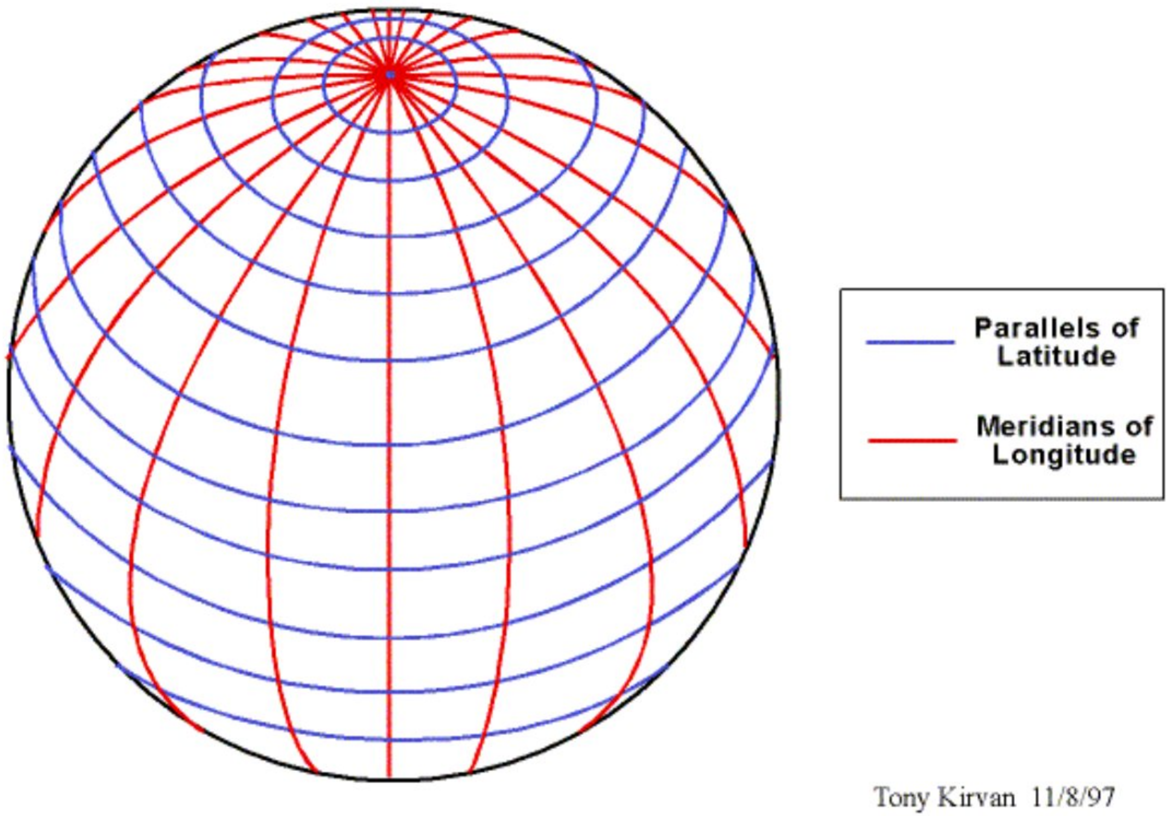
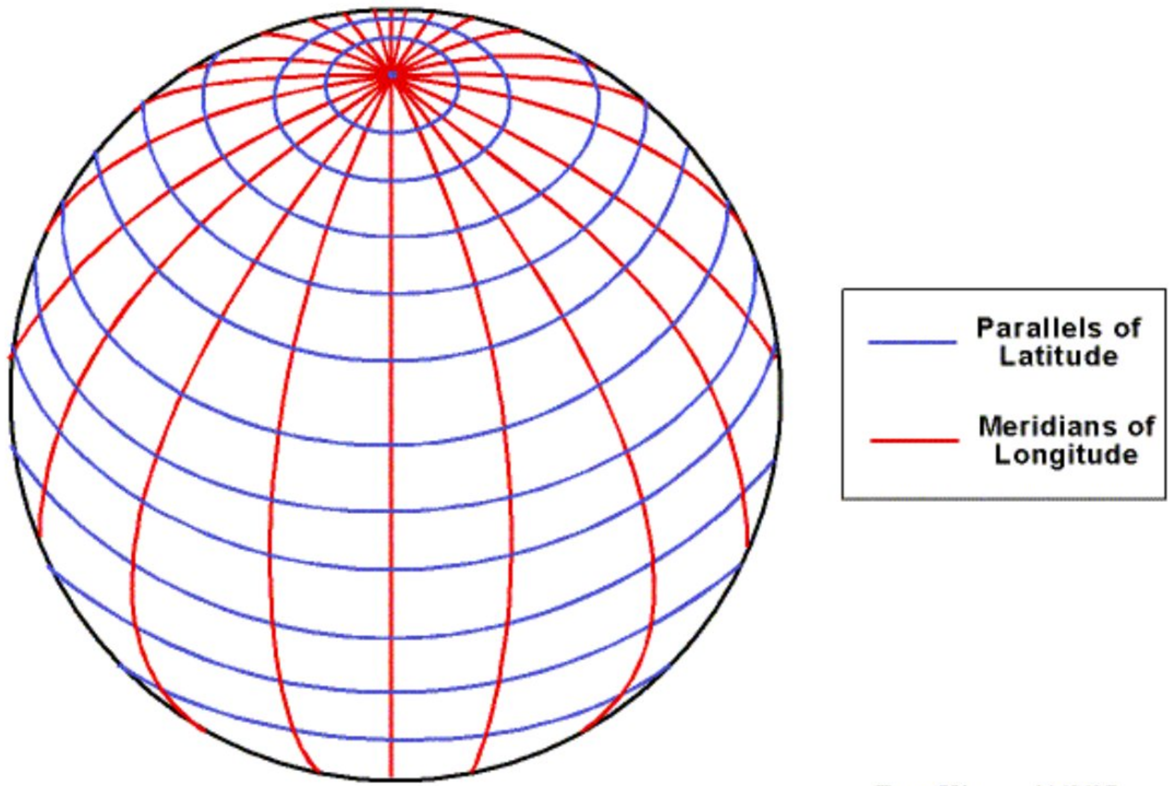
Geographic Coordinates

- Lines of latitude are called **parallels**
- Lines of longitude are called **meridians**



The Graticule

- The **parallels and meridians** of latitude and longitude form a **graticule** on a globe, a grid of orthogonal lines



