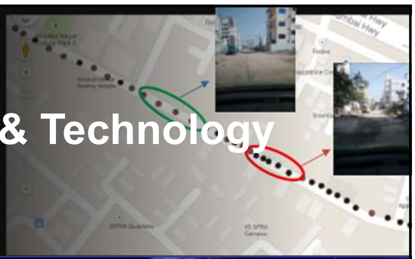
Intro to Spatial Science & Technology



Lec 10: Spatial Data Models – Raster & Projections

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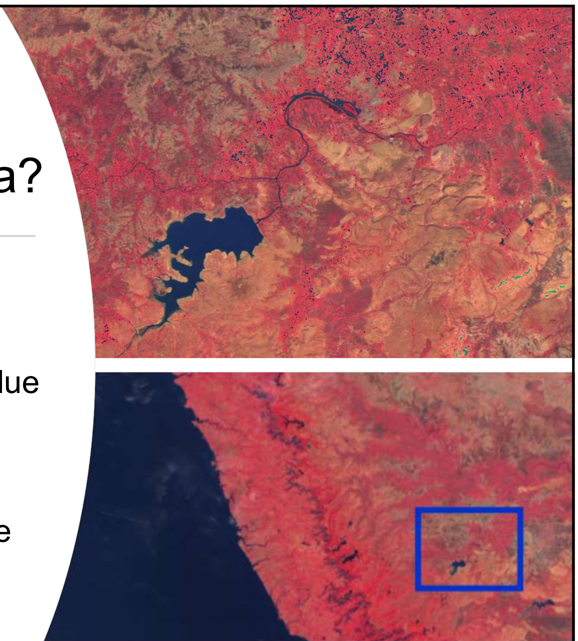
How to handle Continuous Data?

Challenges:
- Don't have clear boundaries
- Gradually vary in value like Clay or Sand content in soil
- But, Computers can store/handle discrete entities

>> Similar to Images.
-- Pixels/Grids/Cells

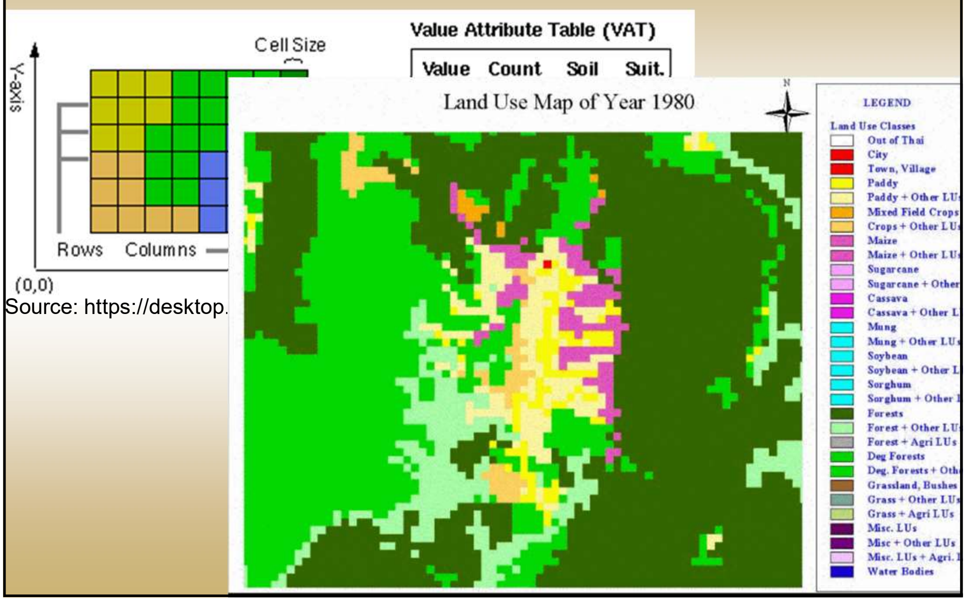


A Satellite Image
- IRS P6 image of the West Coast of India

Raster Data Model

- Divide the Surface into Equally spaced intervals in each dimension - **grid cells or pixels**
- Can be Squares or rectangles that are filled with the measured attribute values.
