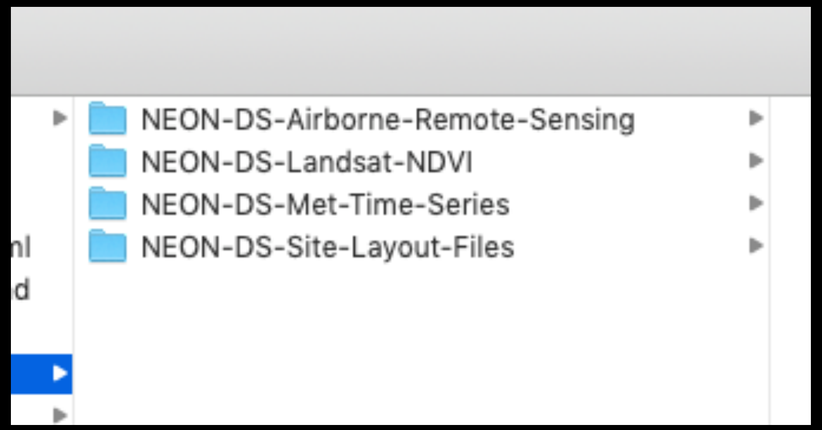
Figure 3: 'Bare earth' digital terrain model (DTM), with houses and trees stripped away reveals the magnificent sculpted ramparts and ditches (© Crown: All rights reserved. *Environment Agency, 100026380, 2011, LD2012_01_07. Funded by the Royal Commission on the Ancient and Historic Monuments of Wales, Cadw, Welsh Government, and National Museum Wales. LiDAR view generated by RCAHMW).*

(Interlude) Landsat



https://upload.wikimedia.org/wikipedia/commons/4/43/Aral_sea.gif

Landsat data today

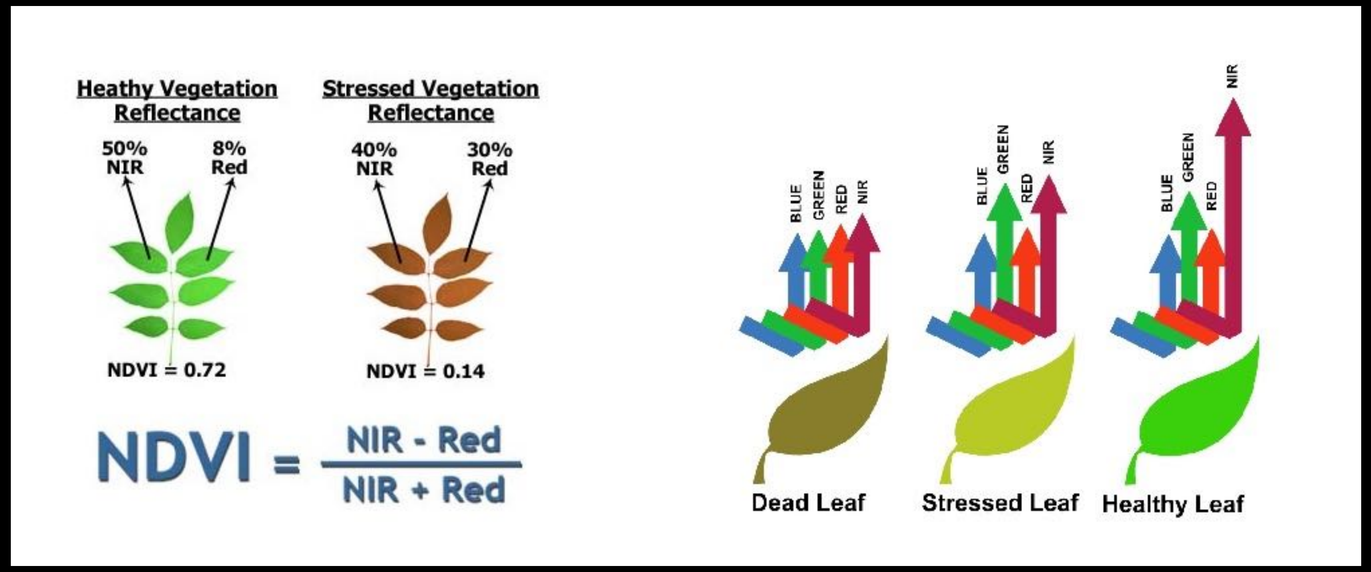


Harvard Forest (HARV) - Massachusetts, USA
San Joaquin Experimental Range (SJER) - California, USA

Dataset	File name	Description
Site layout shapefiles	NEON-DS-Site-Layout-Files.zip	A set of shapefiles for the NEON's Harvard Forest field site and US and (some) state boundary layers.
Meteorological data	NEON-DS-Met-Time-Series.zip	Precipitation, temperature and other variables collected from a flux tower at the NEON Harvard Forest site
Airborne remote sensing data	NEON-DS-Airborne-RemoteSensing.zip	LiDAR data collected by the NEON Airborne Observation Platform (AOP) and processed at NEON including a canopy height model, digital elevation model and digital surface model for NEON's Harvard Forest and San Joaquin Experimental Range field sites.
Landstat 7 NDVI raster data	NEON-DS-Landsat-NDVI.zip	2011 NDVI data product derived from Landsat 7 and processed by USGS cropped to NEON's Harvard Forest and San Joaquin Experimental Range field sites

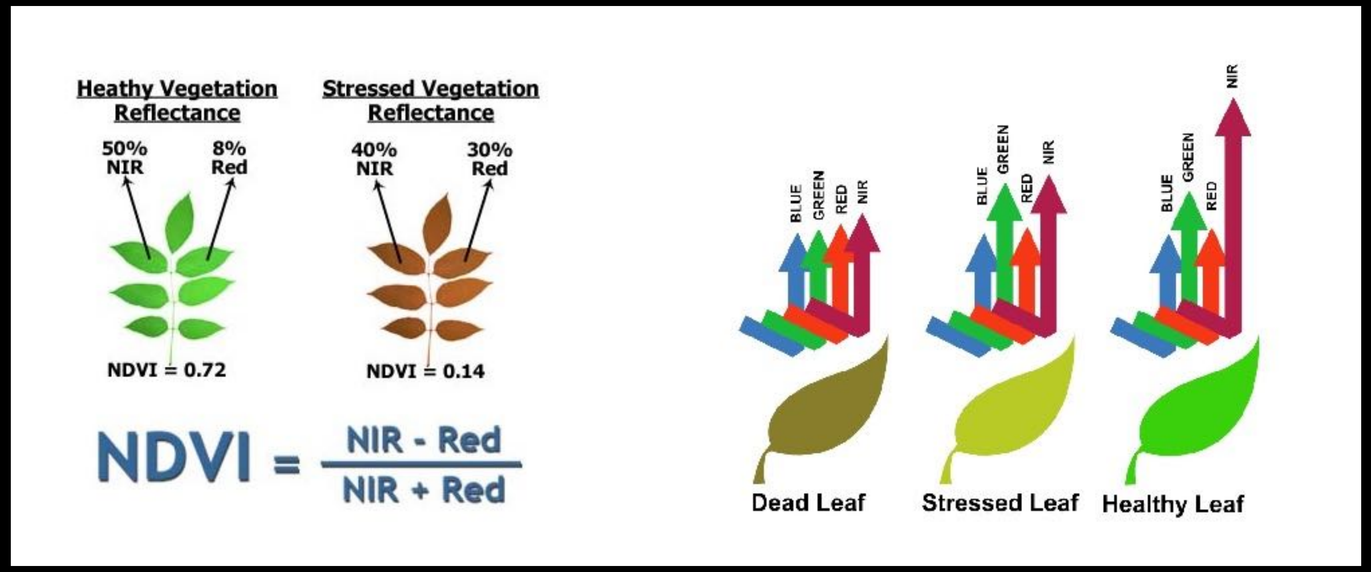
Landsat data today

Normalized difference vegetation index - a common raster operation



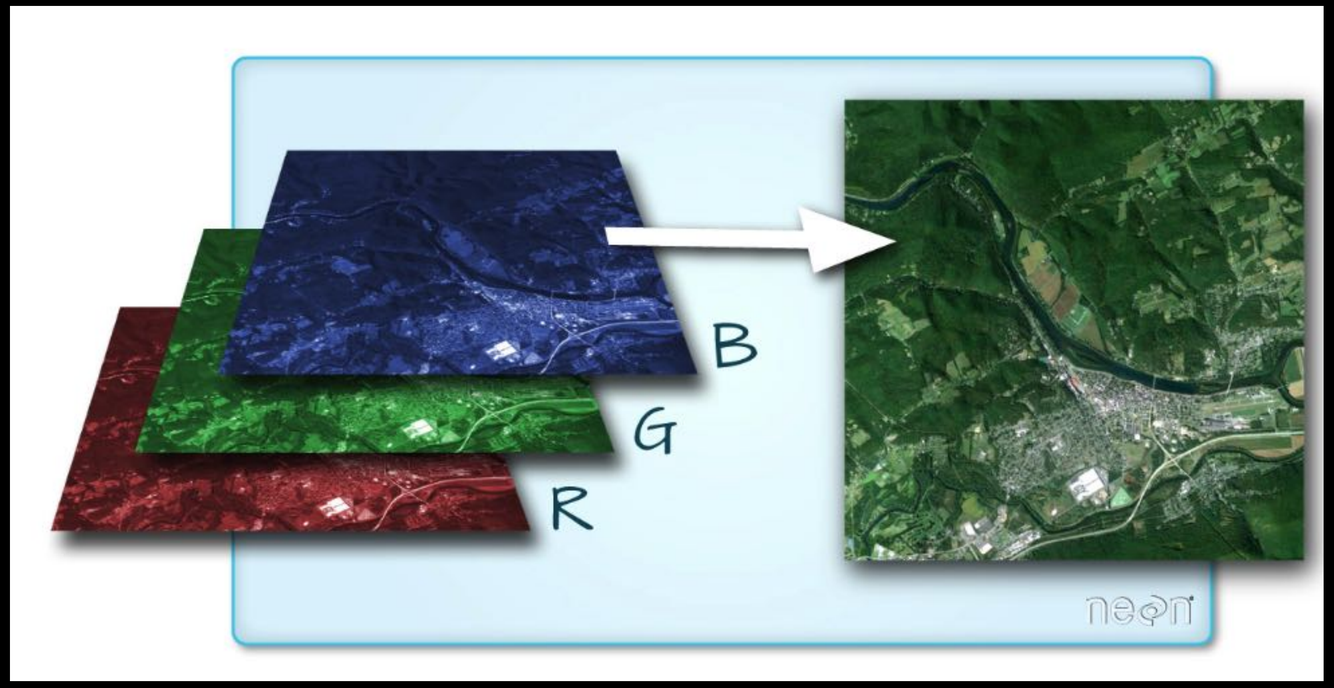
Landsat data today

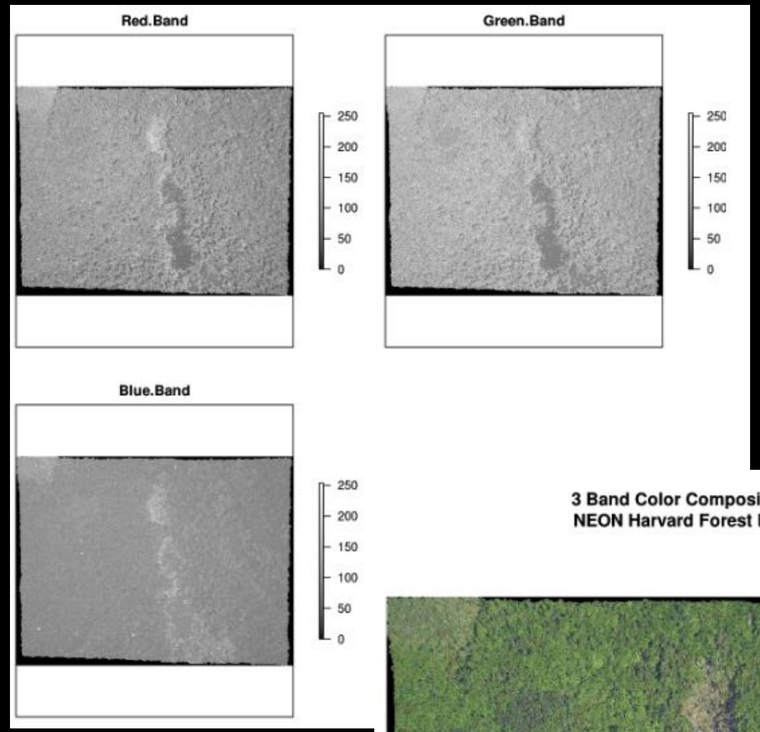
Normalized difference vegetation index - a common raster operation

