CENTER for DIGITAL SCHOLARSHIP

Georeferencing in ArcGIS

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library.nd.edu/cds/

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Outline

CENTER for DIGITAL SCHOLARSHIP

- The Center for Digital Scholarship
- What is GIS?
  - Data types
- GIS software and analysis
- Campus GIS resources

Center for Digital Scholarship

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- Center services:
  - Text Analysis
  - Research design
  - Data management
  - Statistic analysis
  - Geographic Information Services

GIS resources in the library

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- Center for Digital Scholarship
  - Bank of 8 computers with extensive GIS software
    - ESRI ArcGIS
    - DIVA-GIS
    - GRASS
    - Quantum GIS
    - Google Earth Professional
  - 42” sheet-feed map scanner
  - 8 baseline GPS units and 2 high-end data collectors

Layers

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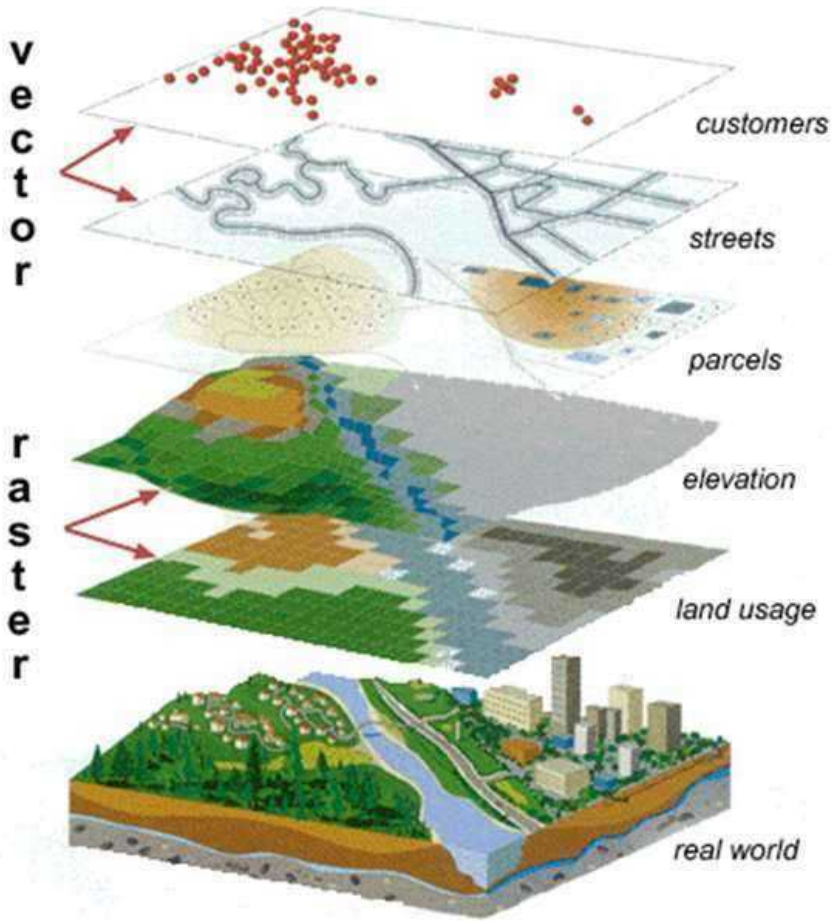
- A GIS is composed of layers of spatial information
- Can be different types of data
- Everything is referenced to a coordinate system
  - e.g. latitude / longitude



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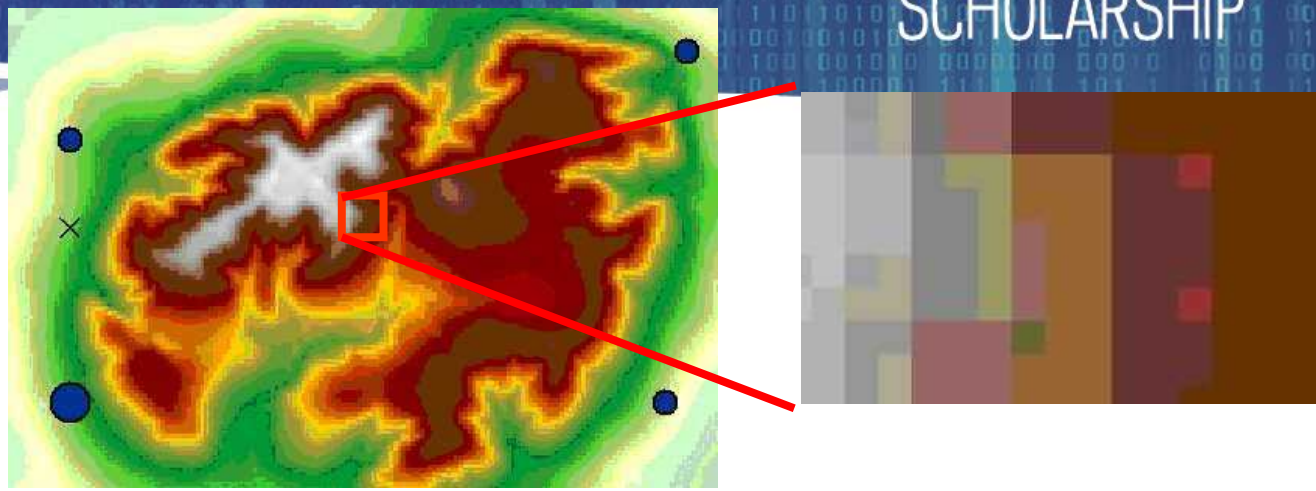
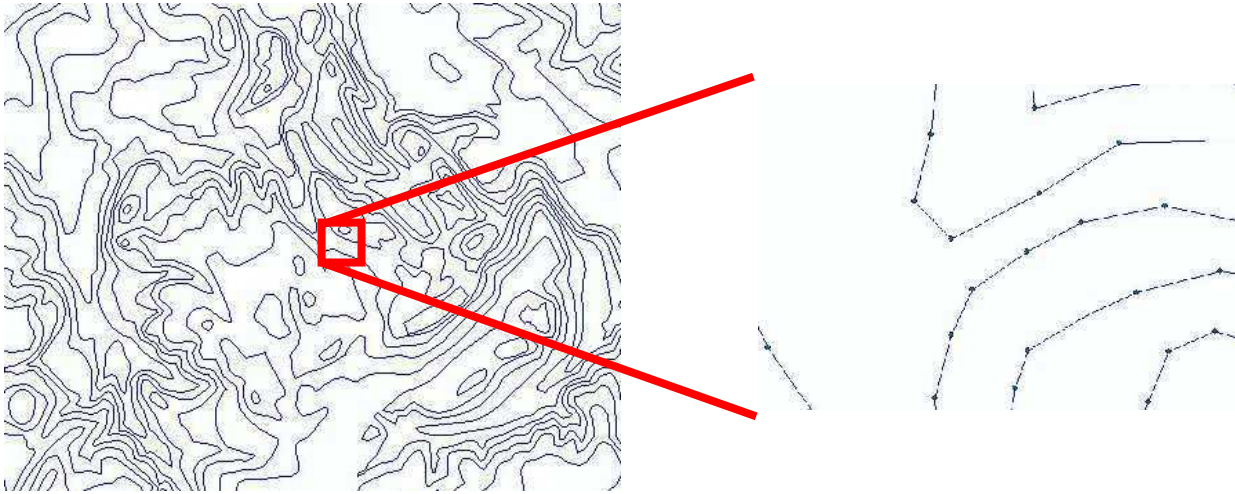
Raster Data