- Location matches each cell - intersection of line and pixel (also ref to as row and column numbers)
- Raster model is not constrained by the **Geometric shape of the Spatial Object**, as long as the shapes can be created with a set of interconnected (or contiguous) cell/s covering the planar surface
- Raster data's positional accuracy depends on the resolution of the data

Raster Data Model



Key aspects of Rasters

- Reference coordinate represents each pixel either at a corner or its centroid.
- Each cell or pixel has discrete attribute data assigned to it.
- Resolution is dependent on the pixel or grid size and may vary from centimeters to many kilometers.
- They are 2-Dimenstional data – hence similar to handling images
- Generally, raster data requires less processing than vector data, but it consumes more computer storage space.
- Scanning paper and other maps to Satellite/Aerial Imagery are stored and handled as raster layers.
- GIS store various information such as forest cover, soil type, land use, wetland habitat, population density, etc., in different raster layers.

Sample Data of a Raster

```
ncols         1000
nrows         900
xllcorner     76.6
yllcorner     12.5
cellsize      0.008333
NODATA_value  -9999
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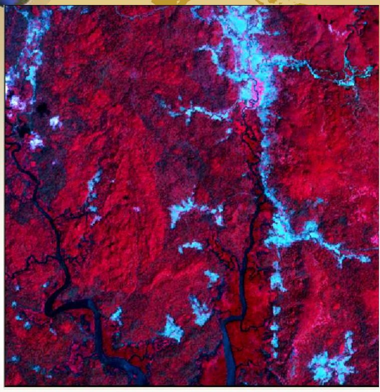
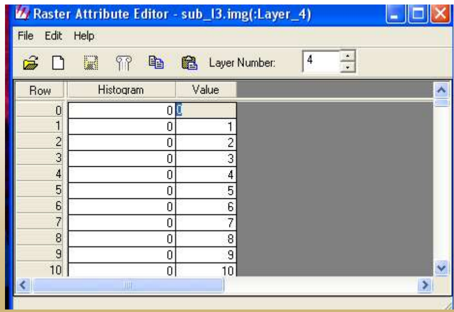
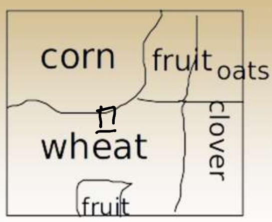


Part of Andaman - Image



Representing Data using *Raster* Model (1/2)

- area is covered by grid with (usually) equal-sized cells
- location of each cell calculated from origin of grid:
- cells often called *pixels* raster data often called ***image*** data
- A pixel is the contraction of the words picture element. Commonly used in remote sensing to describe each unit in an image
- In raster GIS the pixel equivalent is usually referred to as a cell element or **grid cell**.
- Pixel/cell refers to the smallest unit of information available in an image or raster map. This is the smallest element of a display device that can be independently assigned attributes such as colour.