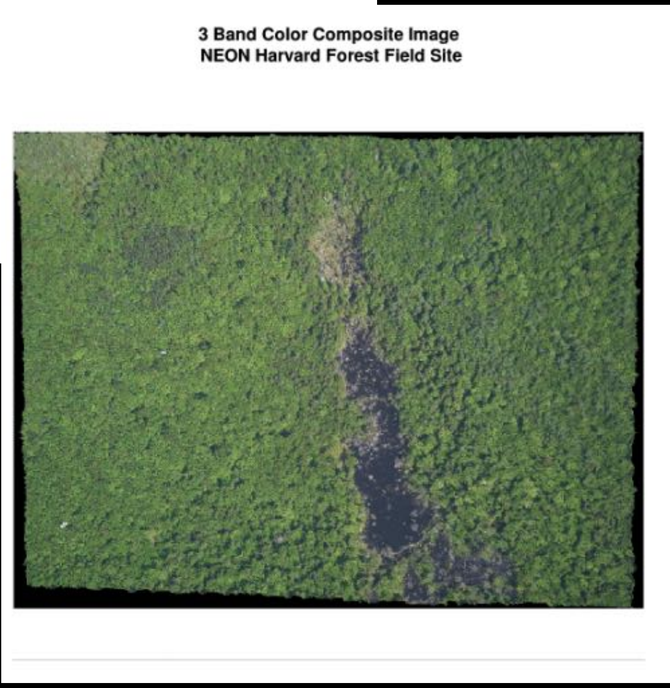


Band	Wavelength	Useful for mapping
Band 1 – Coastal Aerosol	0.435 - 0.451	Coastal and aerosol studies
Band 2 – Blue	0.452 - 0.512	Bathymetric mapping, distinguishing soil from vegetation, and deciduous from coniferous vegetation
Band 3 - Green	0.533 - 0.590	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 4 - Red	0.636 - 0.673	Discriminates vegetation slopes
Band 5 - Near Infrared (NIR)	0.851 - 0.879	Emphasizes biomass content and shorelines
Band 6 - Short-wave Infrared (SWIR) 1	1.566 - 1.651	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 7 - Short-wave Infrared (SWIR) 2	2.107 - 2.294	Improved moisture content of soil and vegetation and thin cloud penetration
Band 8 - Panchromatic	0.503 - 0.676	15 meter resolution, sharper image definition
Band 9 – Cirrus	1.363 - 1.384	Improved detection of cirrus cloud contamination
Band 10 – TIRS 1	10.60 – 11.19	100 meter resolution, thermal mapping and estimated soil moisture
Band 11 – TIRS 2	11.50 - 12.51	100 meter resolution, Improved thermal mapping and estimated soil moisture

Multiband raster





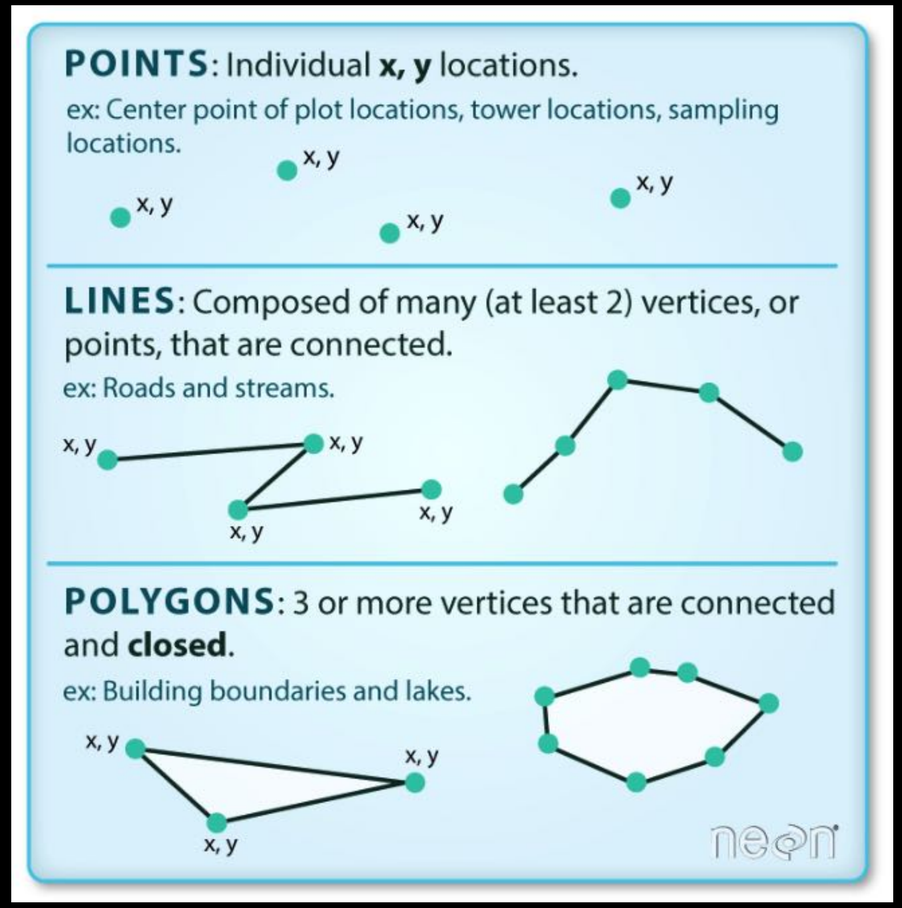


Multi-band raster data might contain:

- **Time series: the same variable, over the same area, over time. We will be working with time series data in the Raster Time Series Data in R episode.**
- **Multi or hyperspectral imagery: image rasters that have 4 or more (multi-spectral) or more than 10-15 (hyperspectral) bands.**

VECTOR

Vector

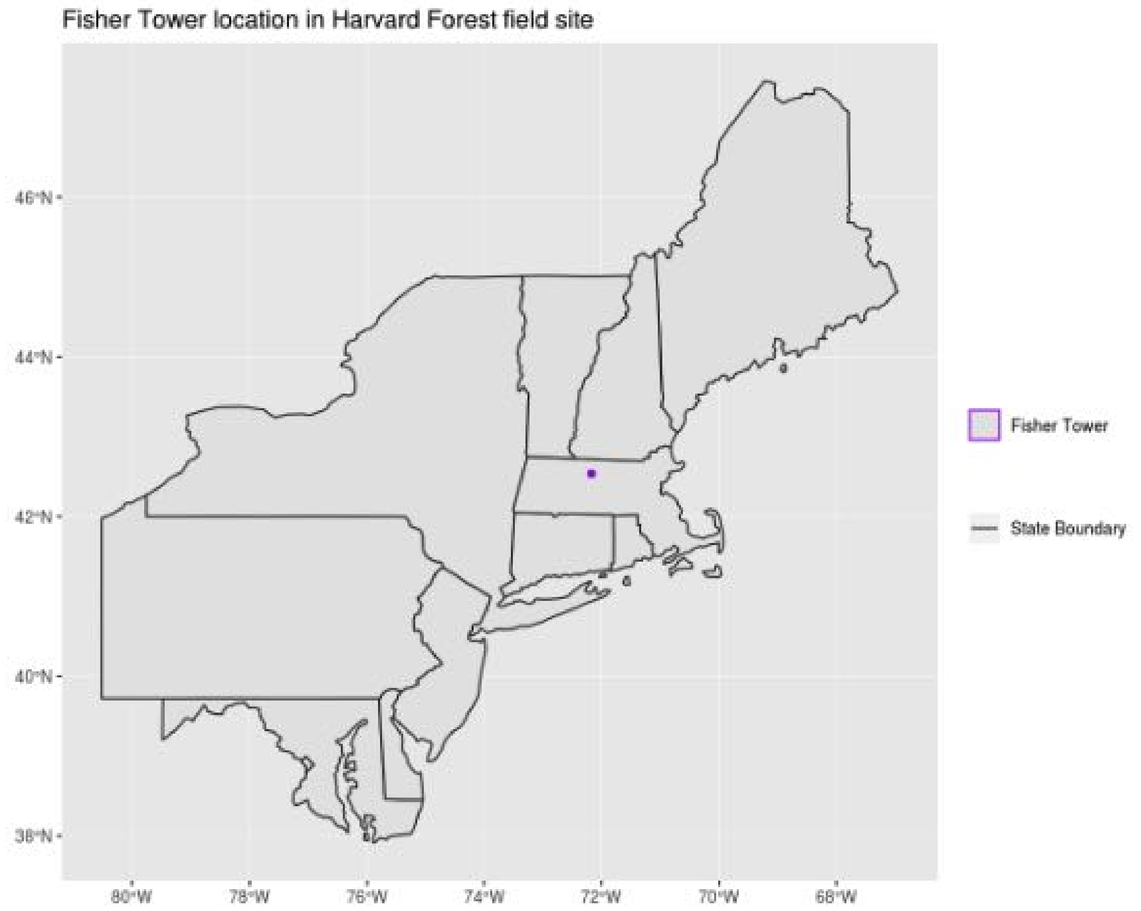


- Vector data structures represent specific features on the Earth's surface, and assign attributes to those features.
- Vector data tends to dominate the social sciences because human settlements tend to have discrete borders.
- They are composed of discrete geometric locations (x, y values) known as vertices that define the shape of the spatial object
  - point: individual (x,y)
  - line: at least two vertices (points);
  - polygon: 3+ connected closed verticies;

Vector Data Types

The plot below includes examples of two of the three types of vector objects. Use the definitions above to identify which features are represented by which vector type.