Based on pixel



Vector Data

Based on discrete points



Coordinate System

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- A system that represents points in 2- and 3-dimensional space
- Needed to measure distance and area on a map
- Rectangular grid systems were used as early as 270 AD
- Can be divided into global and local systems

Two types of coordinate systems

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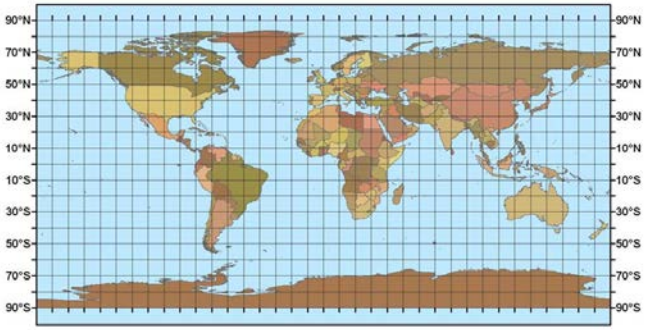
1). Geographic Coordinate Systems

Location on a sphere

2). Projected Coordinate Systems

Cartesian (two-dimensional) location



Geographic coordinate system

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- A global system
- The Prime Meridian and Equator are the reference planes to define spherical coordinates
  - Latitude: North and South
  - Longitude: East and West
- Measured in degrees
  - Degrees, minutes, seconds: 42 º 30’ 37” N
  - Decimal degrees: 42.5102777778 º N
- Distance between degrees latitude is ~110 km
- Longitude is more variable
  - 111 km at equator
  - 19 km at 80 º N
  - 0 at the North Pole

The Earth's Graticule

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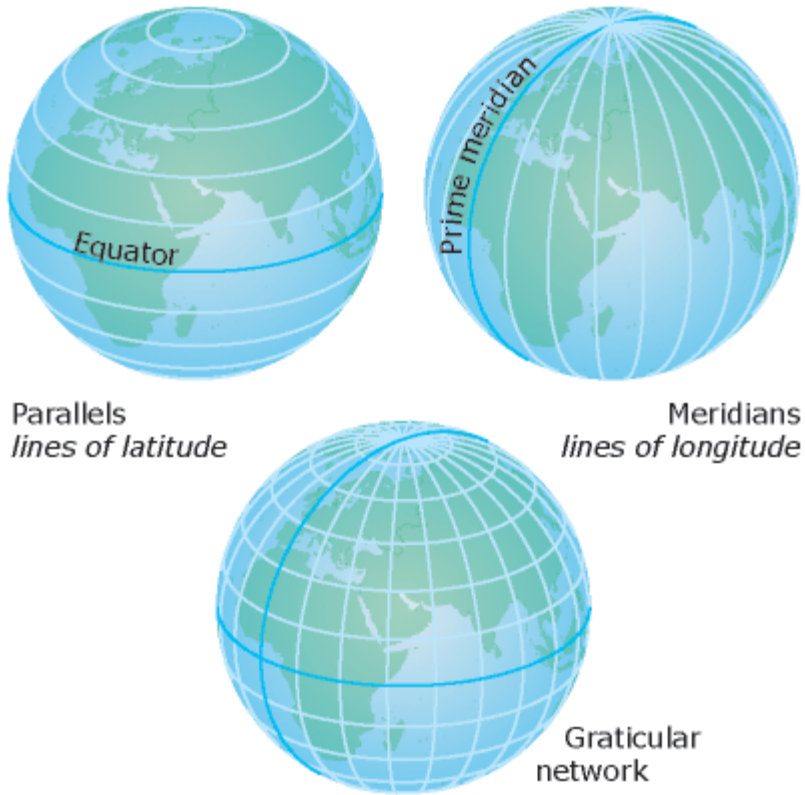
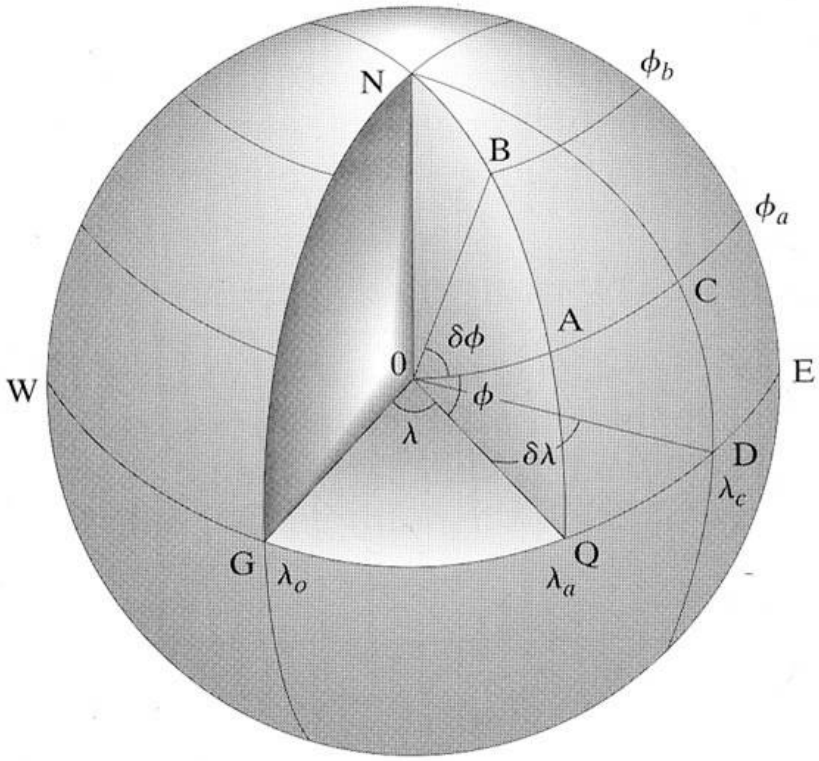
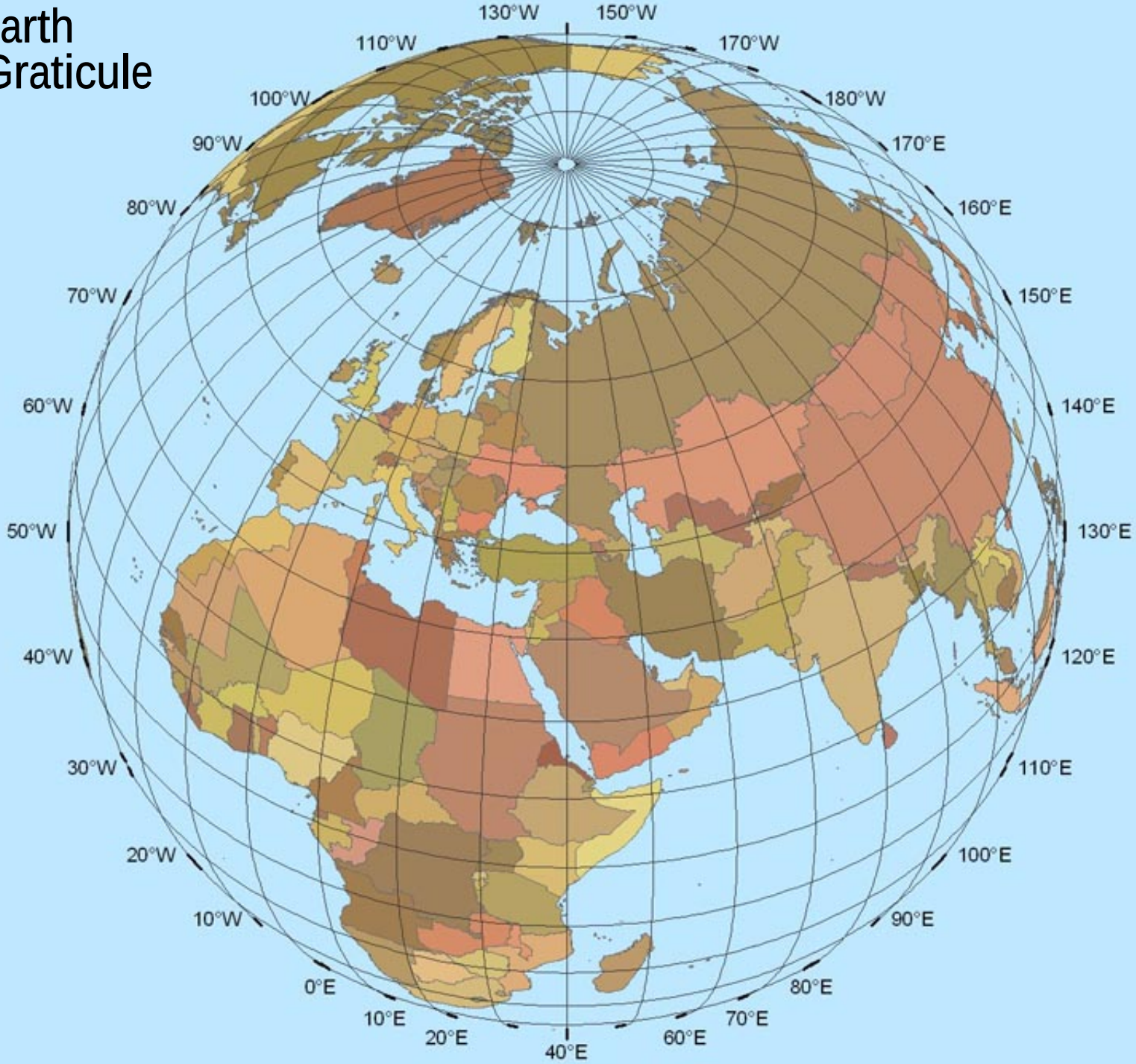