	0	1	2	3	4	5	6	7	8	9
0	1	1	1	1	1	4	4	5	5	5
1	1	1	1	1	1	4	4	5	5	5
2	1	1	1	1	1	4	4	5	5	5
3	1	1	1	1	1	4	4	5	5	5
4	1	1	1	1	1	4	4	5	5	5
5	2	2	2	2	2	2	2	3	3	3
6	2	2	2	2	2	2	2	3	3	3
7	2	2	2	2	2	2	2	3	3	3
8	2	2	4	4	2	2	2	3	3	3
9	2	2	4	4	2	2	2	3	3	3

Representing Data using *Raster* Model (2/2)

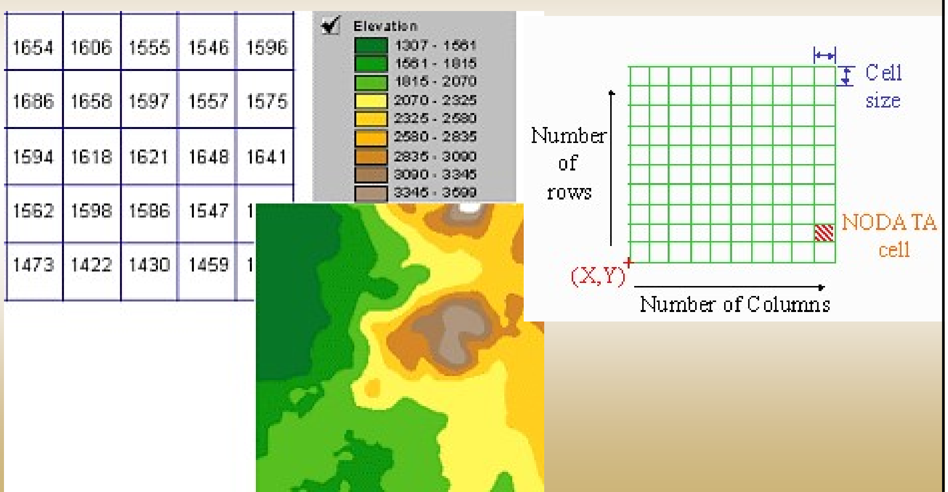
•<u>single</u> values associated with each cell
typically 8 bits assigned to values therefore 256 possible values (0-255) – can be of multiple bit or bytes too

•rules needed to assign value to cell if object does not cover entire cell
- majority of the area (for continuous coverage feature)
- value at cell center
- 'touches' cell (for linear feature such as road).

•easy to do overlays/analyses, just by 'combining' corresponding cell values

•simple data structure
•directly store each layer as a single table (basically, each is analogous to a "spreadsheet")
•computer data base management system <u>not</u> required

A **grid** defines geographic space as a matrix of identically-sized square cells. Each cell holds a numeric value that measures a geographic attribute (like elevation) for that unit of space.



Some Formats of Image datasets:

- Raw formats (BIL,BIP,BSQ)
- ESRI Grid datasets
- Windows bitmap images (BMP) [.bmp]
- Multiband (BSQ, BIL and BIP) and single band images [.bsq, .bil and .bip]
- ERDAS [.lan and .gis], IMAGINE [.img]
- IMPELL Bitmaps [.rlc]
- JPEG [.jpg]
- MrSID [.sid]
- National Image Transfer Format (NITF)
- Sun rasterfiles [.rs, .ras and .sun]
- Tag Image File Format (TIFF) [.tiff, .tif and .tff]

Raster Data Handling

- Raw data formats are -
  - BIP, BIL and BSQ
  - Data size same as rows*col*datasize
  - Note: data can be in bit or bytes
- Data compression are part of many Image or raster data formats
  - Lossless compression (no change in values)
  - Lossy compression (- not used/preferred in GIS operations)

Vector vs Raster Graphics

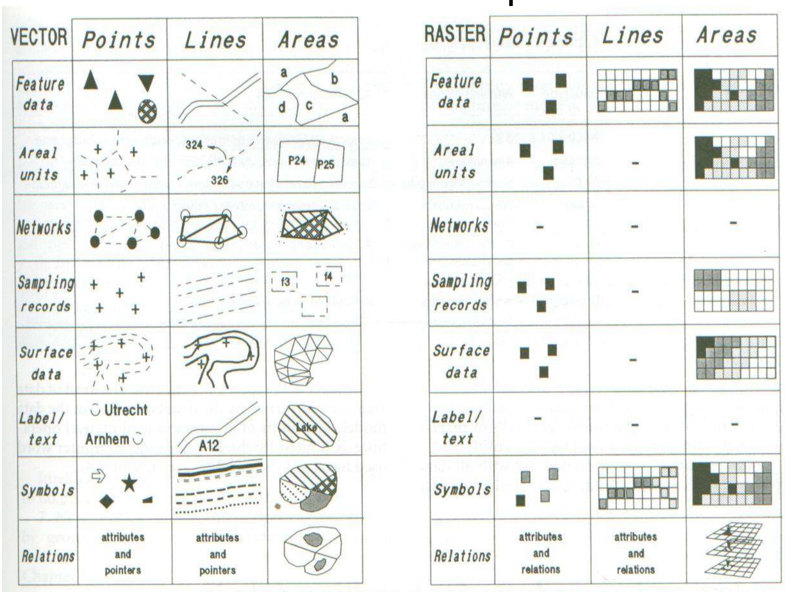


Image Source: Burrough, Peter A. and Rachael A. McDonnell. (1998). *Principles of Geographic Information Systems*. p 27.

