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Principles of Geographical Information System,

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III. Coordinate system

Outline

- Coordinate system?
- Types of coordinate system
  - *Geographic coordinate system*
    - How geographic coordinate systems work to locate position?
  - *Projected coordinate system*
    - Why map projection
    - How projected coordinate systems works to locate position?
- Datum
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What is coordinate system?

- A **coordinate system** is a system that uses numbers or coordinates to determine the position of a point or geometric element within a geographic framework.
- A coordinate system is also used as a reference system to represent locations of geographic features, observation points, GPS (Global Positioning System) points, and imagery within this framework.
- The simplest coordinate system consists of coordinate axes oriented perpendicularly to each other, known as Cartesian coordinates.
- Depending on the type of problem under consideration, a specific type of coordinate systems may be better to use than others (Bolstad, n.d.).

Coordinate system ...

Coordinate system and spatial reference system ??

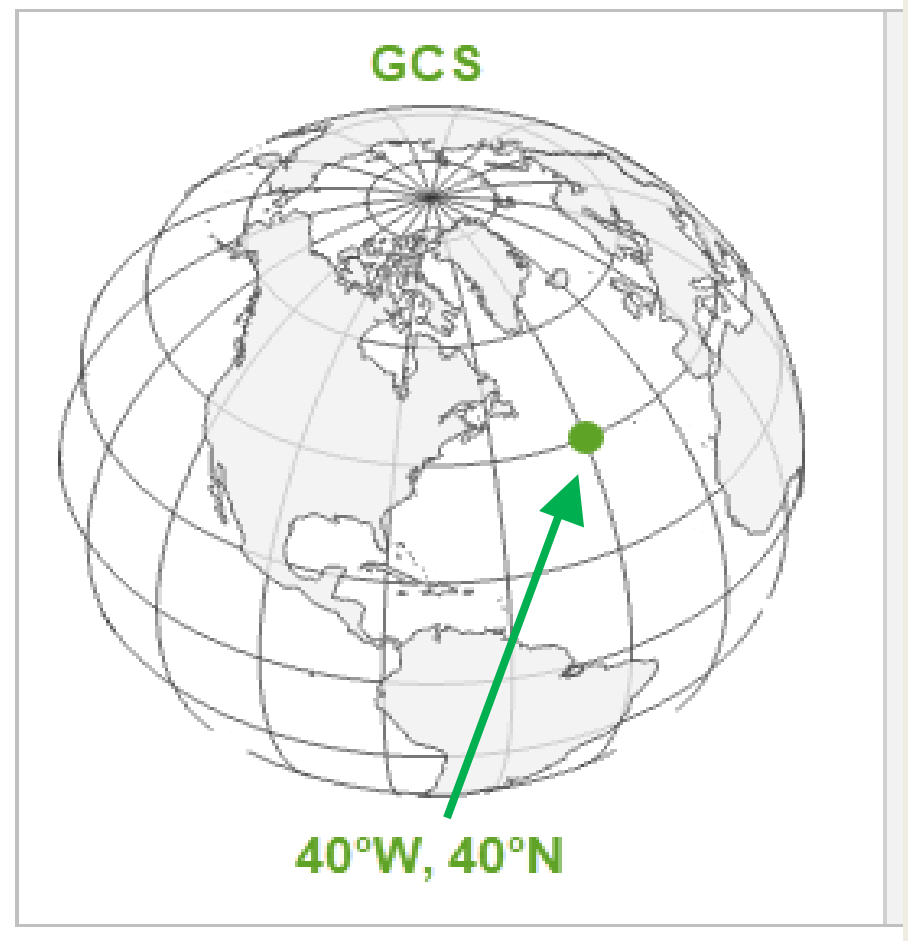
- Coordinate System is the most general term for a system that includes coordinates.
- Spatial Reference System is a coordinate system used to reference spatial information, typically to the surface of the earth. These two terms, and their acronyms, are used interchangeably in GIS.
- A data structure **cannot** be considered **geospatial** unless it is accompanied by coordinate reference system (CRS) information, in a format that geospatial applications can use to display and manipulate the data correctly.
- CRS information connects data to the Earth's surface using a mathematical model.