plot of chunk unnamed-chunk-2



Vector

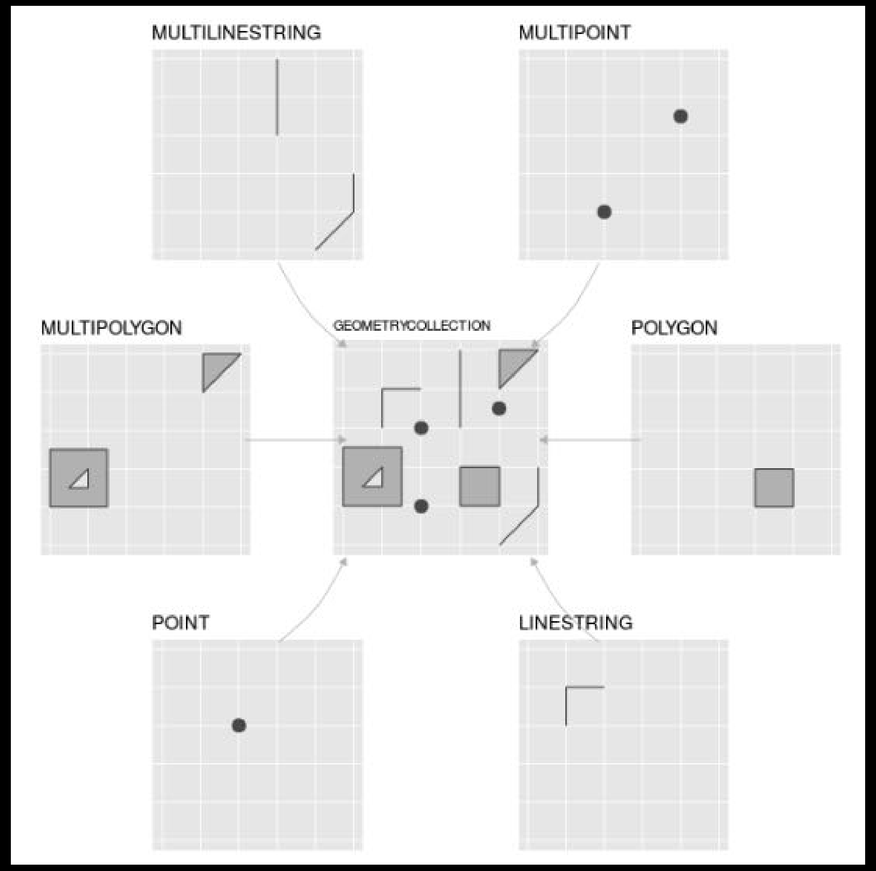
- In your group, brainstorm potential advantages and disadvantages of storing data in vector format.
- Add your ideas to the Etherpad.
- The Instructor will discuss and add any points that weren’t brought up in the small group discussions.

Vector

- Vector data has some important advantages:
  - The geometry itself contains information about what the dataset creator thought was important
  - The geometry structures hold information in themselves - why choose point over polygon, for instance?
  - Each geometry feature can carry multiple attributes instead of just one, e.g. a database of cities can have attributes for name, country, population, etc
  - Data storage can be very efficient compared to rasters
- The downsides of vector data include:
  - potential loss of detail compared to raster
  - potential bias in datasets - what didn’t get recorded?
  - Calculations involving multiple vector layers need to do math on the geometry as well as the attributes, so can be slow compared to raster math.

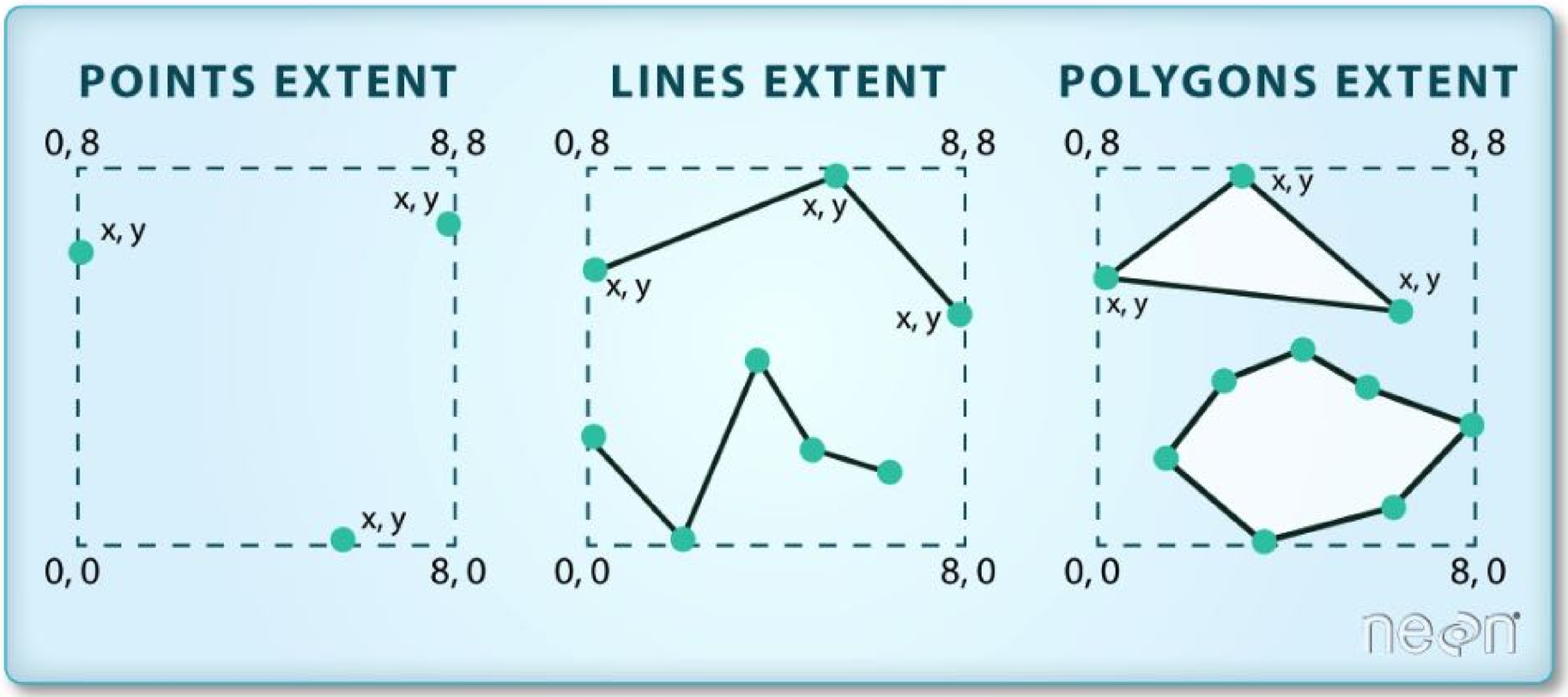
Simple features (sf)

an open standard developed and endorsed by the Open Geospatial Consortium (OGC)
a hierarchical data model that represents a wide range of geometry types.
17 geometry types are supported by the specification; 7 are used in the vast majority of geographic research:
POINT, LINESTRING, POLYGON, MULTIPOINT, MULTILINESTRING, MULTIPOLYGON and GEOMETRYCOLLECTION



Extent (attribute common to raster + vector)

The dashed boxes around each set of objects seems to imply that the three objects have the same extent. Is this accurate? If not, which object(s) have a different extent?



CRS

Coordinate reference systems (CRS)

- Also known as Spatial reference systems
- CRS information connects data to the Earth's surface using a mathematical model.
- CRS is made up of
  - Datum
    - A model of the shape of the earth. It has angular units (i.e. degrees) and defines the starting point (i.e. where is (0,0)?) so the angles reference a meaningful spot on the earth. Common global datums are WGS84 and NAD83. Datums can also be local - fit to a particular area of the globe, but ill-fitting outside the area of intended use.
  - Projection
    - A mathematical transformation of the angular measurements on a round earth to a flat surface
  - Additional parameters:
    - ex. Center of map

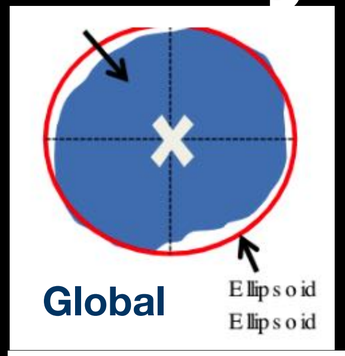
- A datum is the choice of fruit to use. Is the earth an orange, a lemon, a lime, a grapefruit?

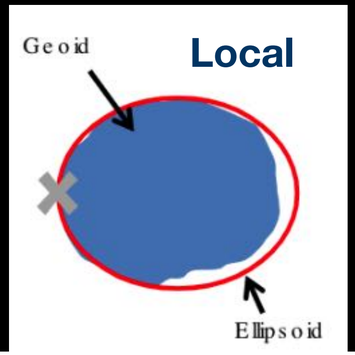
Image source

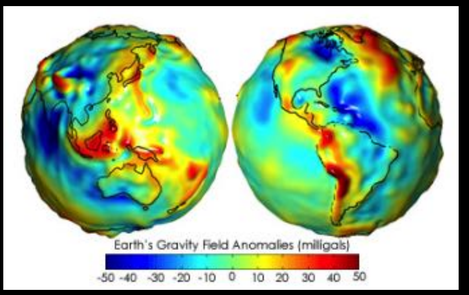
A projection is how you peel your orange and then flatten the peel.

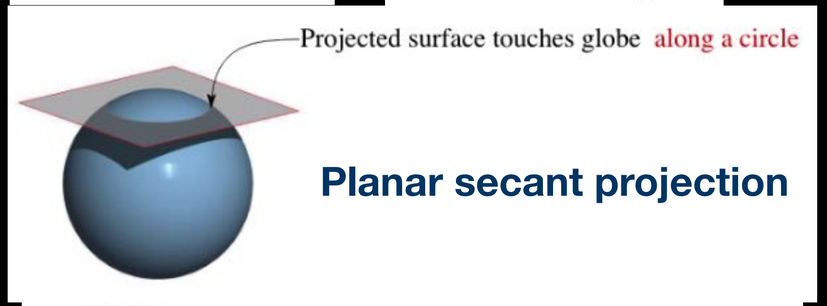
Coordinate reference systems (CRS)

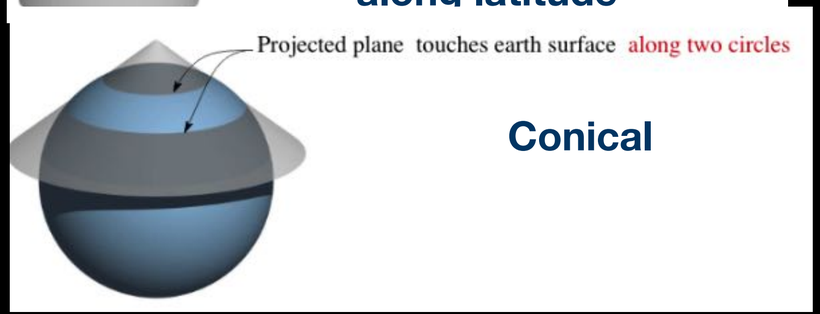
- Also known as Spatial reference systems
- CRS information connects data to the Earth's surface using a mathematical model.
- CRS is made up of
  - Datum (+ elipsoid + geoid)
    - A model of the shape of the earth. It has angular units (i.e. degrees) and defines the starting point (i.e. where is (0,0)?) so the angles reference a meaningful spot on the earth. Common global datums are WGS84 and NAD83. Datums can also be local - fit to a particular area of the globe, but ill-fitting outside the area of intended use.
  - Projection
    - A mathematical transformation of the angular measurements on a round earth to a flat surface
  - Additional parameters:
    - ex. Center of map