Raster Data Model

Advantages

- It is a simple data structure
- Overlay operations are easily and efficiently implemented
- High spatial variability is efficiently represented in a raster format
- The raster model is more or less required for efficient manipulation and enhancement of digital images

Disadvantages

- The raster data structure is less compact data compression techniques (an often overcome this problem)
- Topological relationships are more difficult to represent
- The output of graphics is less aesthetically pleasing because appearance rather than the smooth lines of hand-drawn maps. This can be overcome by using a very large number of cells, but may result in unacceptably large files

Vector Data Model

Advantages

- It provides a more compact data structure than the raster model
- It provides efficient encoding of topology and as a result more efficient implementation of operations that require topological information, such as network analysis
- The vector model is better suited to supporting graphics that closely approximate hand-drawn maps

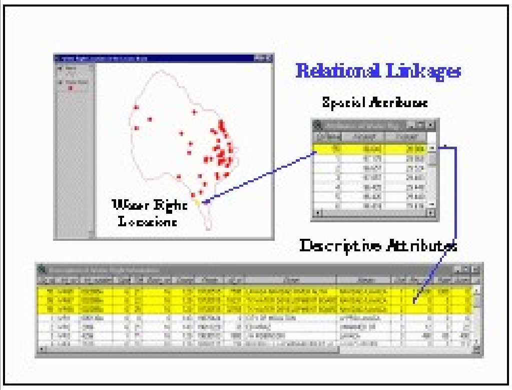
Disadvantages

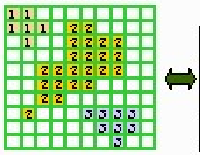
- It is a more complex data structure than a simple raster
- Overlay operations are more difficult to implement
- The representation of high spatial variability is inefficient
- Manipulation and enhancement of digital images cannot be effectively done in the vector domain

Attribute information stored in tables

Feature tables for vector data

Value attribute tables for categorical (integer) grid data

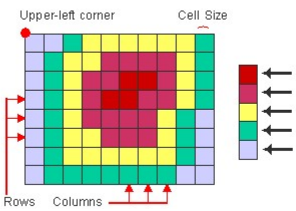




Treetype Grid

Value	Count	Type	Code
1	6	Maple	200