Types of coordinate system

- Two types of coordinate systems or spatial reference systems are commonly used:
  - *Geographic coordinate system and*
  - *Projected coordinates system*

Geographic coordinate system

- A geographic coordinate system (GCS) is a reference framework that defines the locations of features on a model of the earth.
- A GCS is round, and so records locations in angular units (usually degrees).
- Geographic coordinate system is necessary for data to know where exactly on earth's surface it is located (Smith, 2020).



Geographic …

- Geographic Coordinate Systems are defined by a **Datum.**
- A **Datum** essentially defines the Globe Model of the coordinate system
- It has:
  - *angular units (e.g. degrees)*
  - *Defines a **starting point** (i.e. where is (0, 0) in particular which longitude is defined to be 0°?), so the angles reference a meaningful spot on the earth.*
  - *Defines the **position of the spheroid relative to the center** of the earth and therefore the origin and orientation of latitude and longitude lines.*
- A **point** is referenced by its longitude and latitude values**.**
- Longitude and latitude are angles measured from the earth's center to a point on the earth's surface.

Geographic …

- Geographic coordinate system answers the question: where?

Case: Where?

- You are part of a search and rescue (saving) team looking for an injured person in the Australian outback. The point location you have from the person's satellite phone is 134.577°E, 24.006°S. Where is the person located?
  - *A? or B? from the figure in the right*