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Geographic Coordinates

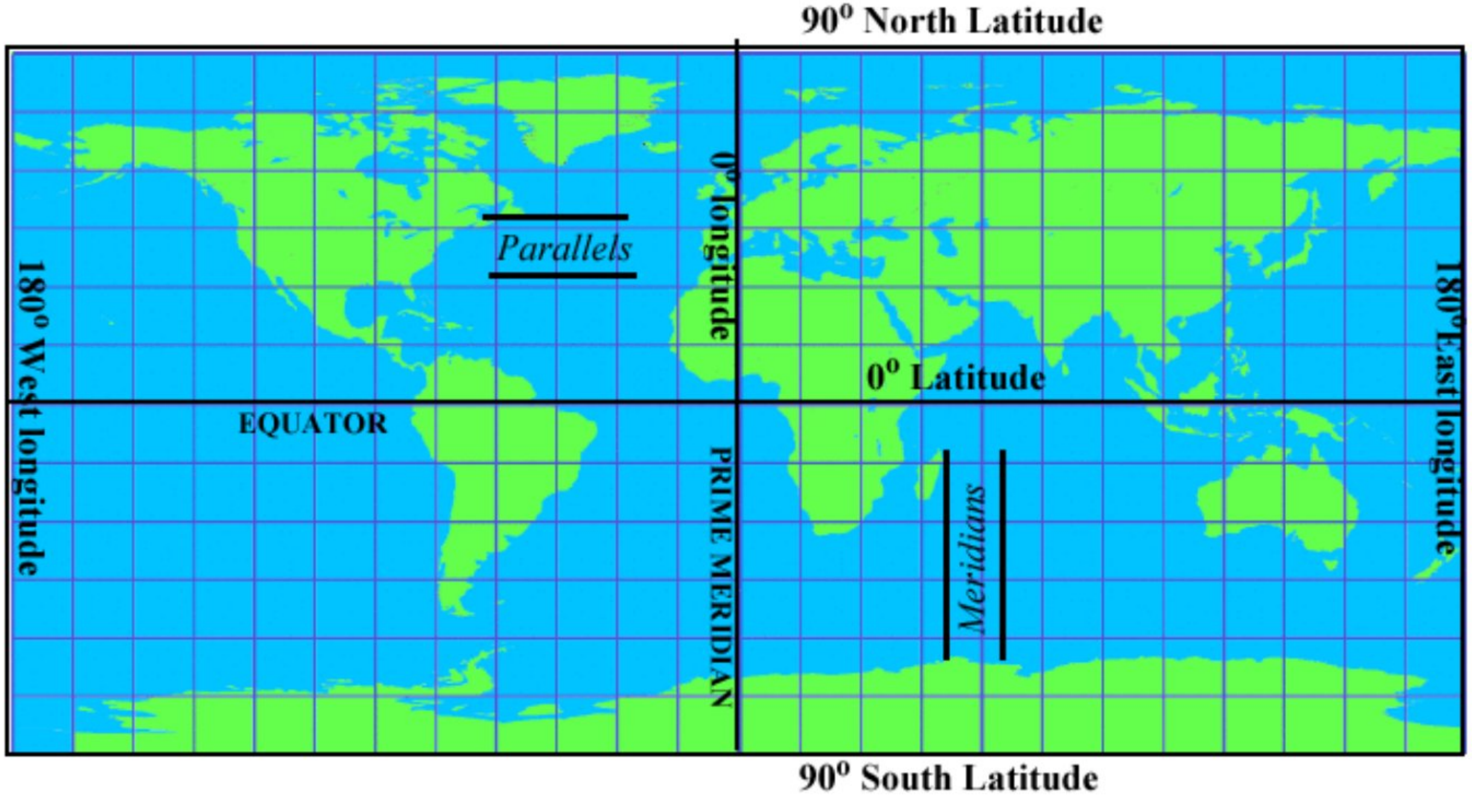
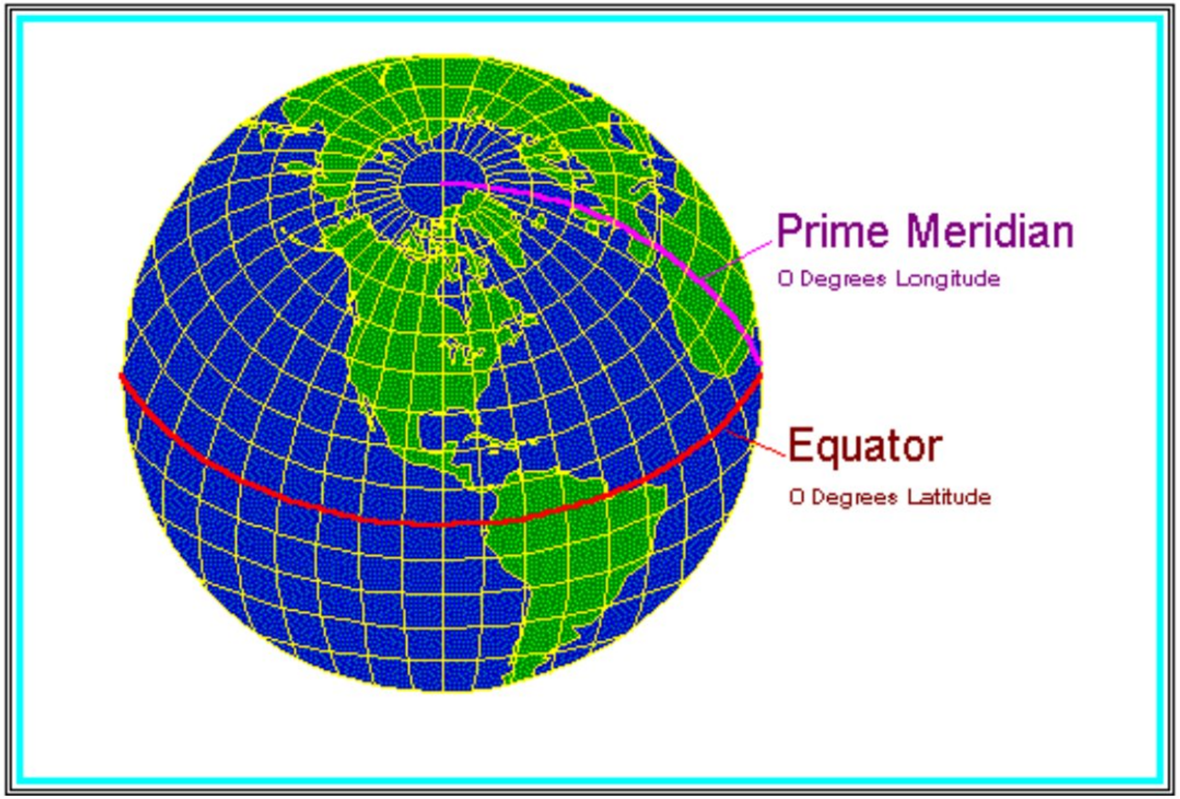


Figure 2.6 Geographic coordinates. The familiar latitude and longitude system, simply converting the angles at the earth's center to coordinates, gives the basic equirectangular projection. The map is twice as wide as high (360° east-west, 180° north-south).