2	23	Oak	400
3	8	Pine	300

Treetype.vat



Value	Fire Spread
1	Day 1
2	Day 2
3	Day 3
4	Day 4
5	Day 5

Additional Reading

Vector models like TIGER, DLG, DNG, DXF, DWG etc

Raster formats like JPEG, TIFF, GEOTIFF, MrSID etc

GIS - Information stored in them

- Spatial (geometric/positional) info – locations of features, relative position to similar or other entities, shape/spread, distribution
- Coordinate System info – the exact location of the feature/s on the surface of the earth
- Attribute info – information pertaining to the spatial features or characteristics of the entities
- Symbology – how the spatial and attribute data are visualized or displayed
- Metadata – “Data about data”; information about the particular file containing the spatial data and its attributes

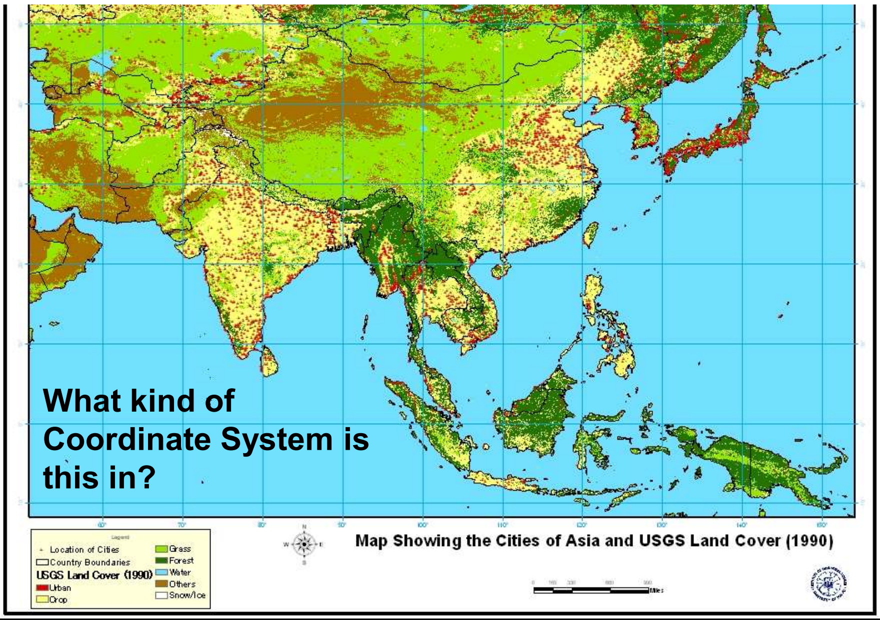
Data Compatibility

- Multi Sources
- Coordinate Systems
  - Local or Global
- Important aspect of GIS
  - Building relationships between Multiple Thematic Layers
- What is the first step?
  - Matching the Coordinate Systems

Other Data Compatibility Issues

- Scale
- Sampling Distances (if raster)
- Geometrical characteristics
- GIS Data Model
- Data Formats
  - Interoperability

USGS Global Land Cover



Plane Orthogonal Cartesian Coordinates

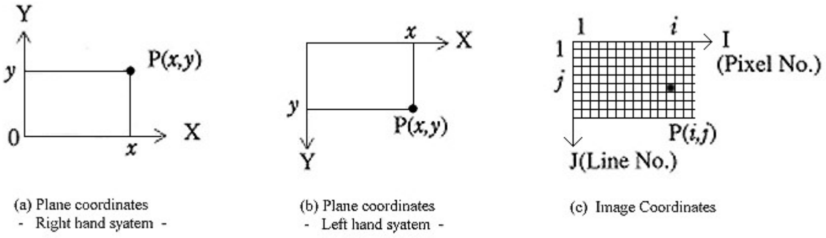


Figure 1.1 Plane Orthogonal Catesian Coordinates

Polar coordinates

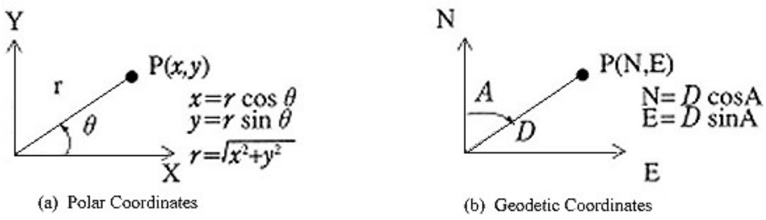


Figure 1.2 Polar Coordinates

Coordinate Systems for a Map

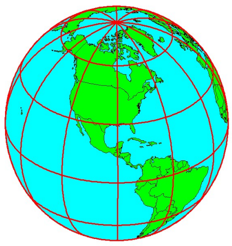
(1) Global Cartesian coordinates (x,y,z) for the whole earth

(2) Geographic coordinates (Longitude, Lattitude and Elevation)