The Earth with Graticule



Geographic Coordinate System in 2d

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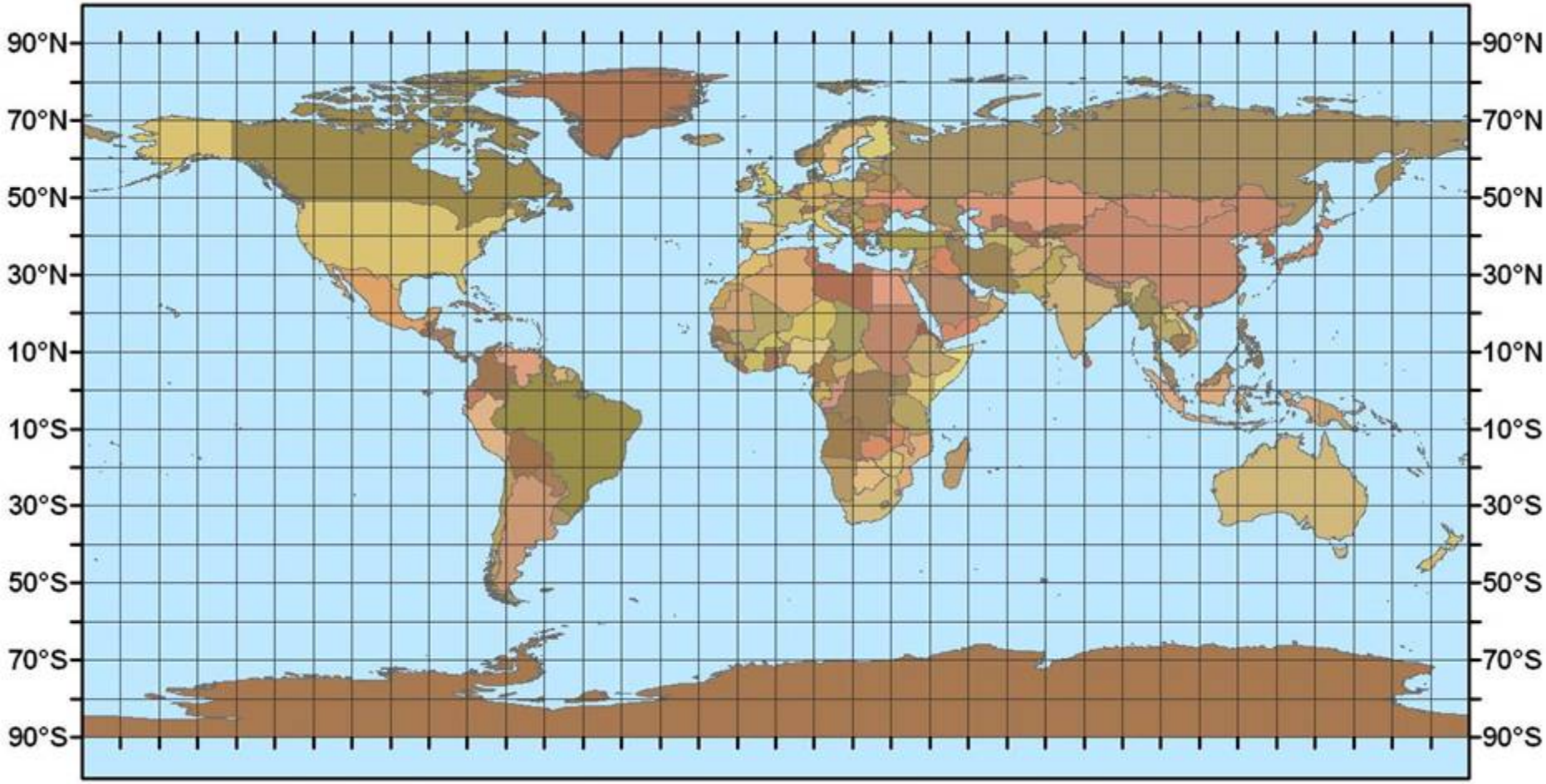