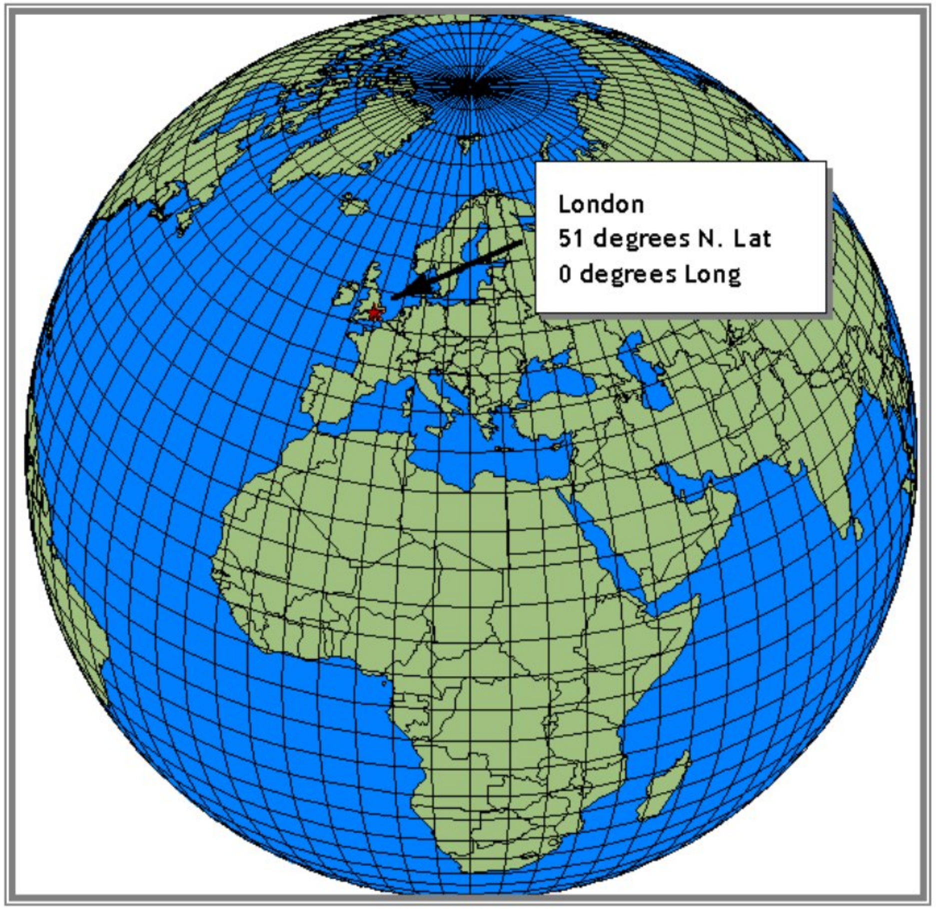
Geographic Coordinates

- The **Prime Meridian** and the **Equator** are the origin lines used to define latitude and longitude



Geographic Coordinates

- Latitude and longitude are based on the **spherical** model of the Earth
- This is the **most commonly-used** coordinate system (i.e. you will have seen it on globes or large-scale maps)



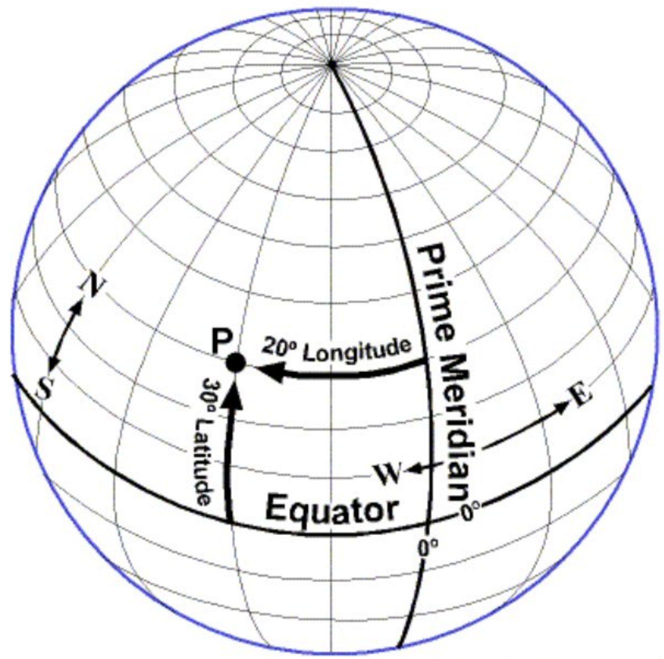
Geographic Coordinates

- We can use **geographic coordinates** (i.e. latitude & longitude) to specify locations
- Treating the Earth as a sphere is accurate enough for small maps of large areas of the Earth (i.e. **very small scale maps**)

The Prime Meridian (1884)

Geographic Coordinates

- Geographic coordinates are calculated using **angles**
- **Units** are in degrees, minutes, and seconds
- **Any location** on the planet can be specified with a **unique pair** of geographic coordinates



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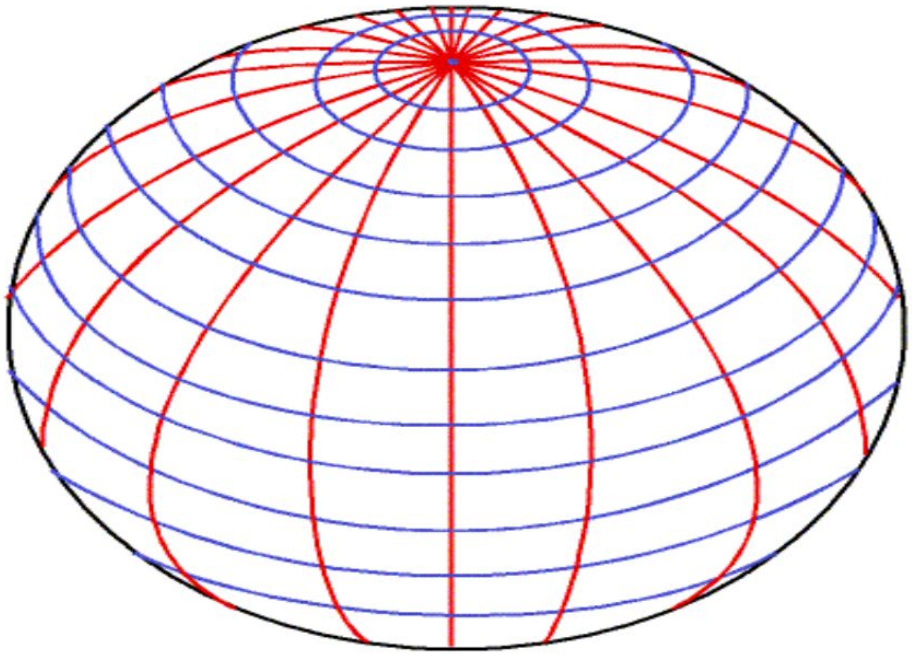
Latitude & Longitude on an Ellipsoid

- On a sphere, lines of latitude (parallels) are an **equal distance** apart everywhere
- On an ellipsoid, the distance between parallels **increases slightly** as the latitude increases



Geographic Coordinates as Data

```
....
0.215  9.297
0.166  9.319
0.050  9.340
0.055  9.324
0.006  9.324
-0.022  9.308
-0.105  9.286
-0.243  9.281
-0.530  9.270
-0.640  9.276
....
```