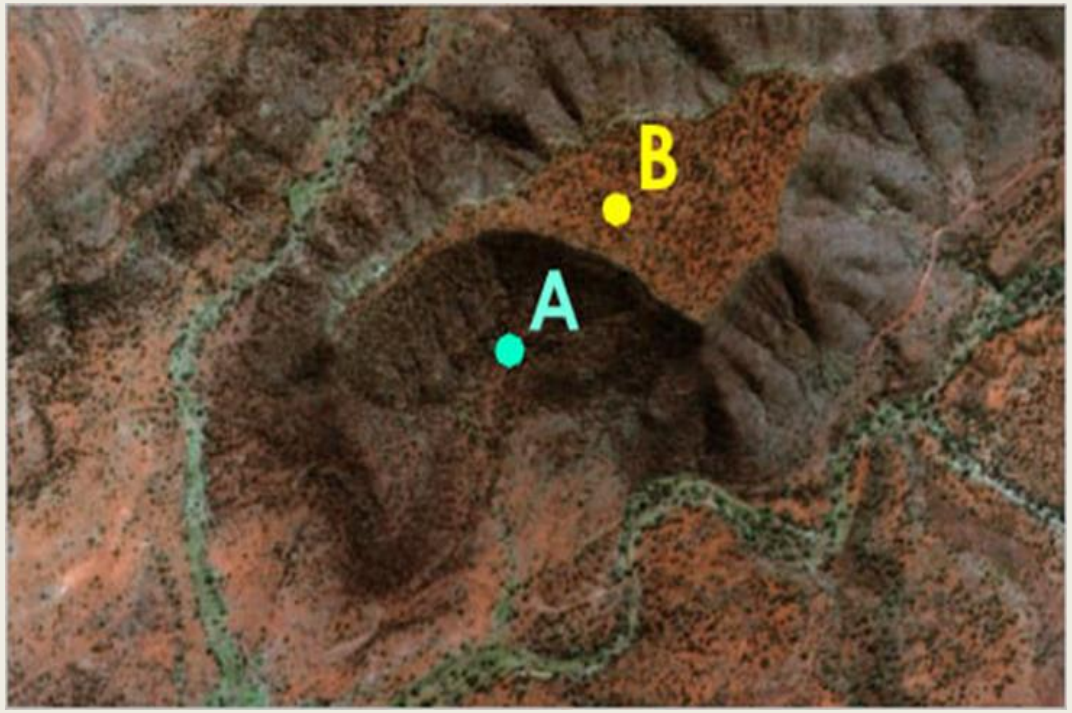


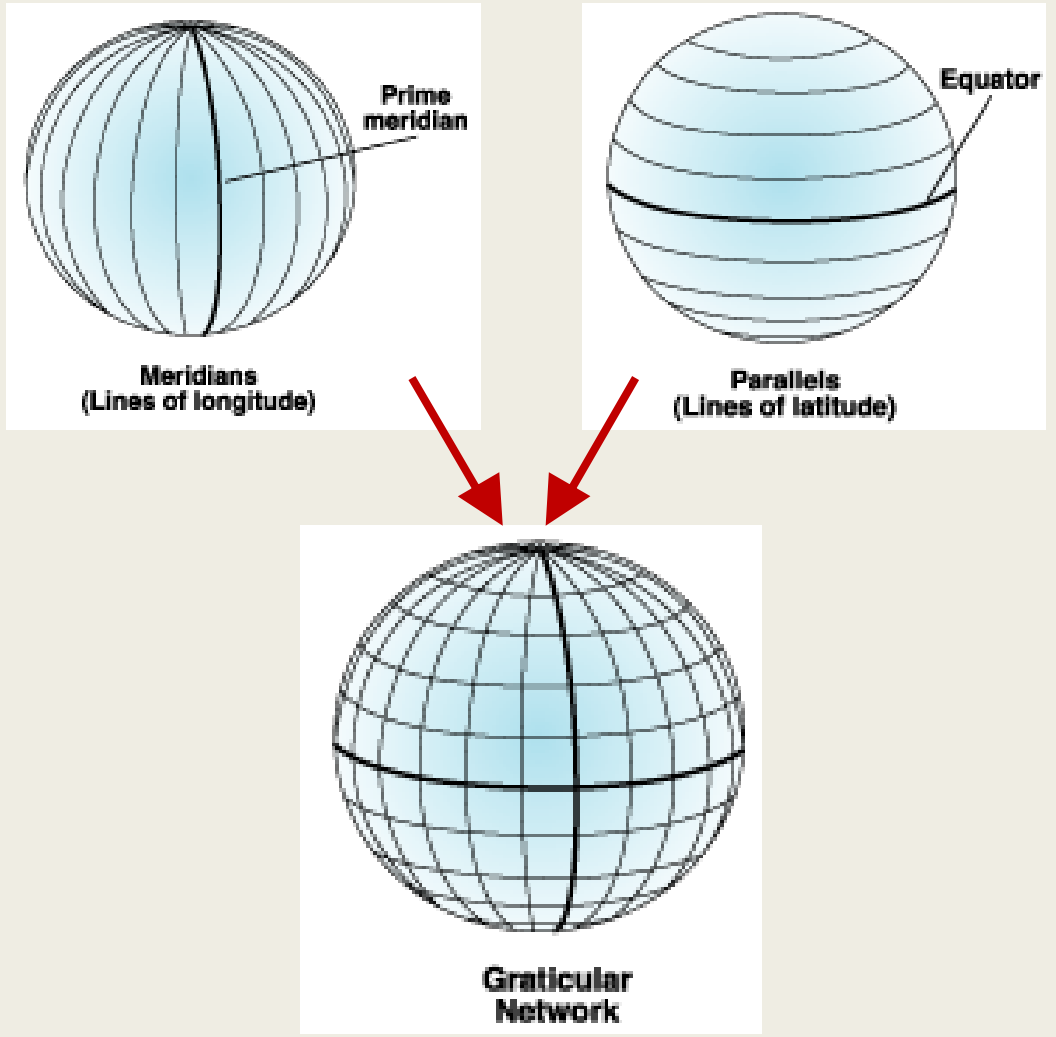
Image source: https://www.esri.com/arcgis-blog/wp-content/uploads/2020/02/4.png