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Two Complicating Factors

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1. Mapping the surface of a sphere to a flat surface

2. The impacts of local variation

Distortion when shown in two dimensions

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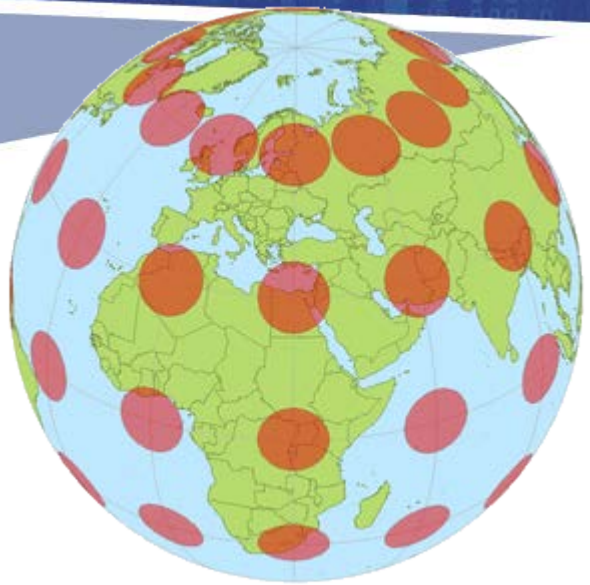
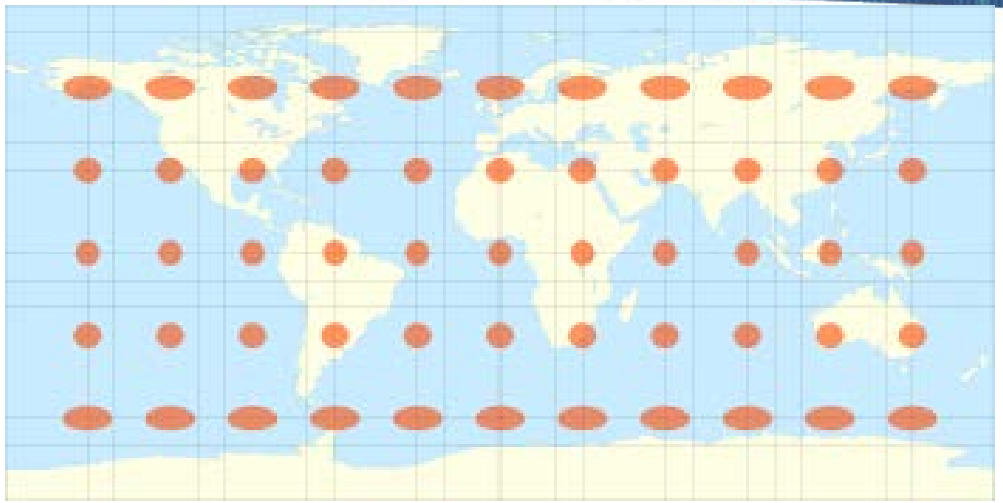
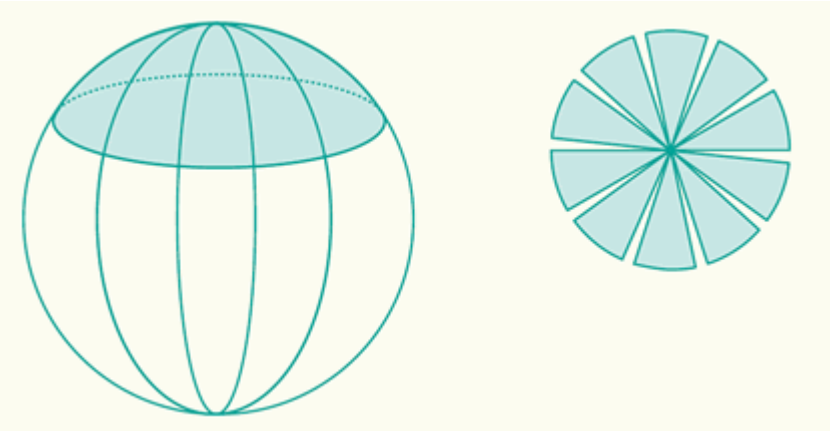




Tissot's Indicatrix



- Impossible to maintain both scale and shape
- Must choose best method for area and size of map

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Projection

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- Method of representing data located on a curved surface onto a flat plane
- All projections involve some degree of distortion of:
  - Distance
  - Direction
  - Scale
  - Area
  - Shape
- Determine which parameter is important

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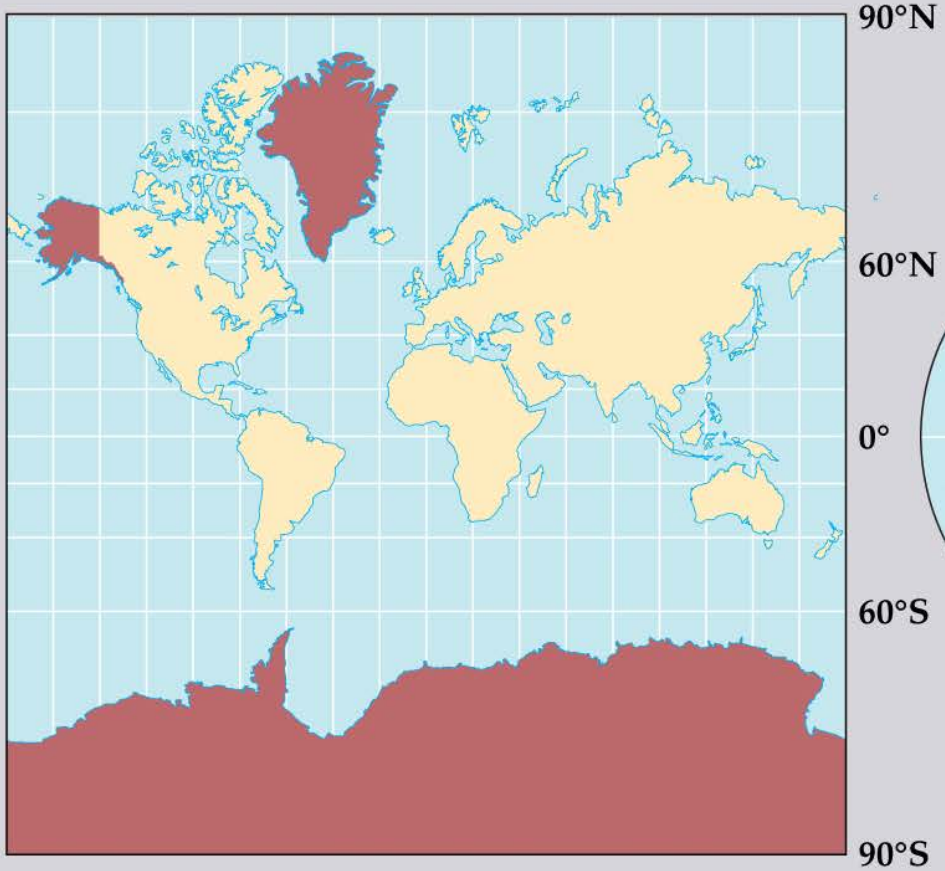
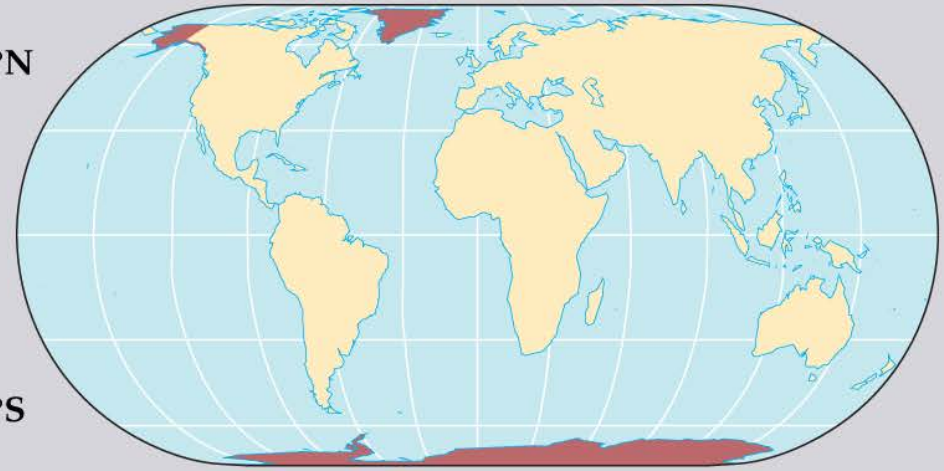