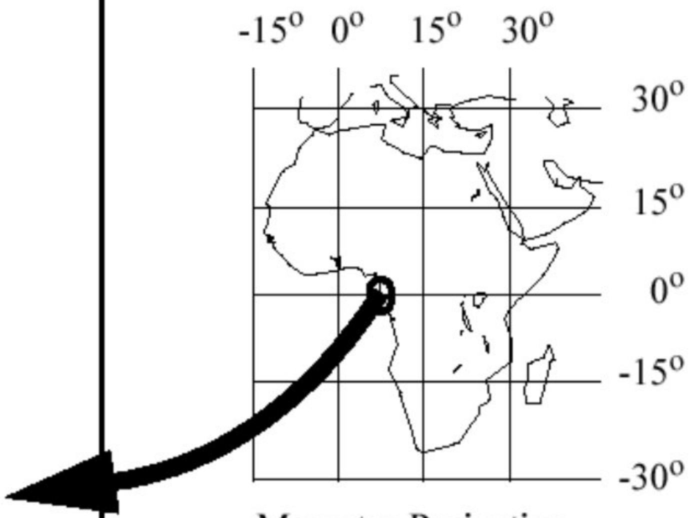


Figure 2.12 Part of the World Data Bank I listing of the coordinates of the coastline of Africa. Format is geographic coordinates in decimal degrees.

Coordinate Systems

- We have addressed both the issue of how to model the shape of the 3-dimensional Earth as an **ellipsoid/geoid**, and how to transform spatial information from the Earth's surface to a 2-dimensional representation using the **projection** process

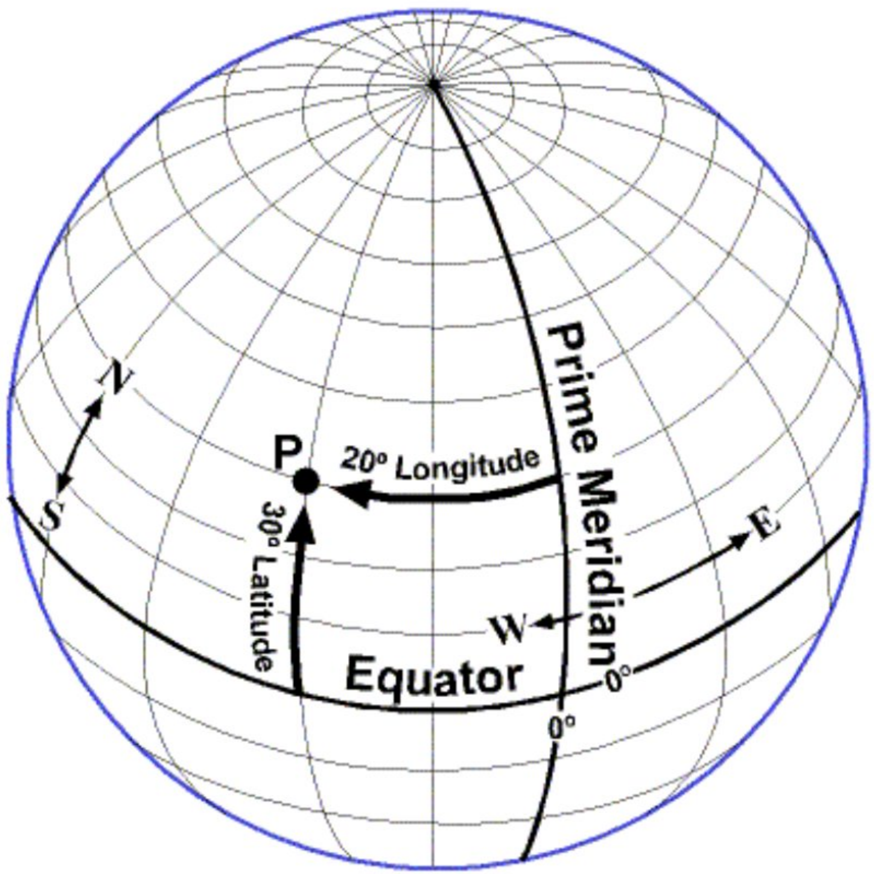
- Our remaining task is to conceive of some system by which we can precisely **specify locations** on a projected map that correspond to actual locations on the surface of the Earth → For this, we need to use some **coordinate system**

Coordinate Systems

- A coordinate system is a **standardized method** for **assigning codes to locations** so that locations can be found **using the codes alone**.
- Standardized coordinate systems use **absolute locations**.
- In a coordinate system, the x-direction value is the **easting** and the y-direction value is the **northing**. Most systems make both values positive.

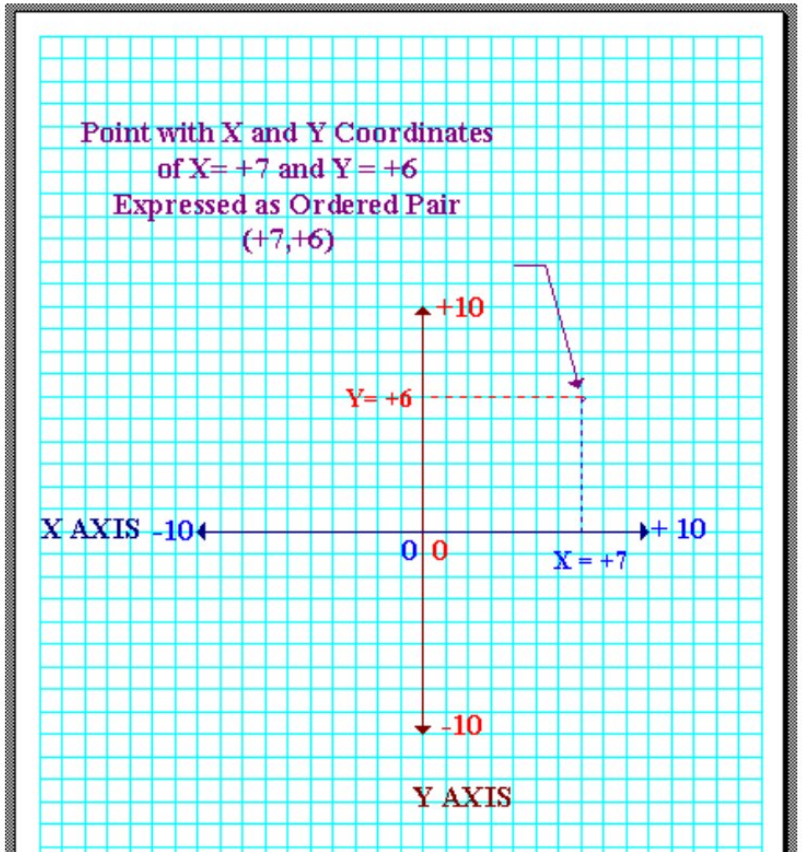
The Geographic Coordinate System

Viewing latitude and longitude angles from a 3D perspective:



Planar Coordinate Systems

- Once we start working with **projected** spatial information, using latitude and longitude becomes **less convenient**
- We can instead use a **planar coordinate system** that has *x* and *y* axes, an arbitrary origin (a Cartesian plane), and some convenient units (e.g. ft. or m.)
- When applied in a geographic context:
  - **Eastings** are ***x*** values
  - **Northings** are ***y*** values



Cartesian Coordinates in a Plane
A Point Defined by X and Y Coordinates

Raster Coordinate Systems

- A raster that has been **assigned a real world coordinate system** is said to have been **georeferenced**. There are two common ways to get to this state:
  - **Case I:** All of the **parameters** (projection, datum, cell size, and x-y coordinates of the upper left corner of the raster) **are known**, and this merely needs to be applied to the dataset
  - Case II: The coordinate system **parameters are completely unknown**, and the process of **geometric correction** is required to change the geometric/spatial properties of the image data so that we can accurately project the image, a.k.a.
    - **image rectification**

Geometric Correction

- Four Basic Steps of Rectification

1. Collect **ground control points (GCPs)**
   Points in the image for which you can determine real-world coordinates

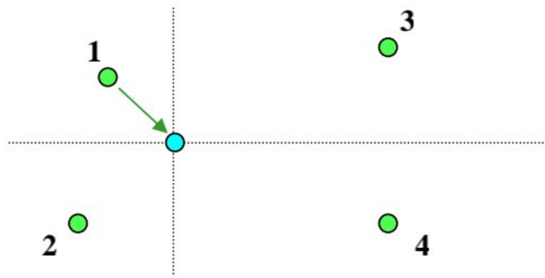
2. Create **equations** relating the image pixel coordinates at those GCPs to their real-world coordinates

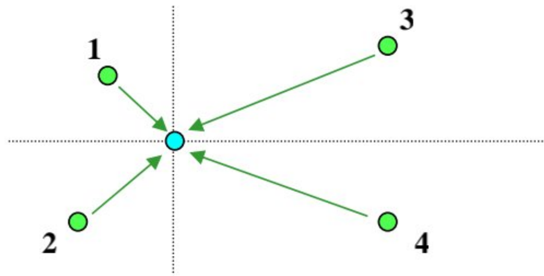
3. **Transform** the pixel coordinates based on the equations

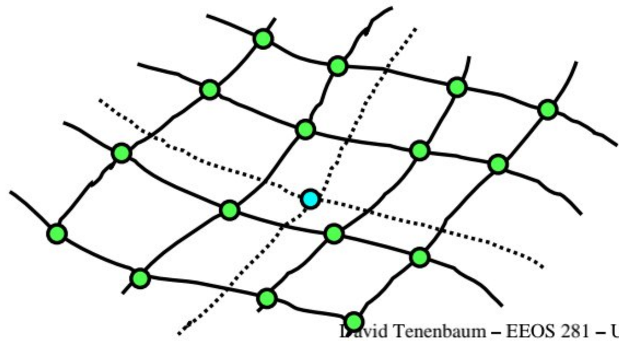
4. **Resample** the pixel values (BVs) from the input image to put values in the newly georeferenced image

Geometric Correction

- Three Types of Resampling
  - **Nearest Neighbor** - assign the new BV from the closest input pixel. This method does not change any values.
  - **Bilinear Interpolation** - distance-weighted average of the BVs from the 4 closest input pixels
  - **Cubic Convolution** - fits a polynomial equation to interpolate a “surface” based on the nearest 16 input pixels; new BV taken from surface

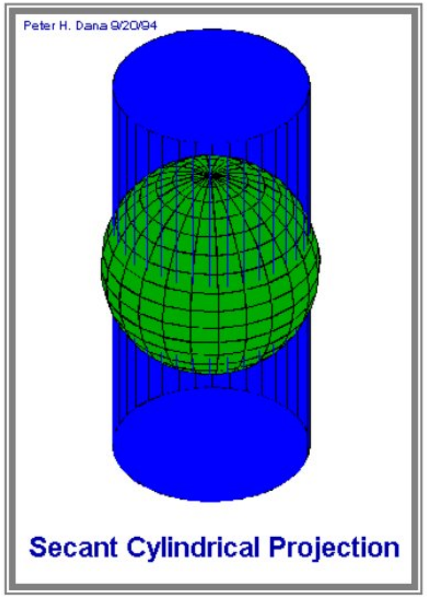


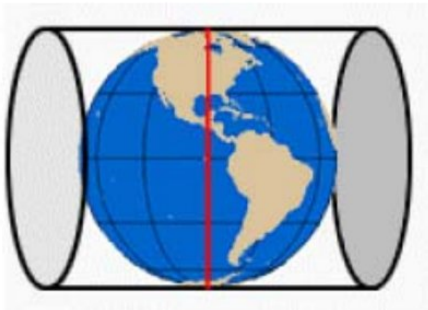




Universal Transverse Mercator

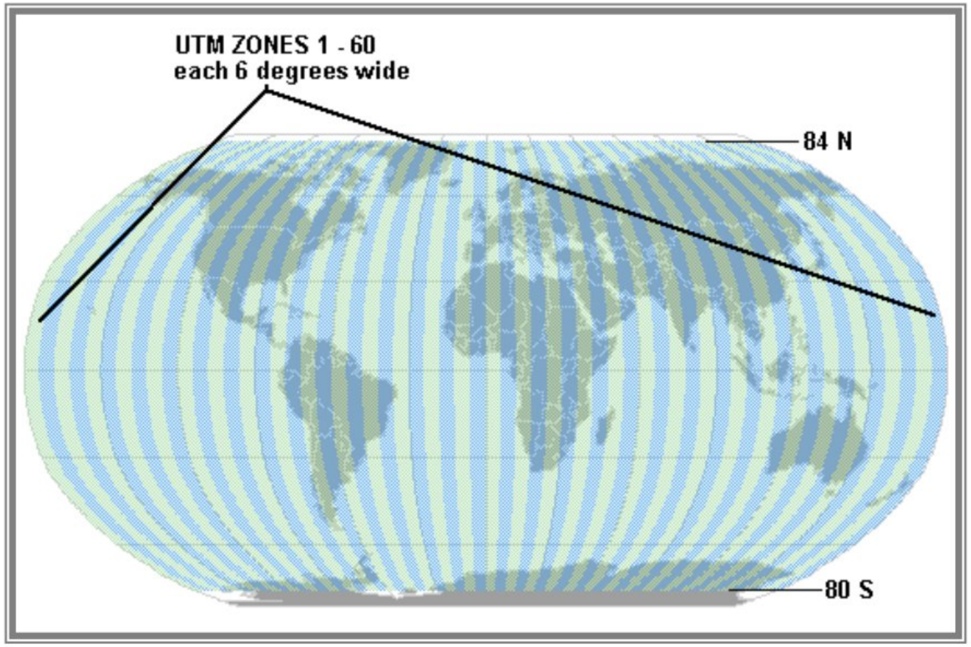
- Earlier, you were introduced to the Transverse Mercator **projection**
- That projection is used as the **basis** of the UTM **coordinate system**, which is widely used for topographical maps, satellite images, and many other uses
- The projection is based on a **secant transverse cylindrical projection**
- Recall that this projection uses a **transverse cylinder** that has **standard lines** that run **north-south**, and **distortion** increases as we move further **east or west**