Geographic …

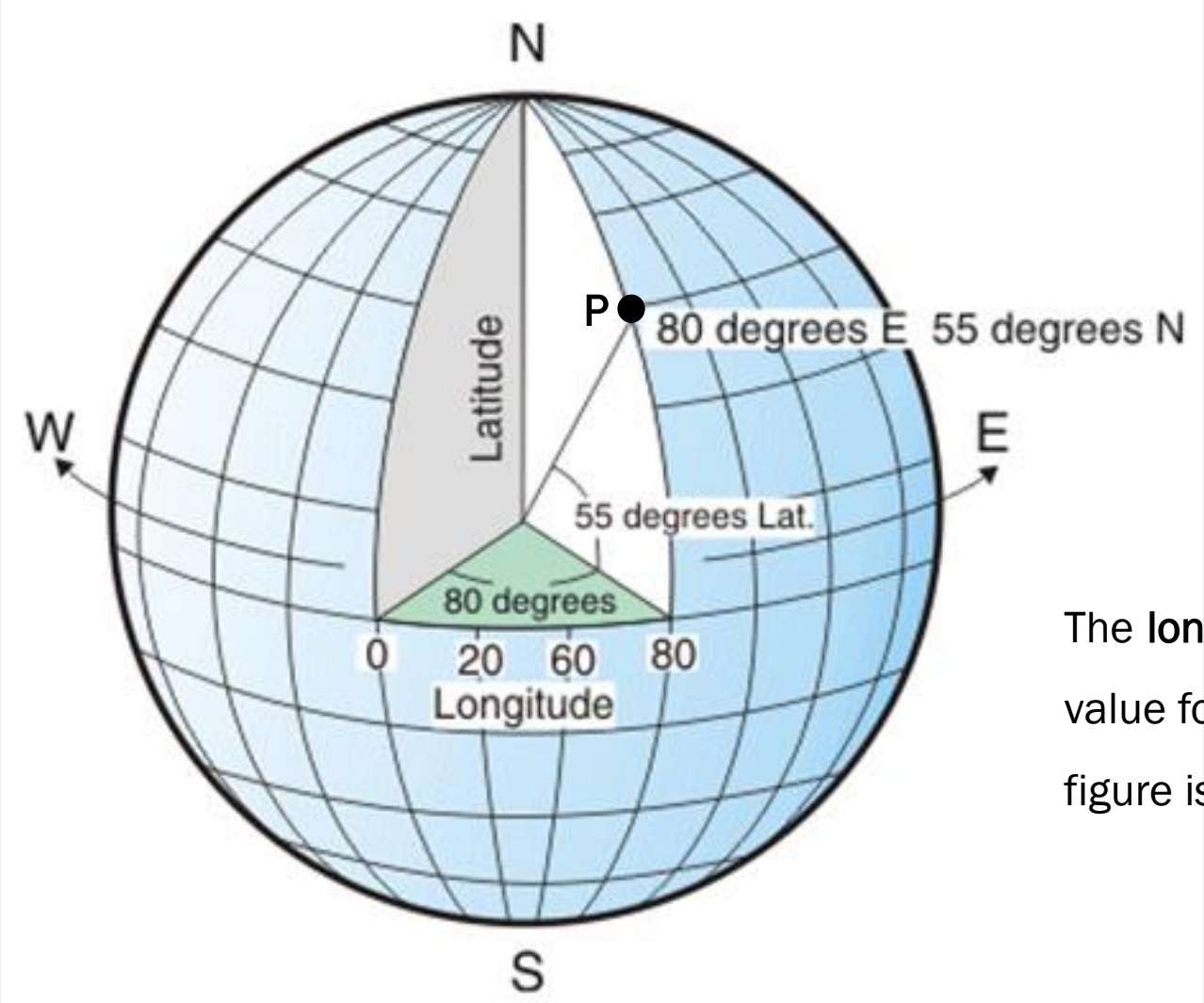
- Both location A and B in the above image are correct. A is 134.577°E, 24.006°S in one GCS (*Australian Geodetic Datum 1984*) and B is the same coordinate location in another (*WGS 1984*).
- Without knowing which GCS the data is in, you don't know if the hiker is on top of the plateau or if the person has fallen off the cliff.

How geographic coordinate system works to locate positions?

- The geographic coordinate system (GCS) uses a network of imaginary lines (longitude and latitude) to define locations (Smith, 2020).
- This network is called a **graticule**.
- They are angles measured from the earth's center to a point on the earth's surface.



How geographic coordinate ...



The **longitude** and **latitude** value for the point **P** in the figure is: **P(80^{0}E, 55^{0}N).**