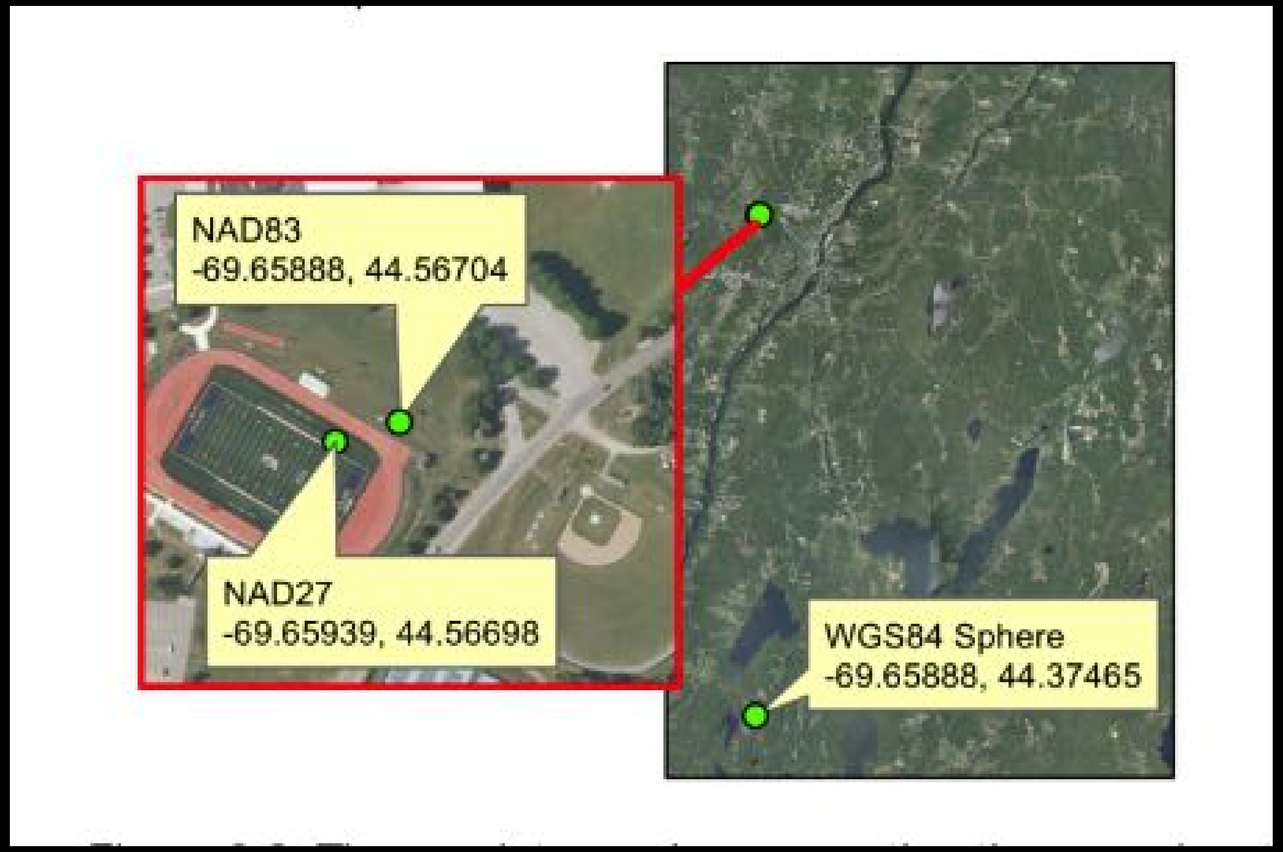




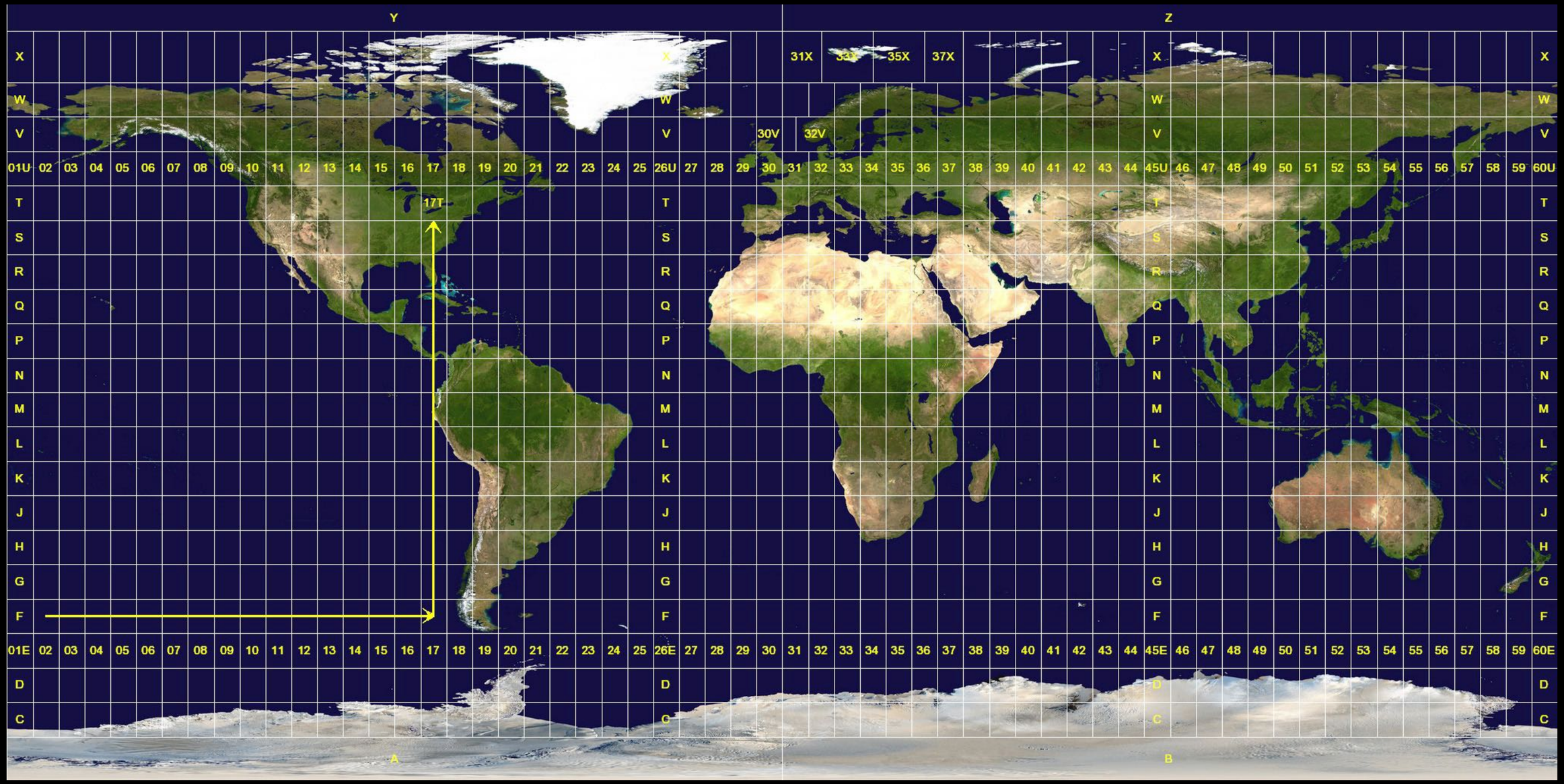
CRS types

- Geographical CRS
  - span the entire world
- Projected CRS
  - are usually localized to minimize visual distortion in a particular region (use a specific ellipsoid which is especially suitable for a this particular part of the Earth)

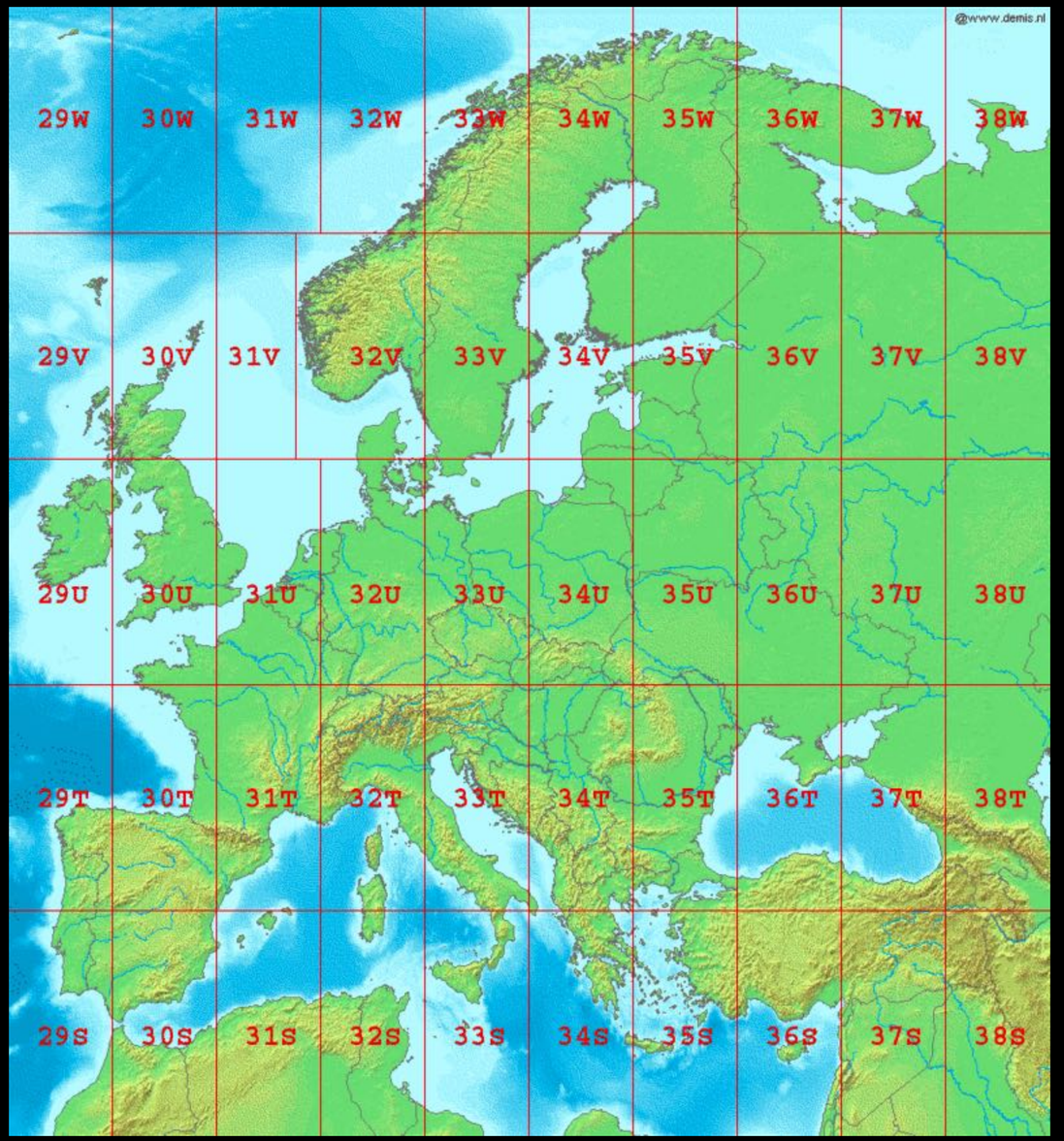
CRS matters!