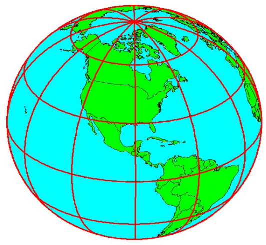
(3) Projected coordinates (x, y, z) on a local area of the earth's surface – based on a local or global reference

Shape of the Earth

We think of the earth as a sphere



It is actually a spheroid, slightly larger in radius at the equator than at the poles

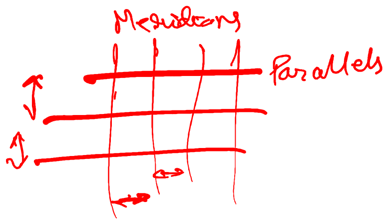


- Latitude (f) and Longitude (l) defined using an Ellipsoid, an ellipse rotated about an axis
- Elevation (z) defined using Geoids, a surface of constant gravitational potential
- Earth Datums define standard values of the ellipsoid and geoid

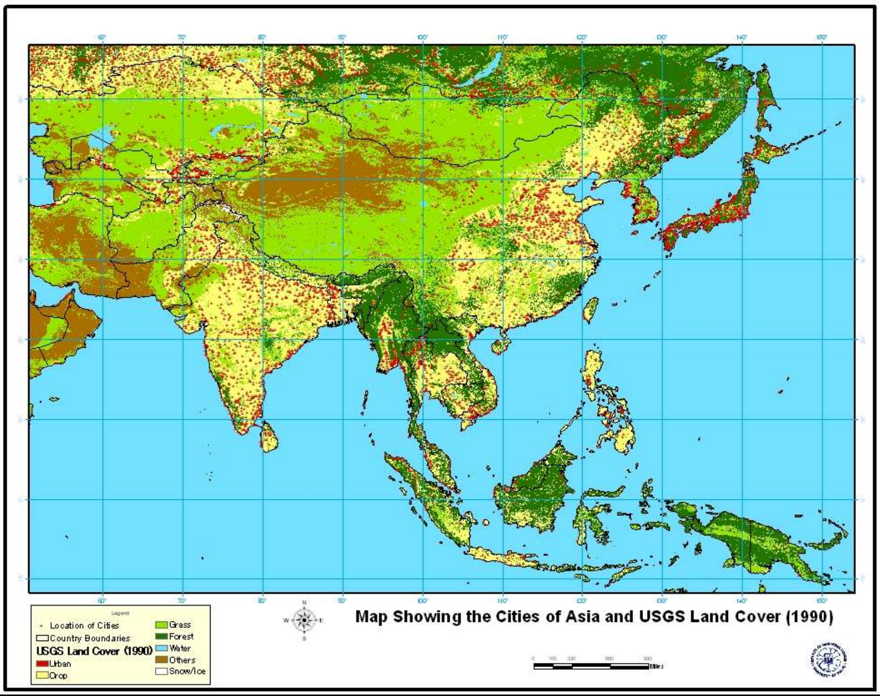
Map projections – Earth's Graticules

The Earth's graticule has the following properties:

- all parallels of latitude are parallel
- parallels are equally spaced along meridians
- meridians are equally spaced along parallels
- meridians of longitude are half great circles and converge at the poles
- meridians and parallels intersect at right angles
- quadrilaterals formed by the same two parallels and having the same longitudinal dimensions have the same areas
- area scale is uniform
- distance scale is uniform



Ellipsoid vs. Sphere



Properties that Projections try to Preserve

1. Conformality is the characteristic of true shape
2. *Equivalence* is the characteristic of equal area.
3. *Equidistance* is the characteristic of true distance measuring.
4. Azimuth means directionality

1807
official projections

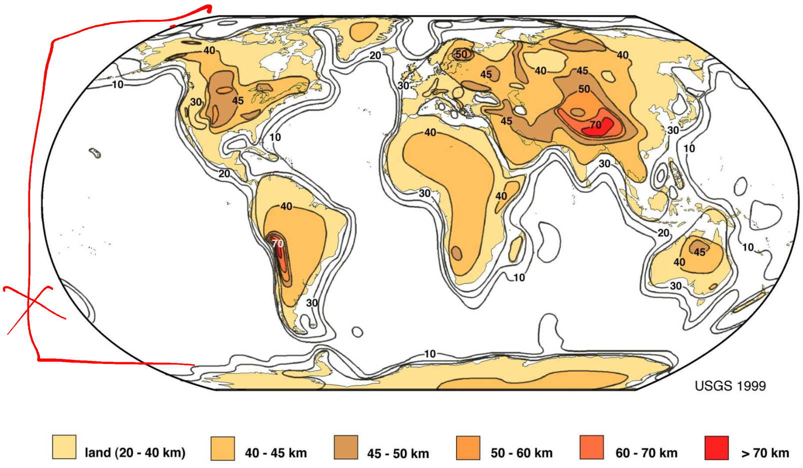
Each projection is a model of the earth's surface and tries to minimize overall distortion but is unable to preserve all the four spatial properties of area, shape, distance, and direction.