(a) Conformal



(b) Equivalent

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Projections

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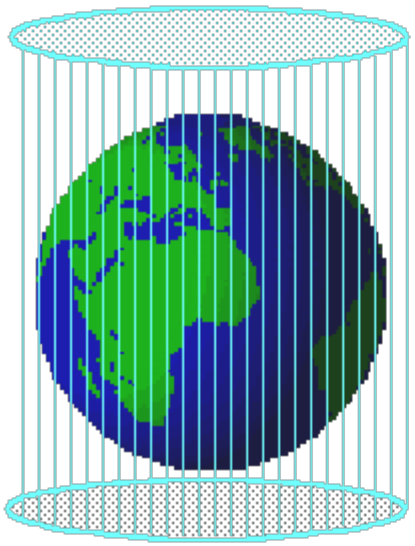
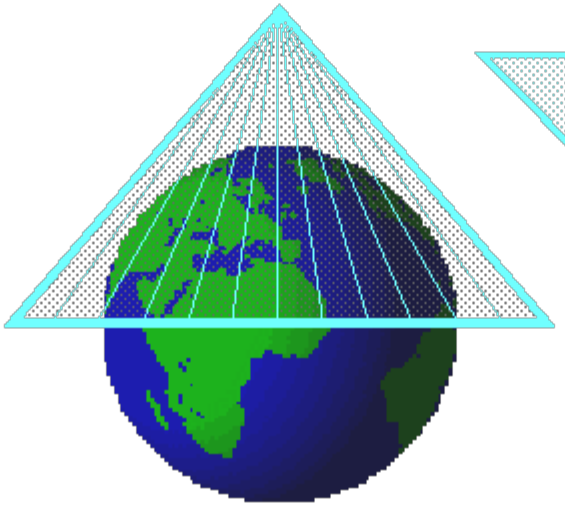
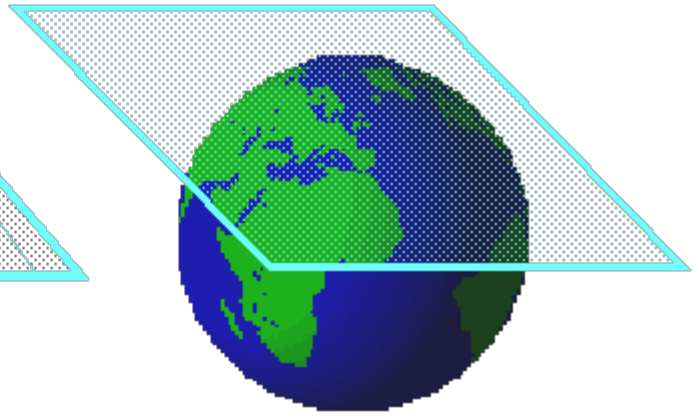
The earth is “projected” from an imaginary light source in its center onto a surface, typically a plate, cone, or cylinder.







Two Complicating Factors

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1. Mapping the surface of a sphere to a flat surface

2. The impacts of local variation

Angular and distance measurements

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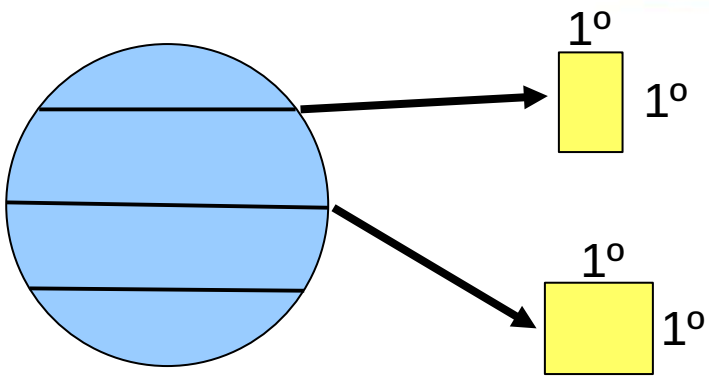
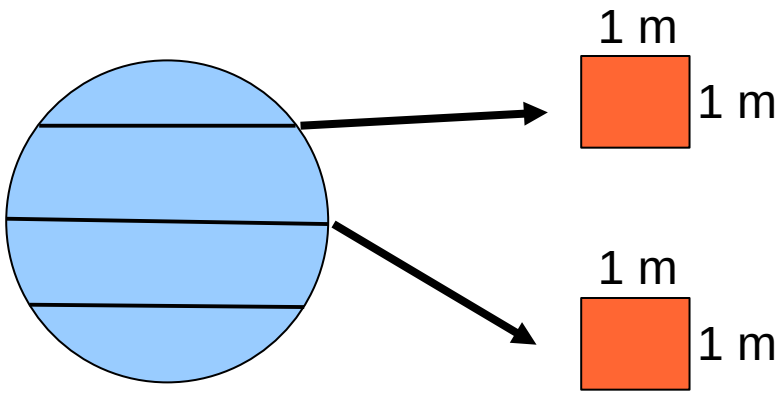
In a Geographic Coordinate System distances are in degrees.

- Longitudinal degrees vary with latitude.



An unprojected raster is distorted because the resolution is not square

- Any calculations of area are inaccurate.