NAD83
-69.65888, 44.56704
NAD27
-69.65939, 44.56698
WGS84 Sphere
-69.65888, 44.37465

Universal transverse Mercator (UTM)



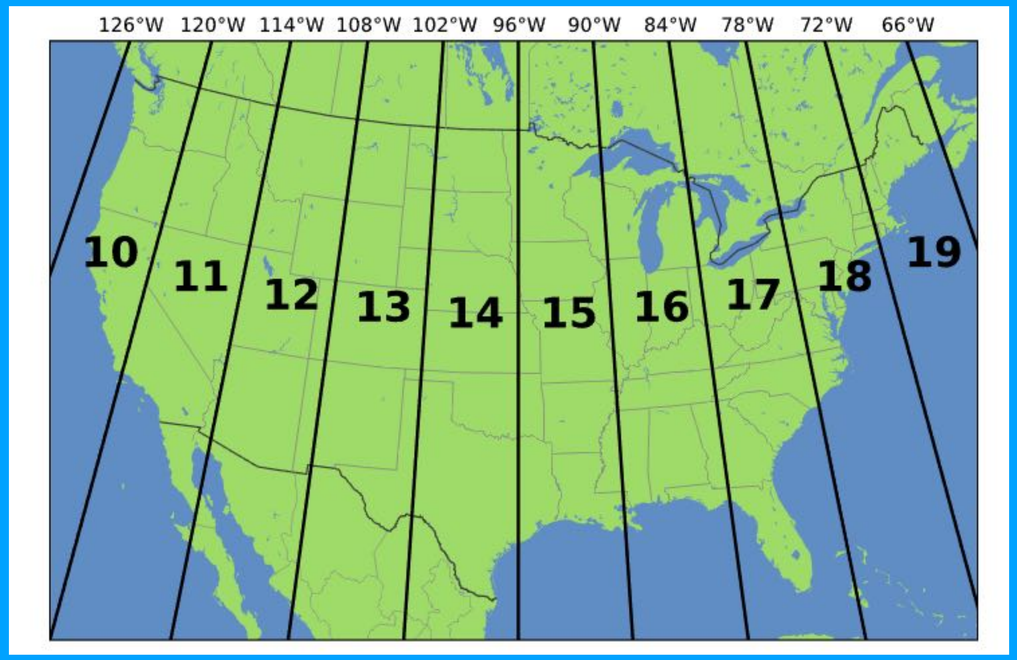
Universal transverse Mercator (UTM)



PROJ4 to specify CRS

- PROJ is an open-source library for storing, representing and transforming CRS information. PROJ.5 has been recently released, but PROJ.4 was in use for 25 years so you will still mostly see PROJ referred to as PROJ.4.
- PROJ represents CRS information as a text string of key-value pairs, which makes it easy to customise
- A PROJ4 string includes the following information:
  - proj=: the projection of the data
  - zone=: the zone of the data (this is specific to the UTM projection)
  - datum=: the datum use
  - units=: the units for the coordinates of the data
  - ellps=: the ellipsoid (how the earth's roundness is calculated) for the data
-

PROJ4 to specify CRS



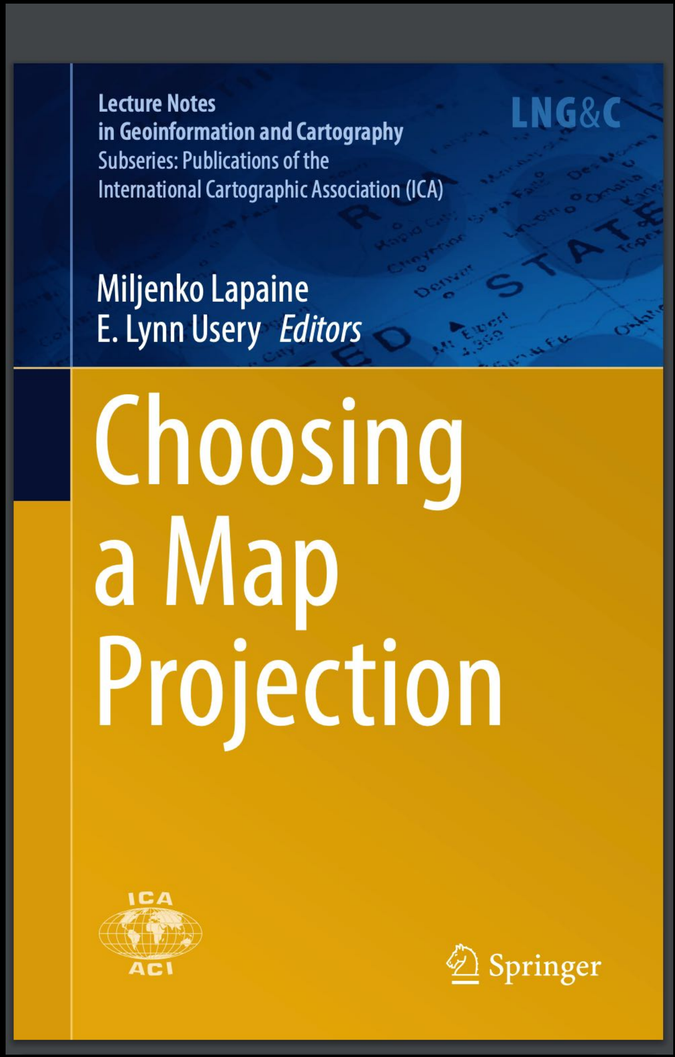
Here is a PROJ4 string for one of the datasets we will use in this workshop:

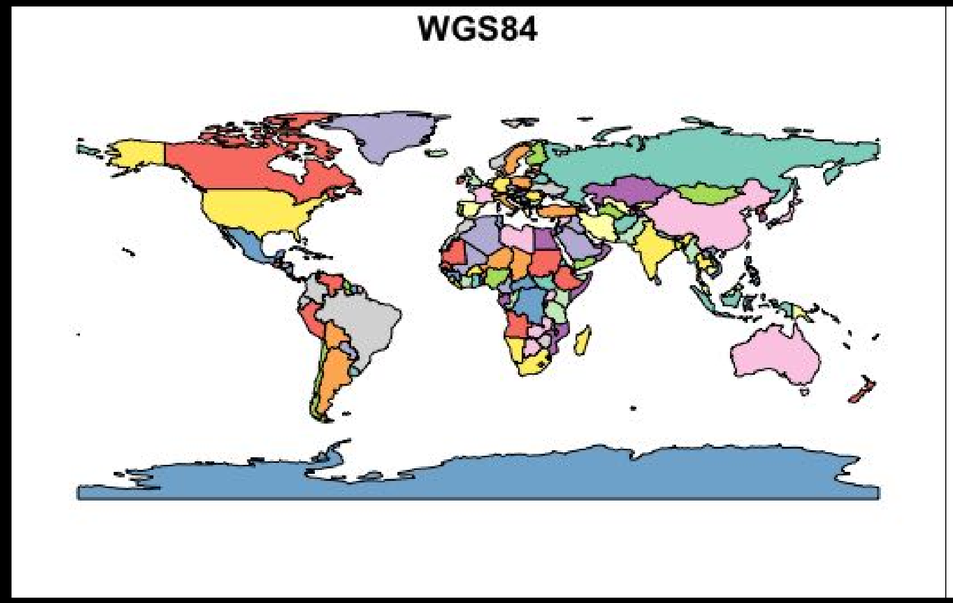
+proj=utm +zone=18 +datum=WGS84 +units=m +no_defs +ellps=WGS84 +towgs84=0,0,0

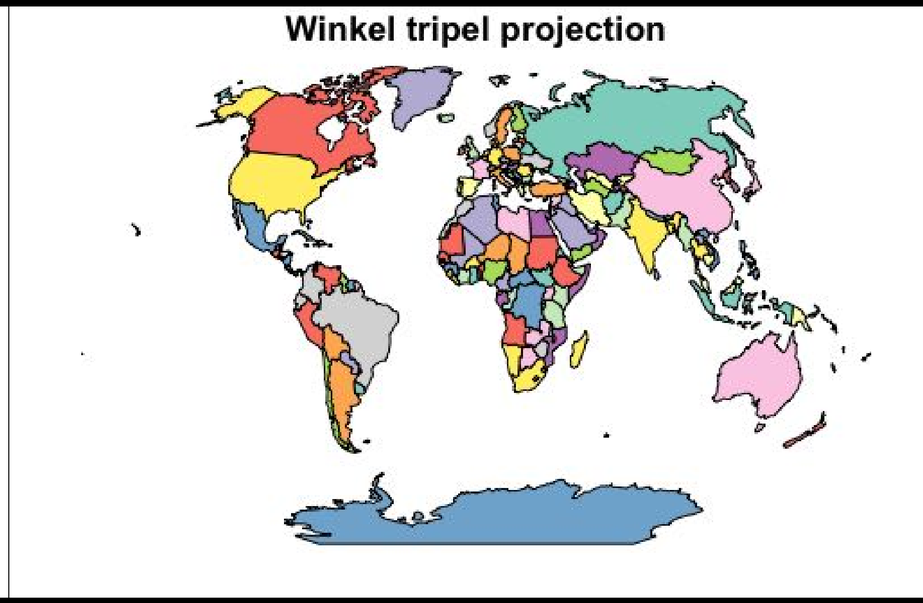
What projection, zone, datum, and ellipsoid are used for this data?
What are the units of the data?
Using the map above, what part of the United States was this data collected from?