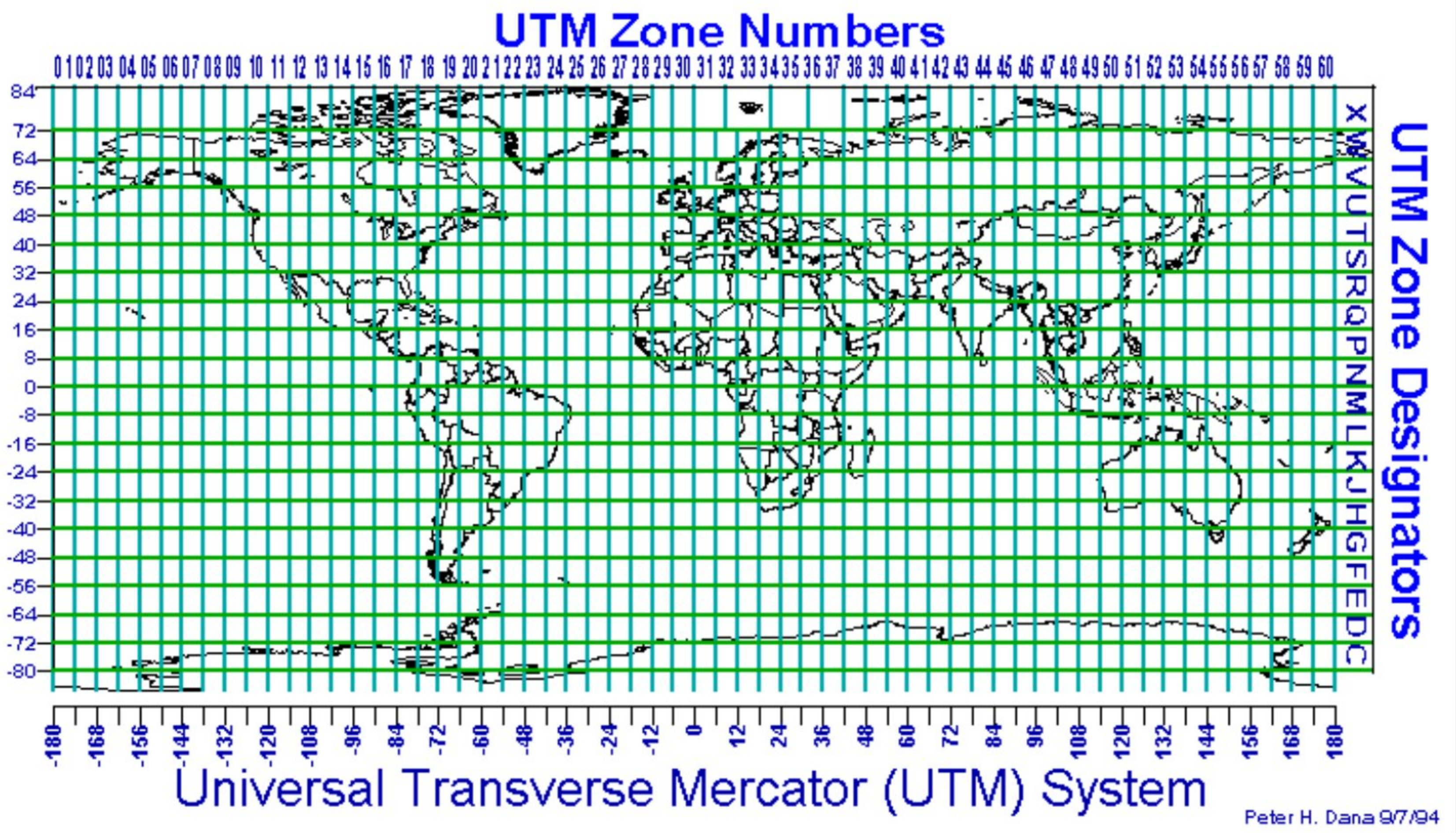


Universal Transverse Mercator

- In order to **minimize** the **distortion** associated with the projection, the UTM coordinate system uses a **separate Transverse Mercator projection** for every **6 degrees** of longitude → the world is divided into **60 zones**, each 6 degrees of longitude in width, each with its own UTM projection:

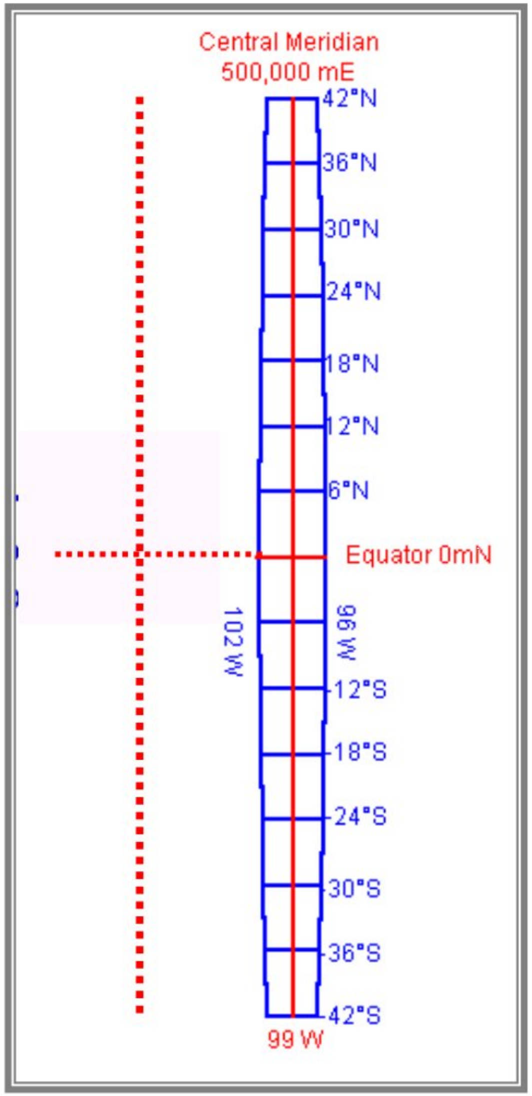


Universal Transverse Mercator



Universal Transverse Mercator

- The **central meridian**, which runs down the middle of the zone, is used to define the position of the origin
- **Distance units** in UTM are defined to be in **meters**, and distance from the origin is measured as an **Easting** (in the x-direction) and a **Northing** (in the y-direction)
- The x-origin is west of the zone (a false easting), and is placed such that the central meridian has an Easting of **500,000 meters**