Better just to use a projected, meter-based, system (like UTM)

The earth is not a perfect sphere

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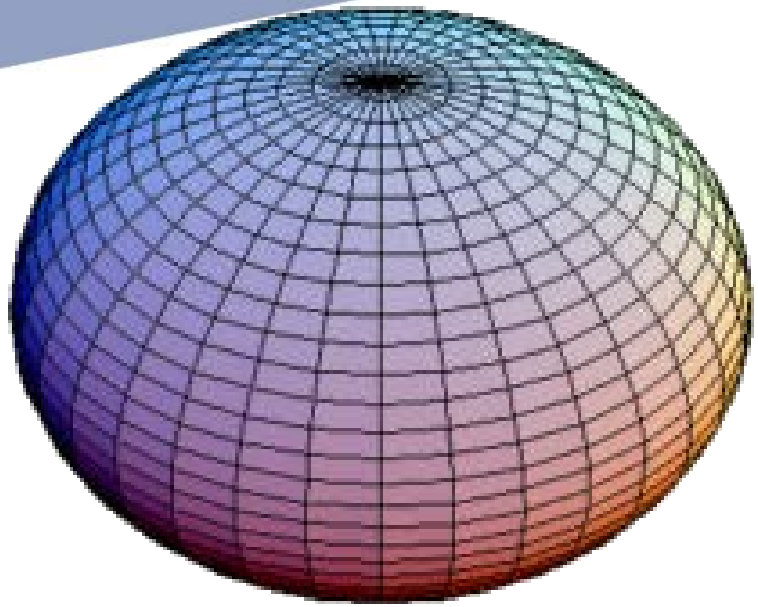
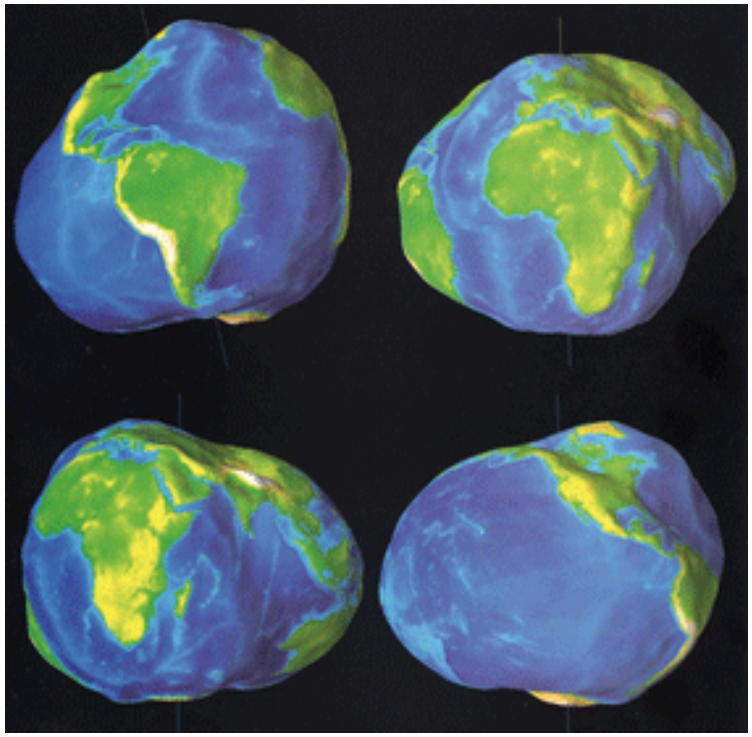
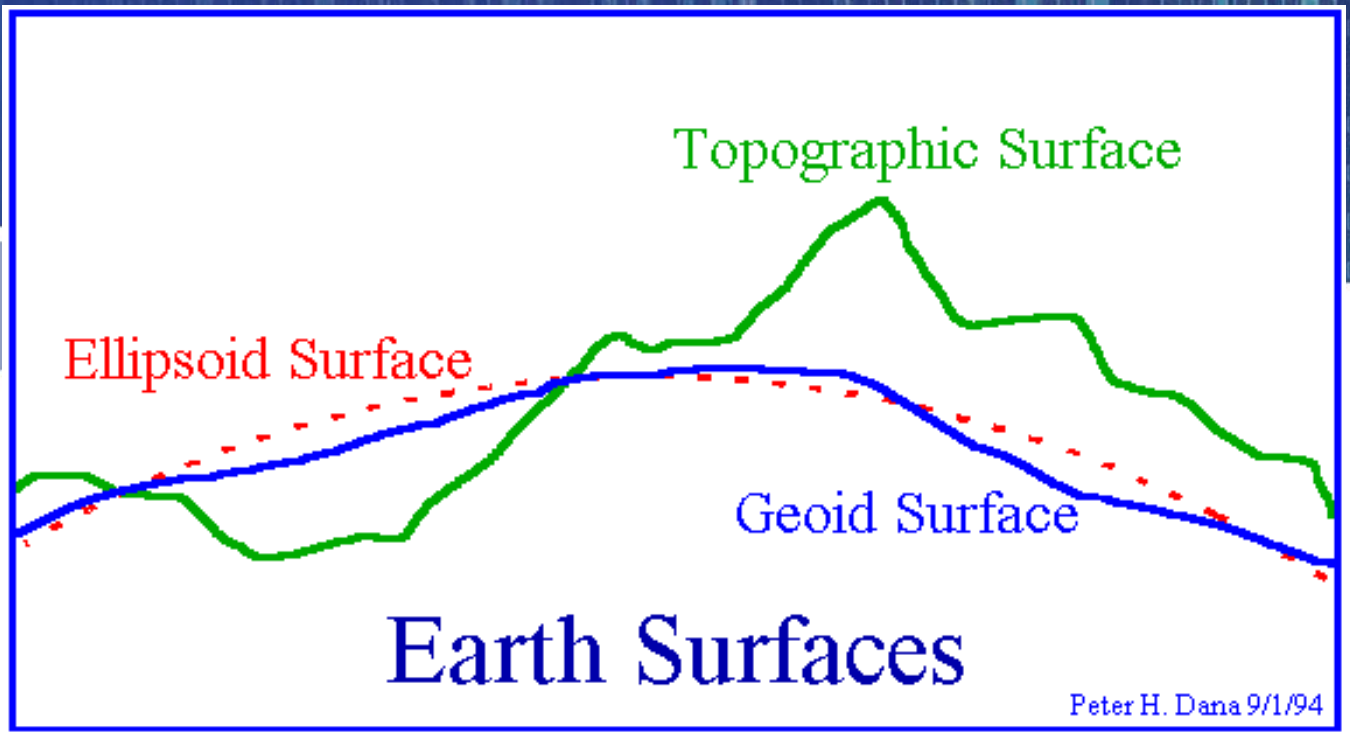




An ellipse is a better, but not perfect measure

Geoide: The actual geometric surface of a resting earth (exaggerated)



- Geoid: the true 3-D shape of the earth considered as a mean sea level extended continuously through the continents
  - Approximates mean sea level
- WGS 84 Datum defines geoid heights for the entire earth

Commonly used datums

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Datum	Spheroid	Region of use
NAD 27	Clark 1866	**Canada, US, Atlantic/Pacific Islands, Central America**
NAD 83	GRS 1980	**Canada, US, Central America**
WGS 84	WGS 84	**Worldwide**

- GPS is based on WGS 84 system

Projections and Datums

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- Projections and datums are linked
- The datum forms the reference for the projection
  - Maps in the same projection but different datums will not overlay correctly
    - Tens to hundreds of meters
  - Maps in the same datum but different projections will not overlay correctly
    - Hundreds to thousands of meters.