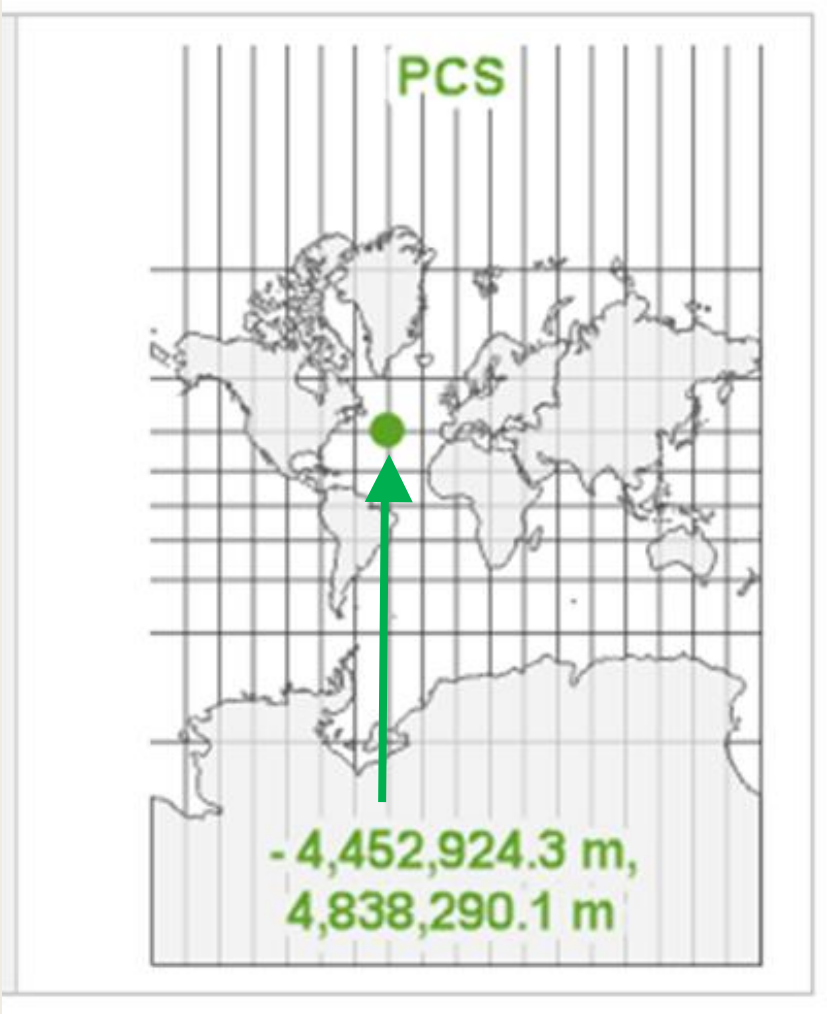
Advantages and disadvantages of geographic coordinate system

Advantages
• Location of points or objects are exactly referenced to the earth's model • No distortions of the properties of geographic objects on the chosen model

Disadvantages
• Position of object is measured in degrees, which make it difficult to measure distance and area

Projected coordinate system

- A projected coordinate system (PCS) is a GCS that has been flattened using math (the projection algorithm) and other parameter**.** It tells the data ***how*** to draw on a flat surface, like on a paper map or a computer screen (Smith, 2020).
- PCS records locations in linear units (usually meters).
- Projected coordinate systems include **a projection.**
- A Projection is a mathematical transformation of the angular measurements on a round earth to a flat surface (i.e. paper or a computer screen).



Why map projection?

- Once your data knows ***where*** to draw, it needs to know ***how***.
- The earth's surface and your GCS are round, but your map and your computer screen are flat. That's a problem.
- You can't draw the round earth on a flat surface without deforming it.
- Imagine peeling an orange and trying to lay the peel flat on a table. You can get close, but only if you start tearing the peel apart. This is where **map projections** come in. They tell you how to distort the earth how to tear and stretch that orange peel so the parts that are most important to your map get the least distorted and are displayed best on the flat surface of the map (Smith, 2020).

Why map projection? …

Image source: http://blogs.lincoln.ac.nz/gis/wp-content/uploads/sites/16/2017/03/laranjoide_1.jpg

Why map projection? …

- A **map projection** is one of many methods used to represent the 3-dimensional surface of the earth or other round body on a 2-dimensional plane in cartography (mapmaking) (Dempsey, 2002).
- The creation of a map projection involves three steps in which information is lost in each step:
  - ✓ *Selection of a model for the shape of the earth or round body (choosing between a sphere or ellipsoid)*
  - ✓ *Transform geographic coordinates (longitude and latitude) to plane coordinates (eastings and northings).*
  - ✓ *Reduce the scale (in manual cartography this step came second, in digital cartography it comes last)*

How projected coordinate systems works to locate positions?

- In a projected coordinate system, locations are identified by x, y coordinates on a grid, with the origin at the center of the grid.
- Each position has two values that reference it to that central location.
- One specifies its horizontal position and the other its vertical position.
- The two values are called the x-coordinate and y-coordinate.
- Using this notation, the coordinates at the origin are x = 0 and y = 0. on the left figure, the values (-4452924.3, 4838290.1) indicates the location (x, y) of the green point. The negative value indicates that the point is to the left (west) of the central y axes indicating negative x values.