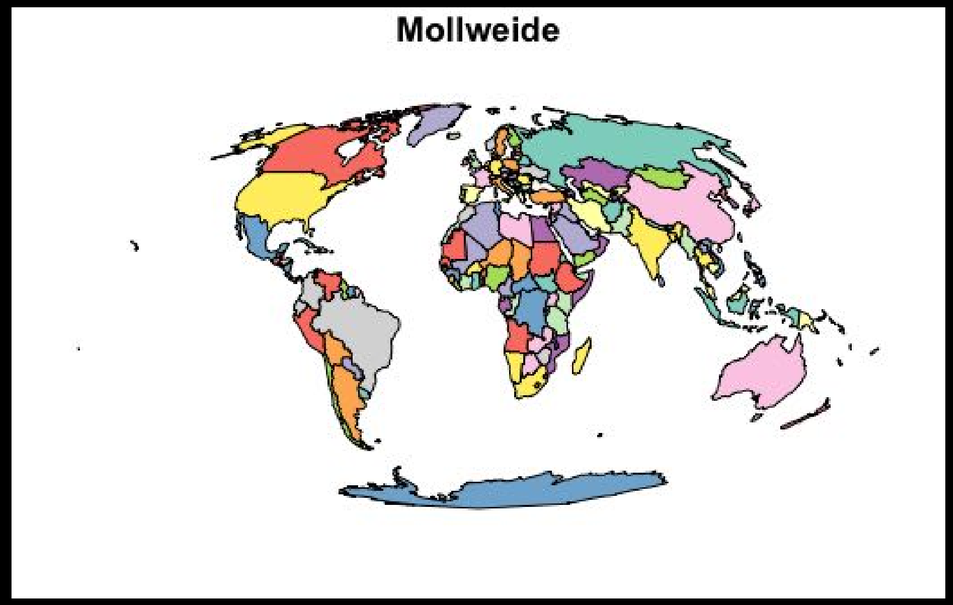
Other ways to specify CRS

- EPSG
  - Database of CRS information maintained by the International Association of Oil and Gas Producers.
  - The dataset contains both CRS definitions and information on how to safely convert data from one CRS to another.
  - Using EPSG is easy as every CRS has a integer identifier, e.g. WGS84 is EPSG:4326.
  - The downside is that you can only use the CRSs EPSG defines and cannot customise them.
- OGC WKT
  - used by a number of important geospatial apps and software libraries.
  - WKT is a nested list of geodetic parameters. The structure of the information is defined on their website.
  - WKT is valuable in that the CRS information is more transparent than in EPSG, but can be more difficult to read and compare than PROJ.
  - Additionally, the WKT standard is implemented inconsistently across various software platforms,









The four spatial properties on a map that are subject to distortion are:

shape - kept by conformal projection
area - kept by equal-area projection
distance - kept by equidistant projection
direction - kept by azimuthal projection

Lambert azimuthal equal-area projection

+proj=laea +lat_0=0 +lon_0=0 +x_0=0 +y_0=0 +ellps=WGS84 +units=m +no_defs

roj=laea +lat_0=-33.8 +lon_0=151.2 +x_0=0 +y_0=0 +ellps=WGS84 +units=m +no_d

Choose a local projection when trying to do math

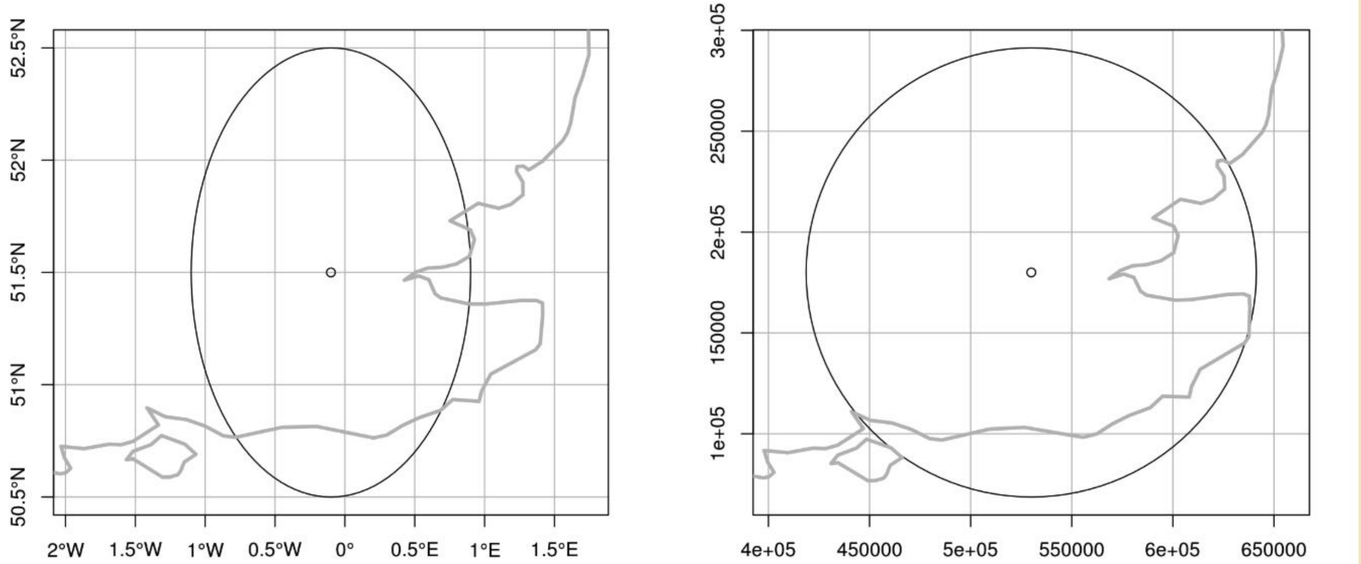


Figure 6.1: Buffers around London with a geographic (left) and projected (right) CRS. The gray outline represents the UK coastline.

General guidelines

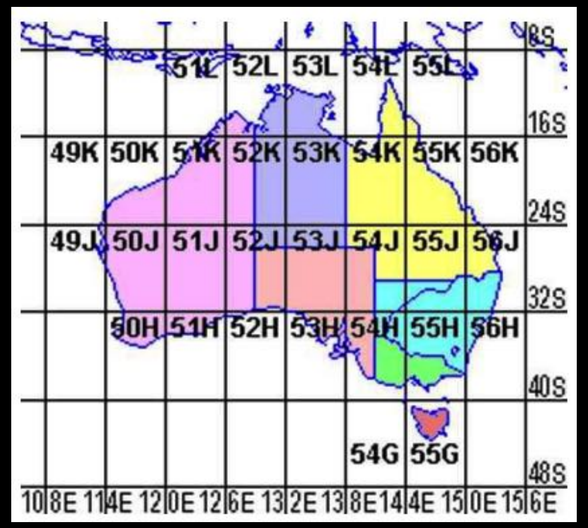
- Performing spatial and geometric operations makes little or no difference in some cases (e.g. spatial subsetting)

- For operations involving distances such as buffering, the only way to ensure a good result is to create a projected copy of the data and run the operation on that.

- Publishing data online with the leaflet package may require a geographic CRS, usually WGS84 aka EPSG 4326 (because GPS datasets and thousands of raster and vector datasets are provided in this CRS by default)

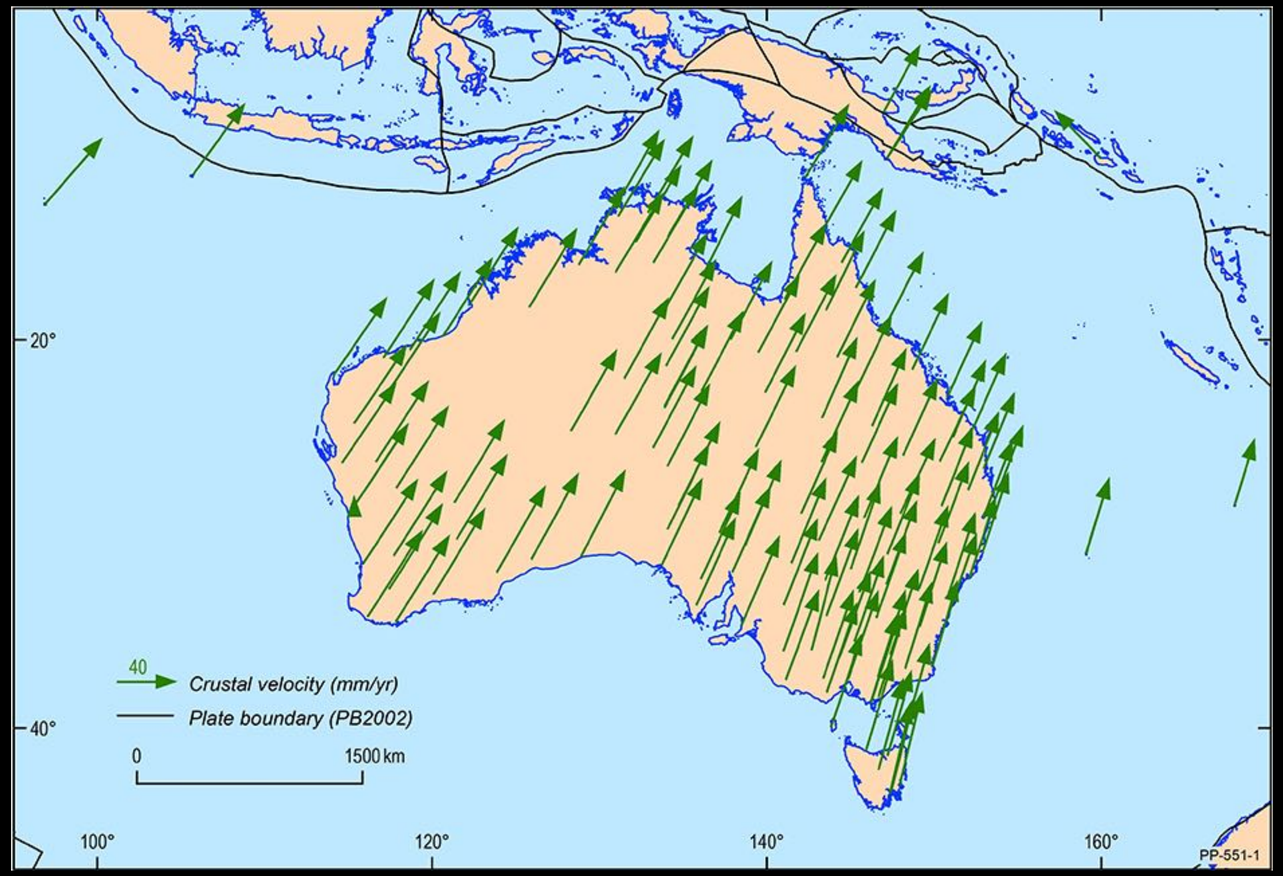
Australia

The Map Grid of Australia (MGA) is based on UTM



A typical set of fully specified coordinates are E 578315, N 5789240, UTM Zone 54H, Datum GDA94
Australia now uses the GDA94 datum (Geocentric Datum of Australia 1994) for latitude / longitude and the MGA94 map grid (Map Grid of Australia 1994) for UTM coordinates. GDA94 is the same as WGS84 for most practical purposes.

Australia



Since the implementation of the previous Australian datum, the Geocentric Datum of Australia 1994 (GDA94), the Australian plate has moved approximately 1.6 m, and Australia's coordinates are no longer aligned with Global Navigation Satellite Systems (GNSS) such as GPS.

GDA2020

Transitioning to GDA2020

Due to the significant growth in the number of users of precise positioning and the expected improvement in positioning technology over the coming decade, Australia has started modernising its datum.

Australia's datum will be modernised in a two-stage approach to ensure that Australians continue to have access to the most accurate location information.

Stage 1: GDA2020 (available now)

The first stage is underway with the transition to the GDA2020. GDA2020 is the projected position of the Australian continent in 2020. Like GDA94, this datum is fixed to the Australian continent, where coordinates do not change with time. As a consequence, coordinates from GNSS such as GPS, will be offset by approximately 20 cm from GDA2020 in 2017; however, these coordinates will converge by 2020.