Transverse Cylindrical Projection

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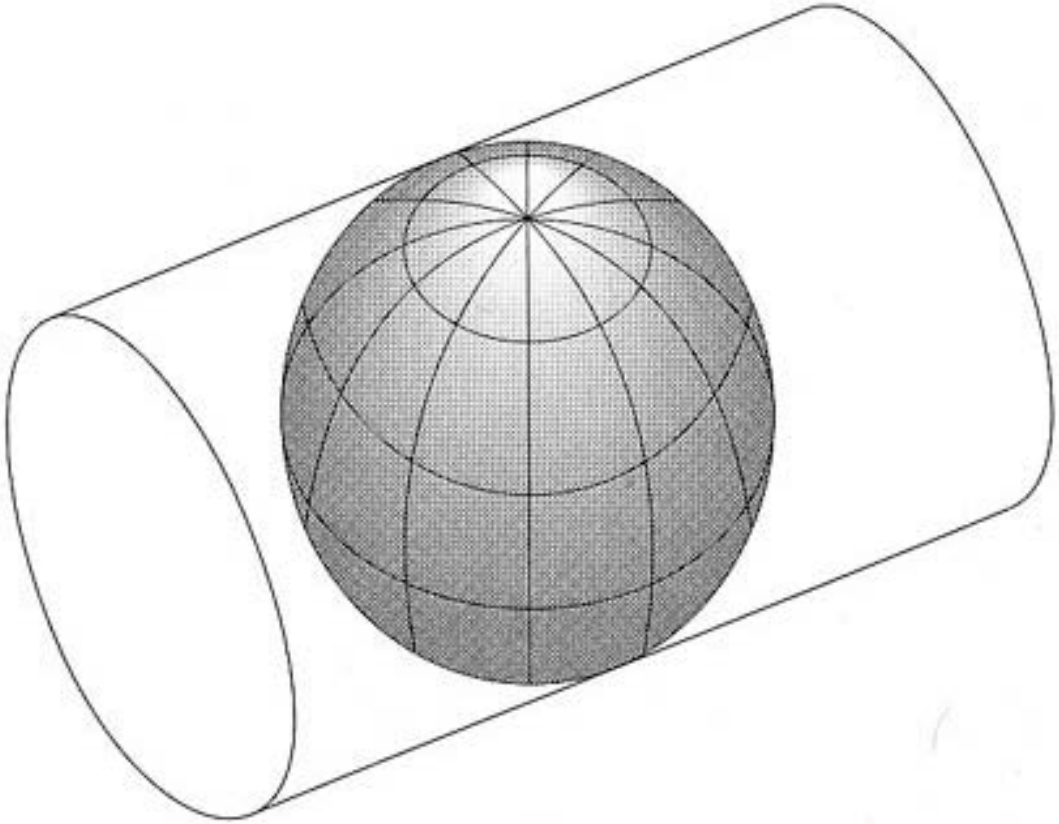

Basis for Universal Transverse Mercator (UTM) Projections and Coordinate Systems

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The Universal Transverse Mercator (UTM) Projection

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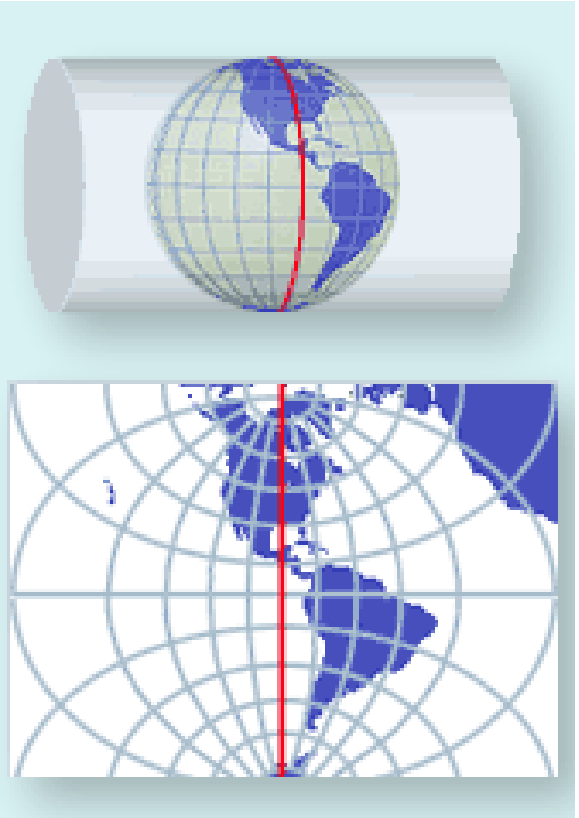
- A type of cylindrical projection
- Implemented as an internationally standard coordinate system
  - Initially devised as a military standard
  - Uses a system of 60 zones
  - Maximum distortion is 0.04%
- *Transverse* Mercator because the cylinder is wrapped around the Poles, not the Equator



The Universal Transverse Mercator (UTM) Projection

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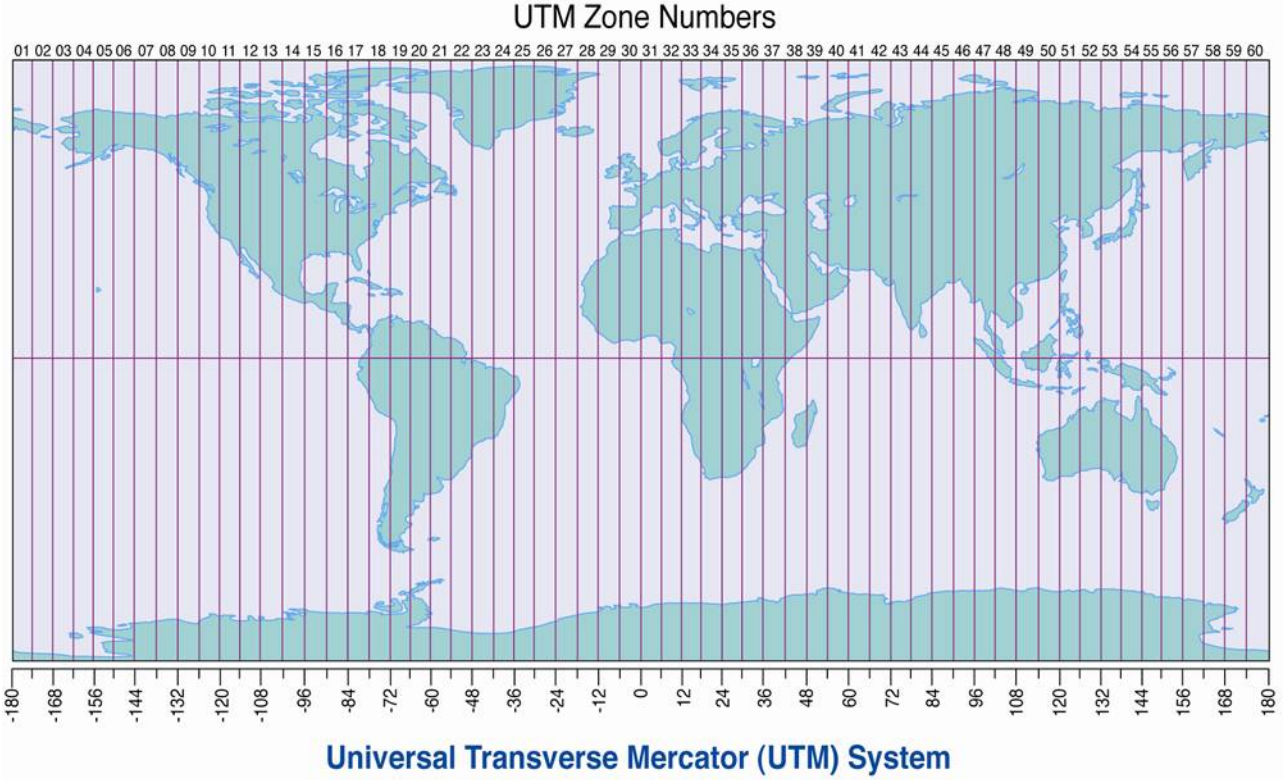