Advantages and disadvantages of projected coordinate system

Advantages	Disadvantages
• Easy to display objects on flat plane or paper. • Easier to measure distance and area of objects.	• We can only see the 2-D figure of the geographic object. • Distortion of shape, area, scale during the projection.

GCS Vs PCS

GCS	PCS
• Objects are located on the 3-D model of the Earth • Uses longitude and latitude to locate position • Position coordinates are measured in degrees • Distance and area are not easy to measure • Objects are on the reference model of the earth, so the properties of the object do not change	• Representation of the object on 2-D model of the Earth • Uses eastings (x) and northings (y) to locate position of objects • Position coordinates are measured in meter • Easier for distance and area measurement • When projecting from 3-D to 2-D, some properties of the object distorted.

Datum

- The **datum** is the part of the GCS that determines which model (spheroid) is used to represent the earth's surface and where it is positioned relative to the surface (Smith, 2020).
- A **datum** is a reference from which spatial measurements are made. In surveying and geodesy, a datum is a set of reference points on the earth's surface against which position measurements are made, and (often) an associated model of the shape of the earth (reference ellipsoid) to define a geographic coordinate system (Bolstad, n.d.).
- A *datum* in general is a reference point, surface, or baseline from which measurements are made. Naturally, there needs to exist consistent and standard regional or global reference frames for locating features on earth.

Types of datum

Vertical datums

- Vertical datums are used as a reference (zero surface) from which elevations and depths are measured.
- Vertical datums are either tidal, based on **sea levels**, or geodetic, based on the same **ellipsoid** models of the earth used for computing horizontal datums.
- In the past, datums were measured by survey control points using level bars and optical surface measurement tools. Today, vertical measurements are used via **GPS**, laser, and satellite (“Datum,” n.d.).

Types of datum …

Horizontal datums

- *Horizontal datums* act as base reference for measuring locations on the surface of the Earth. We use it to measure North and South (latitude), and to measure East and West (longitude).
- Both of these reference frames (datums) are dependent on the way the size and shape of the Earth is represented.
- Different models of the Earth produce different datums, and therefore affect the value of a location's elevation and position (coordinates). Consequently, an understanding of the shape of the Earth and different ways of representing it is a prerequisite to any discussion of datums.

Commonly used coordinate systems and datums

World wide

- Geographic coordinate system:
  - *CRS: WGS 84*
    - Datum: WGS 84
    - *EPSG: 4326*
  - *EPSG stands for European Petroleum Survey Group.*
  - WGS 84: *World Geodetic System 1984*

Ethiopia

- **Geographic coordinate system**
  - *CRS: GCS_Adindan*
    - *Datum: D_Adindan*
    - *EPSG code: 4201*
- ***Projected coordinate system***
  - *CRS: WGS 84/UTM Zone 36|37|38N*
    - *Datum: WGS 84*
    - *EPSG codes: 32636|7|8*
  - *CRS: Adindan/UTM Zone 36|7|8N*
    - Datum: Adindan
    - *EPSG Codes: 20136|7|8*

Thank you!!!

References

- Bolstad, P., n.d. GIS Fundamentals: A First Text on Geographical Information Systems, in: Chapter 3. p. 92.
- Coordinate Reference Systems – Introduction to Geospatial Concepts [WWW Document], n.d. URL https://datacarpentry.org/organization-geospatial/03-crs/ (accessed 12.28.20).
- Datum [WWW Document], n.d. URL http://geokov.com/education/datum.aspx (accessed 12.29.20).
- Dempsey, C., 2002. What is a Map Projection? GIS Lounge. URL https://www.gislounge.com/map-projection/ (accessed 12.28.20).
- GIS basics [WWW Document], n.d. URL https://annakrystalli.me/intro-r-gis/gis.html (accessed 12.23.20).
- GSP 270: Introduction to Coordinate Systems [WWW Document], n.d. URL http://gsp.humboldt.edu/OLM/Lessons/GIS/03%20Projections/IntroductionToCoordinateSystems1.html (accessed 12.24.20).
- Smith, H., 2020. Geographic vs Projected Coordinate Systems. ArcGIS Blog. URL https://www.esri.com/arcgis-blog/products/arcgis-pro/mapping/gcs_vs_pcs/ (accessed 12.23.20).