The Robinson projection, for example, is neither equal area nor conformal but is aesthetically pleasing and useful for general mapping.

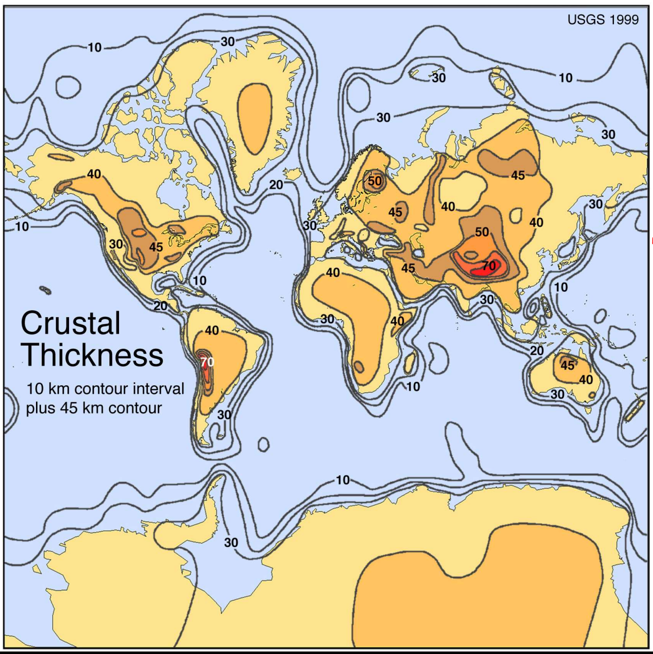
[Source: http://www.forestry.umt.edu/academics/courses/FOR503/Part4.htm]

Robinson

The Thickness of the Earth's Crust



CS4.408 Spatial Informatics



Mercator

Transverse

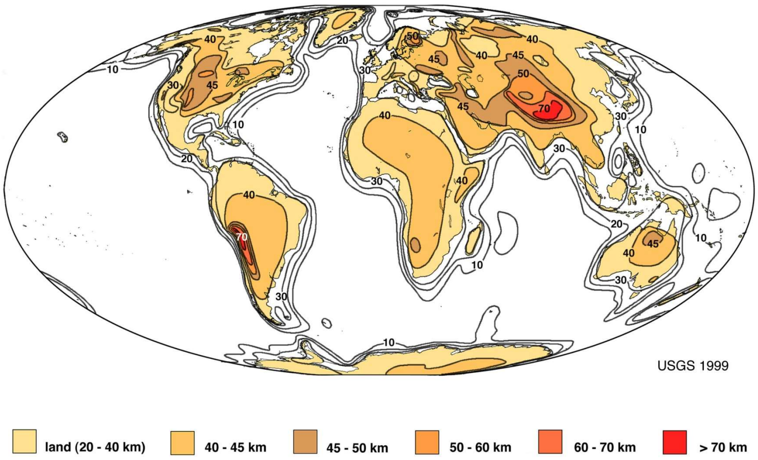
TM

UTM

Universal

Molleweide

The Thickness of the Earth's Crust



CRS – Projection Codes

- Coordinate Reference System or Spatial reference System – helps to use a common framework to define the various parameters of the Projection system and helps in interoperability
- Also referred as EPSG Codes or SRID integer
- Proj4, now PROJ, is a Coordinate transformation software library that provides methods to transform between different coordinate reference systems. It is an Open Source Project managed by OSGeo Foundation https://proj.org/

UTM 32644 44N

- Also see
  - https://www.w3.org/2015/spatial/wiki/Coordinate_Reference_Systems
  - https://en.wikipedia.org/wiki/Spatial_reference_system