Stage 2: Australian Terrestrial Reference Frame (starting in 2020)

The second stage will commence in January 2020, when users will be able to transition to a time-dependent reference frame, that is, a datum/reference frame in which coordinates will change with time. This datum will be called the Australian Terrestrial Reference Frame (ATRF) and will provide the Australian community with a sustainable, traceable, high-precision geodetic reference system capable of meeting the most demanding positioning requirements. This datum will be fixed to the earth and will model the locations of reference points and their movement over time by maintaining full alignment to the International Terrestrial Reference Frame (ITRF).

NOTE: GDA2020 will still be available for users who do not need a time-dependent reference frame.

http://www.ga.gov.au/scientific-topics/positioning-navigation/datum-modernisation

The Geospatial Landscape

Software

- Commercial
  - ESRI - ArcGIS
  - Pitney Bowes produce MapInfo Professional, which was one of the earliest desktop GIS programs on the market.
  - Hexagon Geospatial Power Portfolio includes many geospatial tools including ERDAS Imagine, a powerful remotely sensed image processing platform.
  - Manifold is a desktop GIS that emphasizes speed through the use of parallel and GPU processing.
  - Global mapper (OK ArcGIS alternative)
- FOSS:
  - QGIS is a professional GIS application that is built on top of and proud to be itself Free and Open Source Software (FOSS). QGIS is written in Python, but has several interfaces written in R including RQGIS.
  - GRASS GIS, commonly referred to as GRASS (Geographic Resources Analysis Support System), is a FOSS-GIS software suite used for geospatial data management and analysis, image processing, graphics and maps production, spatial modeling, and visualization. GRASS GIS is currently used in academic and commercial settings around the world, as well as by many governmental agencies and environmental consulting companies. It is a founding member of the Open Source Geospatial Foundation (OSGeo).
  - GDAL is a multiplatform set of tools for translating between geospatial data formats. It can also handle reprojection and a variety of geoprocessing tasks. GDAL is built in to many applications both FOSS and commercial, including GRASS and QGIS.
  - SAGA-GIS, or System for Automated Geoscientific Analyses, is a FOSS-GIS application developed by a small team of researchers from the Dept. of Physical Geography, Göttingen, and the Dept. of Physical Geography, Hamburg. SAGA has been designed for an easy and effective implementation of spatial algorithms, offers a comprehensive, growing set of geoscientific methods, provides an easily approachable user interface with many visualisation options, and runs under Windows and Linux operating systems.
  - PostGIS is a geospatial extension to the PostGreSQL relational database.

Geospatial Data Abstraction Library (GDAL)

- GDAL is a set of software tools that translate between almost any geospatial format in common use today (and some not so common ones).
- GDAL also contains tools for editing and manipulating both raster and vector files, including reprojecting data to different CRSs.

This workshop

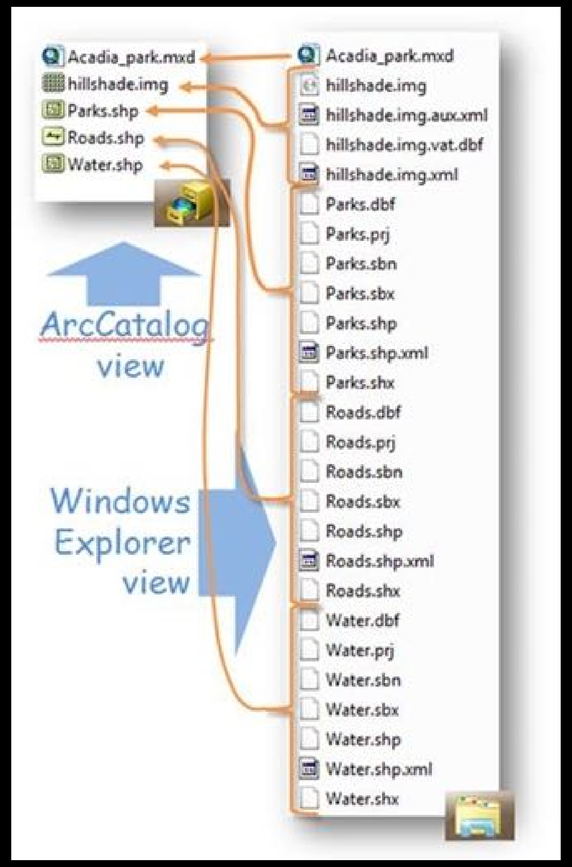
File formats - raster

	GeoTIFF	.tiff	Popular raster format similar to `.tif` format but stores raster header.	Raster	Open
	Arc ASCII	.asc	Text format where the first six lines represent the raster header, followed by the raster cell values arranged in rows and columns.	Raster	Open
	R-raster	.gri, .grd	Native raster format of the R-package raster.	Raster	Open
	SQLite/SpatiaLite	.sqlite	Standalone relational database, SpatiaLite is the spatial extension of SQLite.	Vector and raster	Open
	ESRI FileGDB	.gdb	Spatial and nonspatial objects created by ArcGIS. Allows: multiple feature classes; topology. Limited support from GDAL.	Vector and raster	Proprietary
	GeoPackage	.gpkg	Lightweight database container based on SQLite allowing an easy and platform-independent exchange of geodata	Vector and raster	Open

File formats - vector

Name	Extension	Info	Type	Model
ESRI Shapefile	.shp (the main file)	Popular format consisting of at least three files. No support for: files > 2GB; mixed types; names > 10 chars; cols > 255.	Vector	Partially open
GeoJSON	.geojson	Extends the JSON exchange format by including a subset of the simple feature representation.	Vector	Open
KML	.kml	XML-based format for spatial visualization, developed for use with Google Earth. Zipped KML file forms the KMZ format.	Vector	Open
GPX	.gpx	XML schema created for exchange of GPS data.	Vector	Open

ESRI shapefile - more than 1 file!




```
192-168-1-16:US-Boundary-Layers darya$ ls -1 US-State-Boundaries-Census-2014*
US-State-Boundaries-Census-2014.cpg
US-State-Boundaries-Census-2014.dbf
US-State-Boundaries-Census-2014.prj
US-State-Boundaries-Census-2014.qpj
US-State-Boundaries-Census-2014.shp
US-State-Boundaries-Census-2014.shp.xml
US-State-Boundaries-Census-2014.shx
```

Data for this workshop

GeoTIFF is a standard .tif image format with additional spatial (georeferencing) information embedded in the file as tags. These tags should include the following raster metadata:

- **Extent**
- **Resolution**
- **Coordinate Reference System (CRS)**
- **Values that represent missing data (NoDataValue) - we will introduce this concept in the programming lesson.**

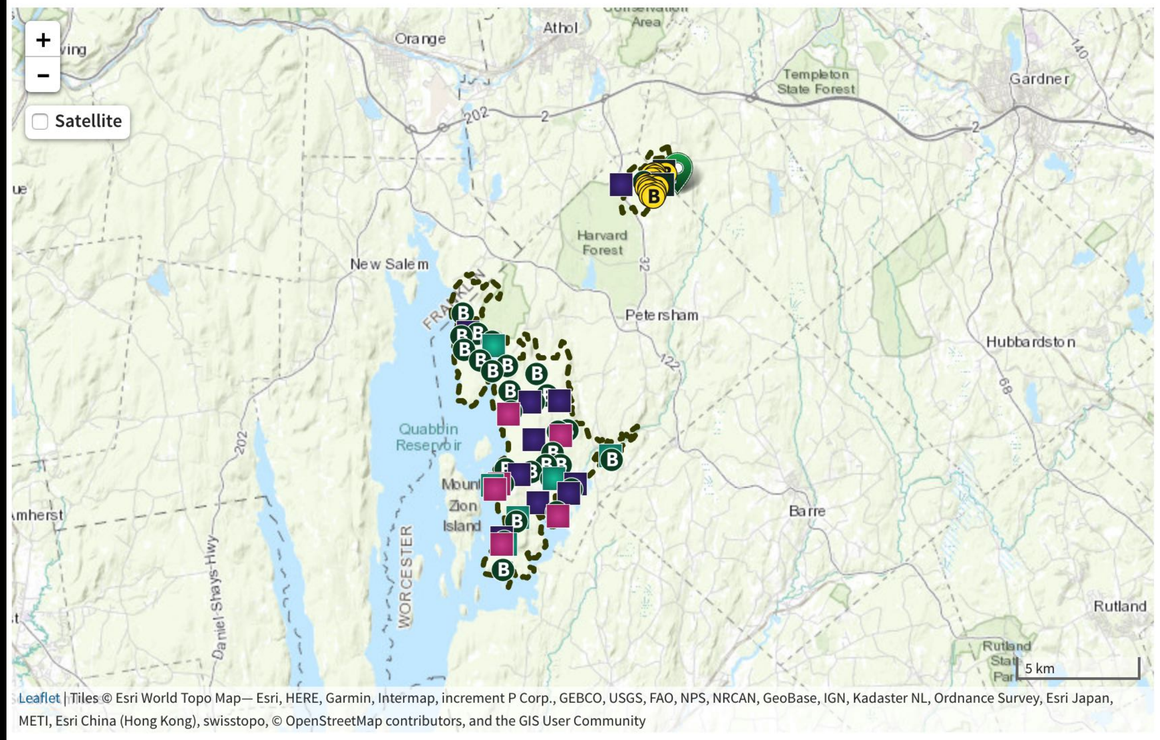
ESRI shape files will also store metadata for the vector data encoded in them:

- **Extent**
- **Coordinate Reference System (CRS)**

HARV

Harvard Forest - HARV

Core Terrestrial | Massachusetts | D01: Northeast



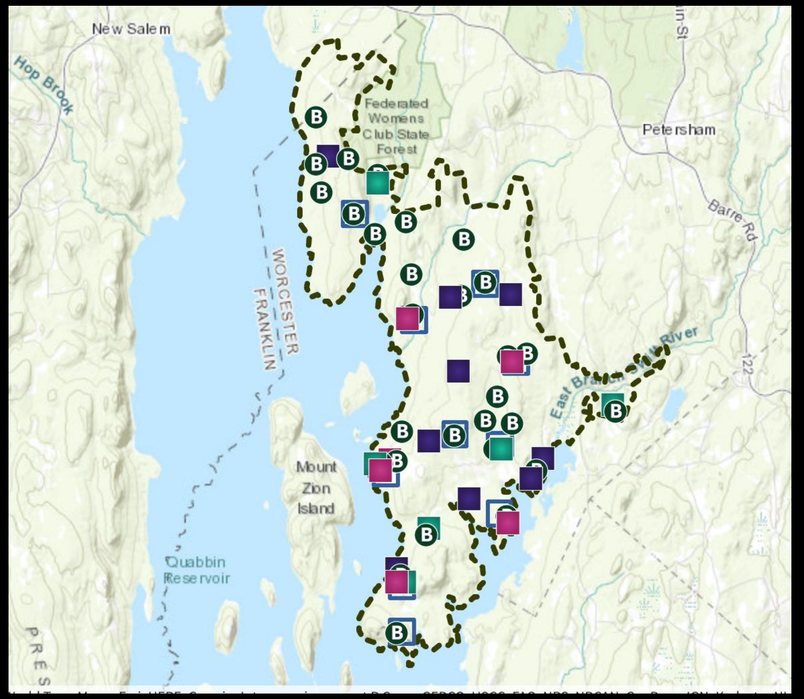
Map Legend

Click the check boxes to filter results on the map

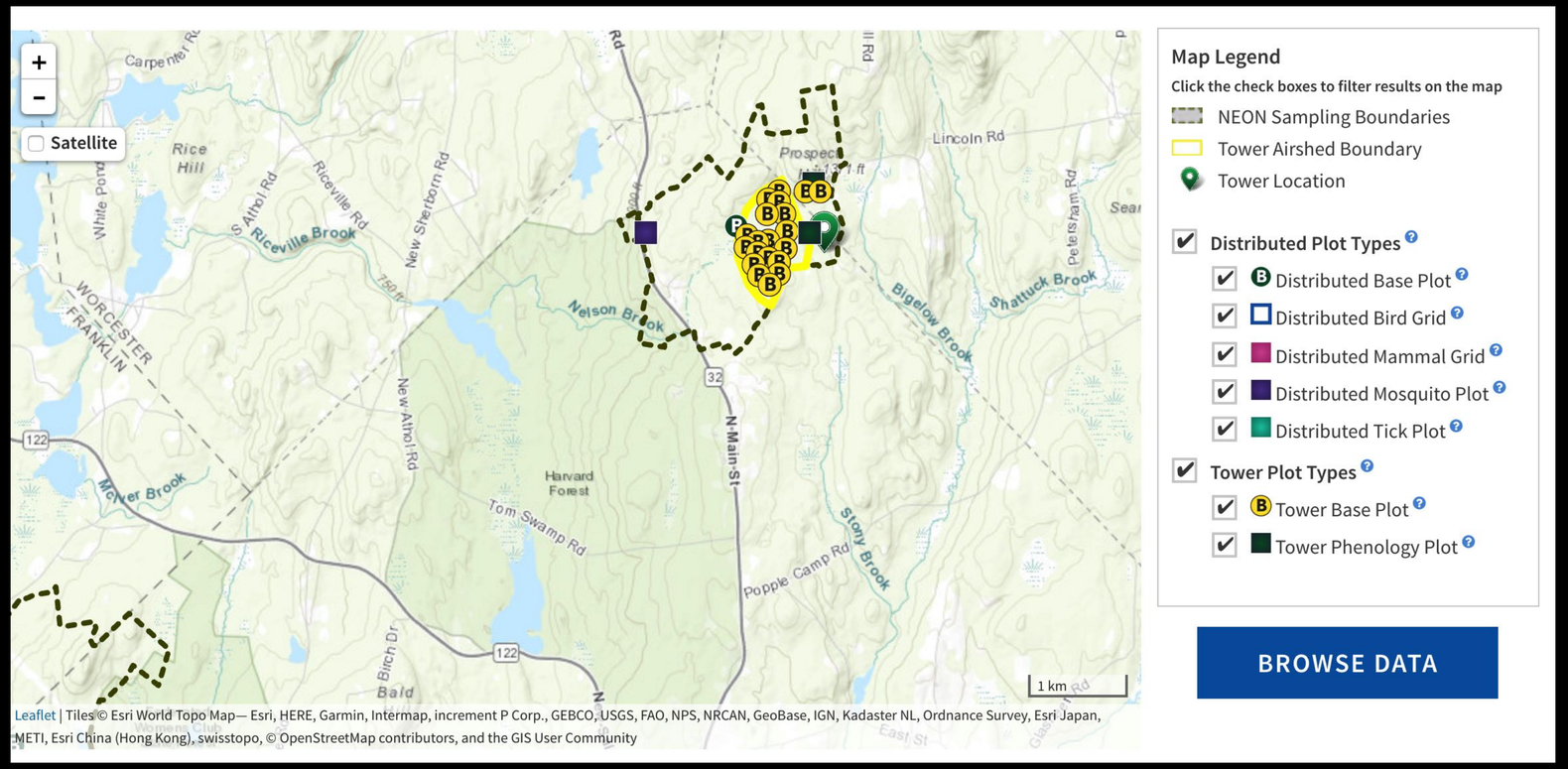
- NEON Sampling Boundaries
- Tower Airshed Boundary
- Tower Location

- ☑ **Distributed Plot Types**
  - ☑ Distributed Base Plot
  - ☑ Distributed Bird Grid
  - ☑ Distributed Mammal Grid
  - ☑ Distributed Mosquito Plot
  - ☑ Distributed Tick Plot
- ☑ **Tower Plot Types**
  - ☑ Tower Base Plot
  - ☑ Tower Phenology Plot

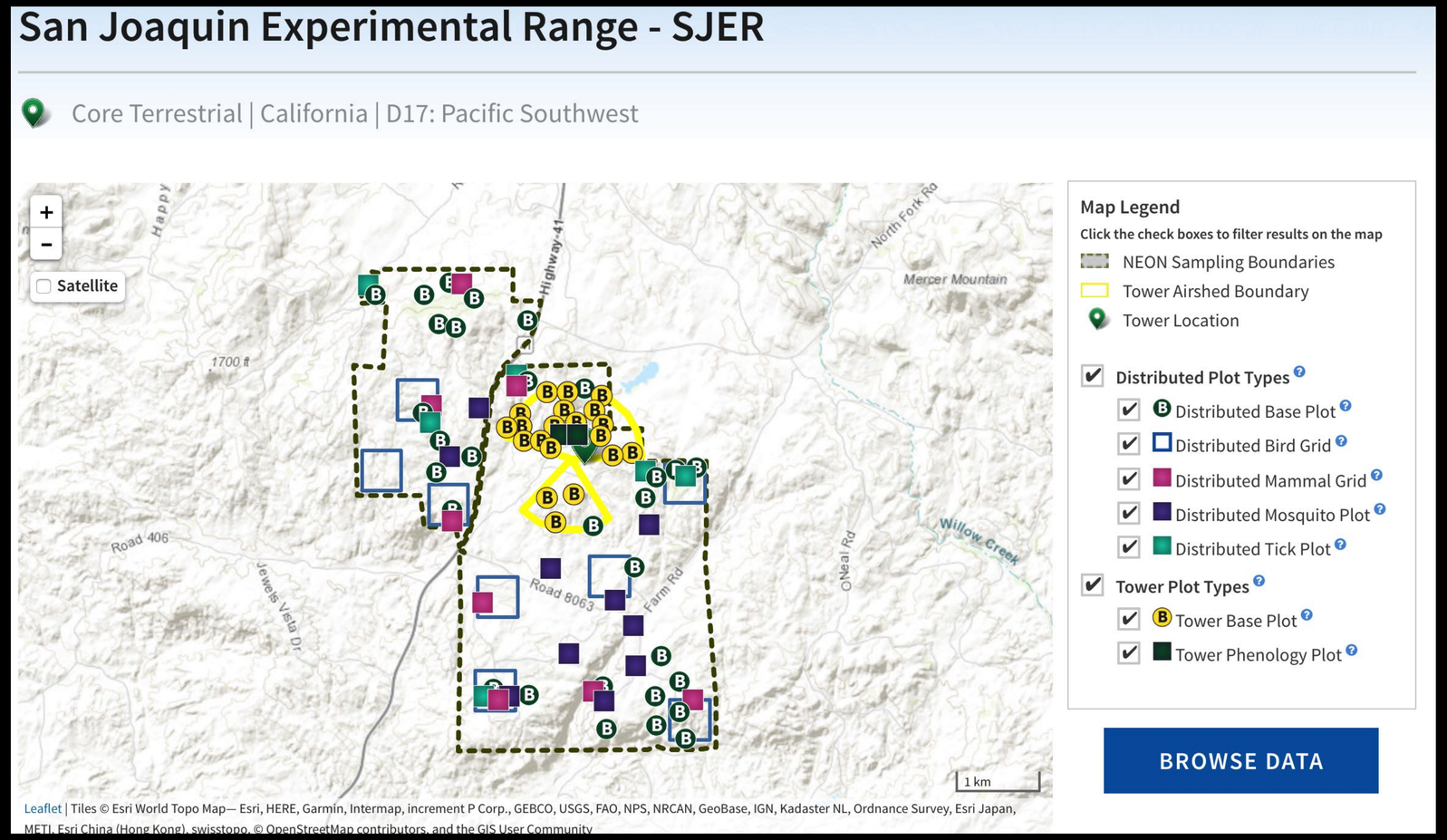
BROWSE DATA



HARV


Satellite
Rice Hill
White Pond
Riceville Rd
Riceville Brook
New Sherborn Rd
Lincoln Rd
Nelson Brook
Bigelow Brook
Shattuck Brook
WORCESTER
FRANKLIN
New Athol Rd
N Main St
32
122
Harvard Forest
Tom Swamp Rd
Popple Camp Rd
Stony Brook
McIver Brook
Birch Dr
Bald
1 km
Leaflet | Tiles © Esri World Topo Map— Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
Map Legend
Click the check boxes to filter results on the map
NEON Sampling Boundaries
Tower Airshed Boundary
Tower Location
Distributed Plot Types
Distributed Base Plot
Distributed Bird Grid
Distributed Mammal Grid
Distributed Mosquito Plot
Distributed Tick Plot
Tower Plot Types
Tower Base Plot
Tower Phenology Plot
BROWSE DATA

SJER


San Joaquin Experimental Range - SJER
Core Terrestrial | California | D17: Pacific Southwest
Satellite
Happy
Highway-41
North Fork Rd
Mercer Mountain
1700 ft
Road 406
Jewels Vista Dr
Road 8063
Farm Rd
ONeal Rd
Willow Creek
1 km
Leaflet | Tiles © Esri World Topo Map— Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
Map Legend
Click the check boxes to filter results on the map
NEON Sampling Boundaries
Tower Airshed Boundary
Tower Location
Distributed Plot Types
Distributed Base Plot
Distributed Bird Grid
Distributed Mammal Grid
Distributed Mosquito Plot
Distributed Tick Plot
Tower Plot Types
Tower Base Plot
Tower Phenology Plot
BROWSE DATA

MAIN R libraries

- Tidyverse (non GIS-specific), including ggplot
- sf (supersedes sp) - vector
- raster - raster data
- rgdal
- [recommended] tmap, leaflet

Other useful resources and libraries

- R packages:
  - gstat, for spatial and spatio-temporal geostatistics
  - geosphere, for spherical trigonometry
  - adehabitat used for the analysis of habitat selection by animals
  - rgeos, an R interface to the open-source geometry library (GEOS)
  - tmap, mapview, leaflet
  - tidycensus (US)
- Online courses/textbooks:
  - https://geocompr.robinlovelace.net #AMAZING online textbook!
  - Earth analytics course https://www.earthdatascience.org/courses/earth-analytics/
  - https://mgimond.github.io/Spatial/index.html
- Mailing list
  - https://stat.ethz.ch/pipermail/r-sig-geo/

Getting data

Package	Description
getlandsat	Provides access to Landsat 8 data.
osmdata	Download and import of OpenStreetMap data.
raster	getData() imports administrative, elevation, WorldClim data.
rnaturalearth	Access to Natural Earth vector and raster data.
rnoaa	Imports National Oceanic and Atmospheric Administration (NOAA) climate data.
rWBclimate	Access World Bank climate data.