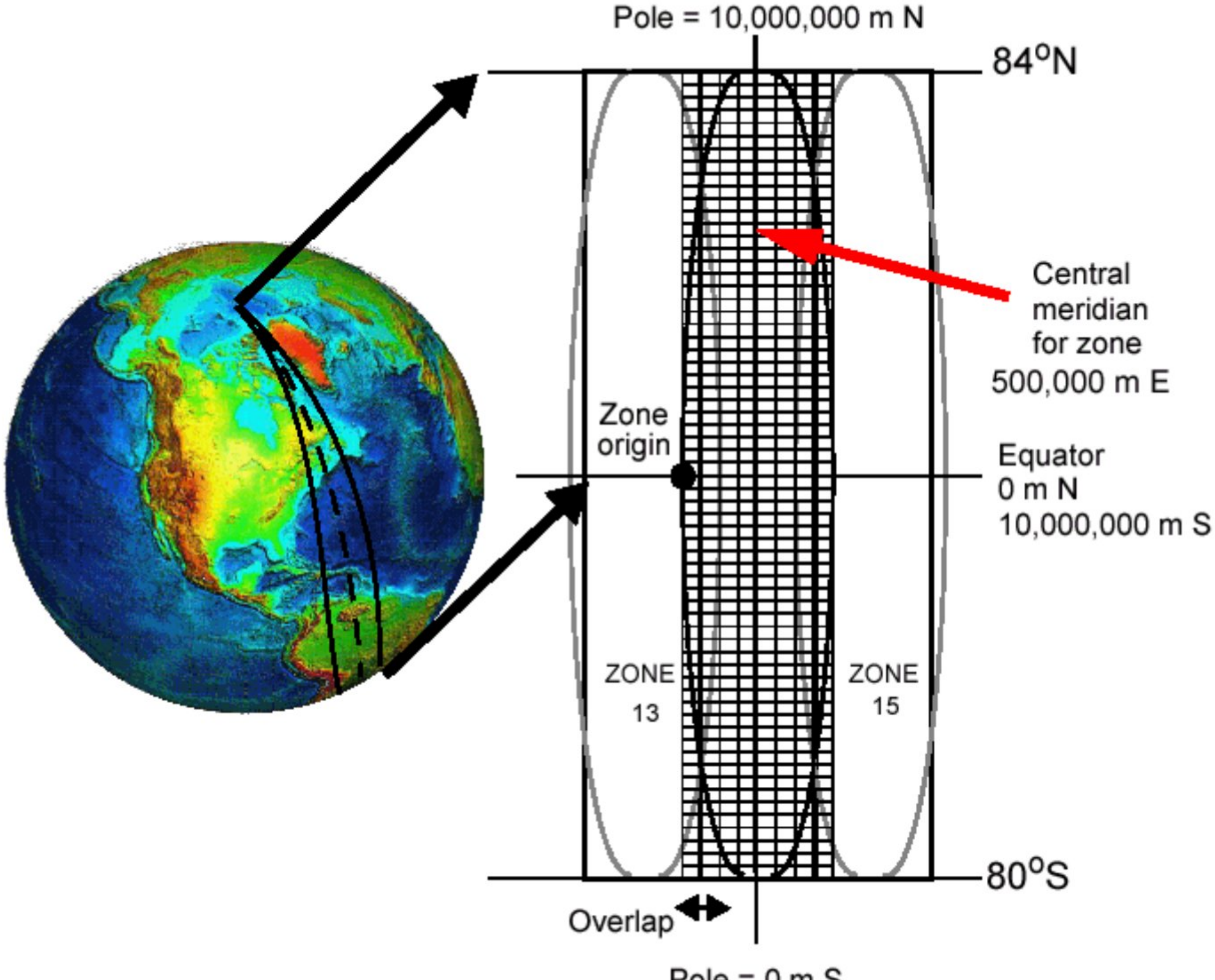


Figure 2.14 The universal transverse Mercator coordinate system.

UTM Zones in the Lower 48

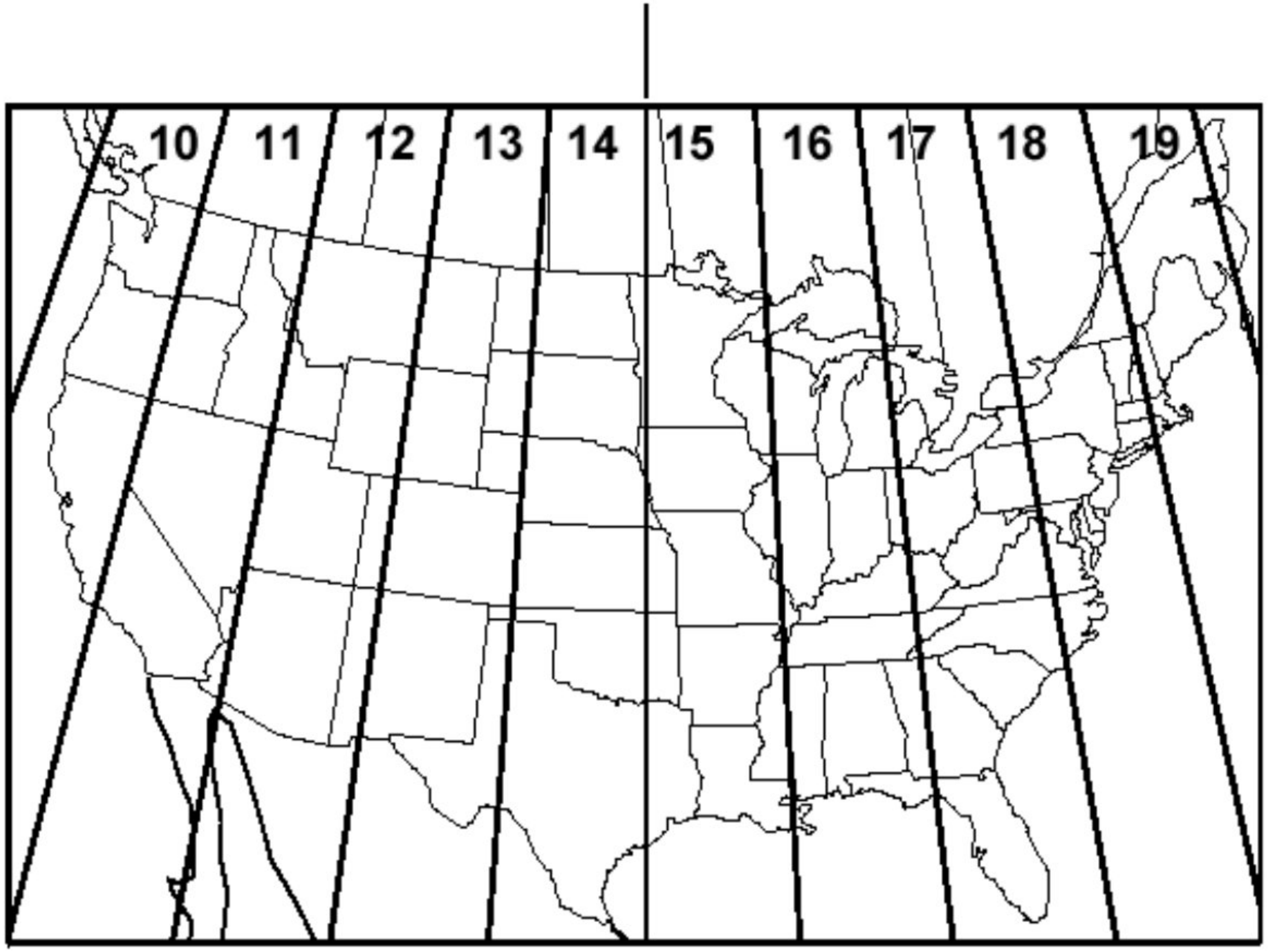
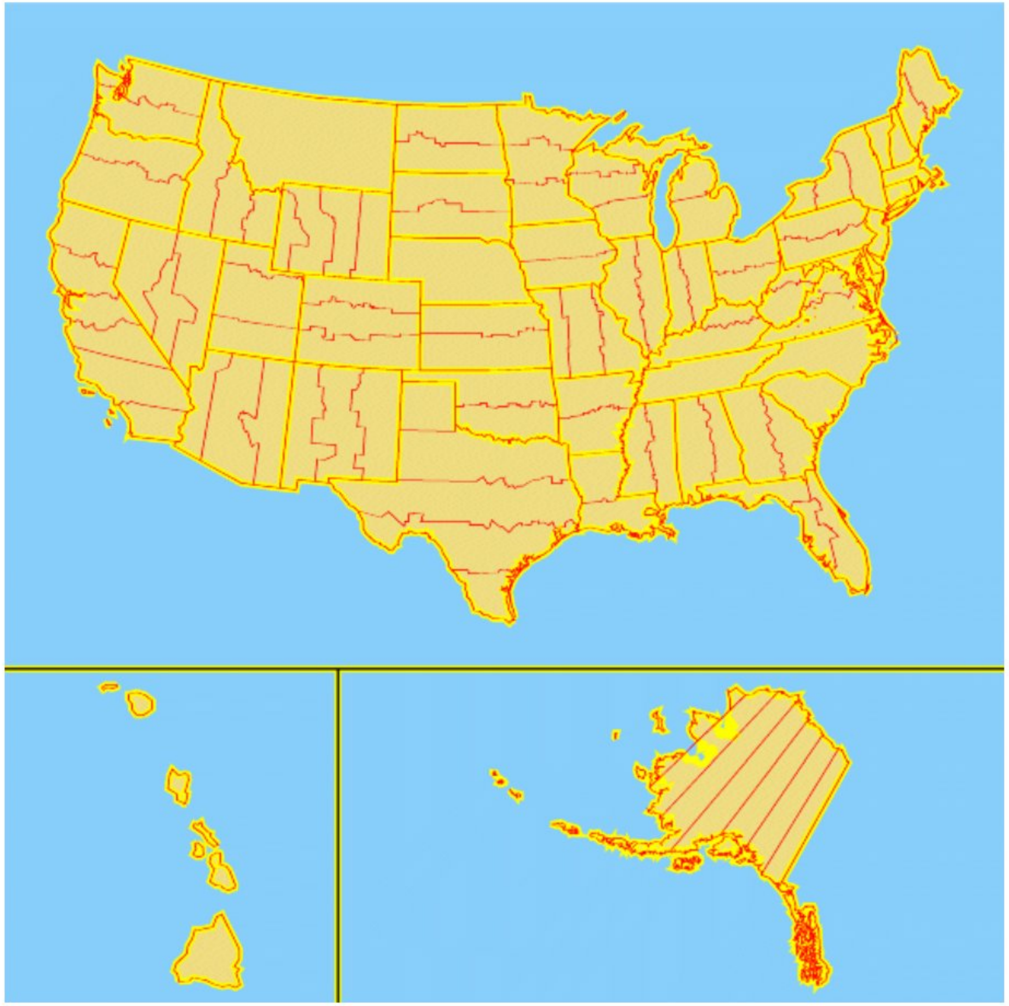


Figure 2.13 Universal transverse Mercator zones in the 48 contiguous states.

State Plane Coordinate Systems

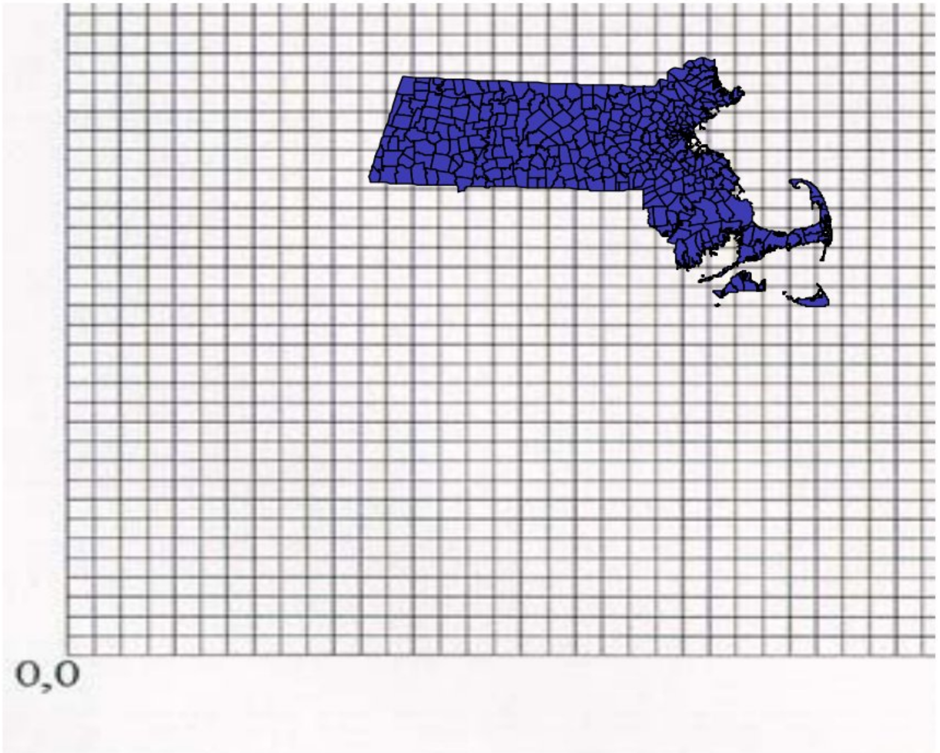
- Each state in the U.S. has its own **planar coordinate system(s)** known as State Plane Coordinate Systems (SPCS)
  - Depending on the size of the state, its coordinate system **may be divided into multiple zones** (e.g. Alaska has 8 zones)
- These may **make use of three different projections**, **depending on the shape** of the state:
  - Lambert Conformal Conic
  - Transverse Mercator
  - Oblique Mercator

State Plane Coordinate Systems



State Plane Coordinate Systems – Massachusetts (feet)

Units: Feet



State Plane Coordinate Systems – Massachusetts (feet)