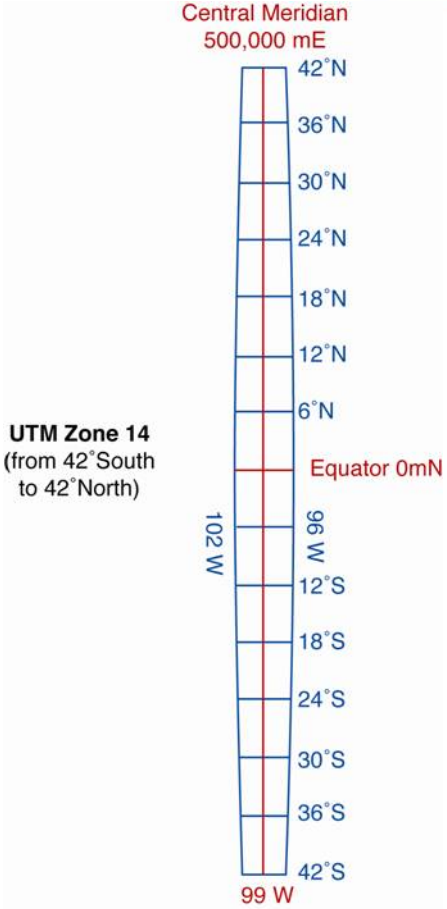

Zones are each six degrees of longitude, numbered as shown at the top, from W to E

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UTM Zones in the Central US

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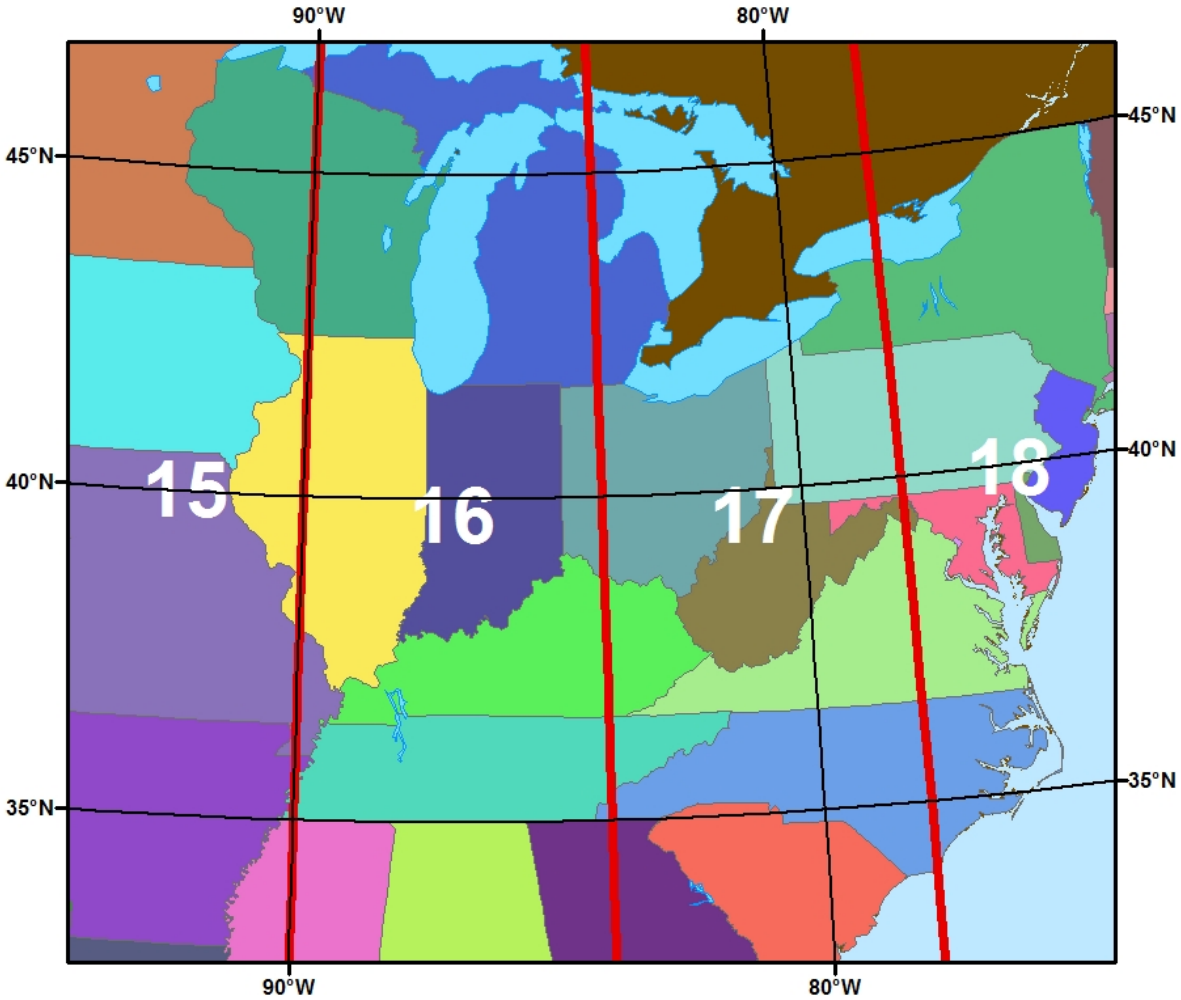

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Implications of the UTM System

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- UTM coordinates are in meters
  - Makes it easy to calculate distances between locations
- Each zone is actually a different projection (60 total)
  - Thus, maps will not fit together across a zone boundary
- At high latitudes zones are very narrow
  - Areas and cities can cross boundaries
- Jurisdictions that span two zones must make special arrangements
  - Use only one of the two projections, and accept the slightly greater-than-normal distortions in the other zone
  - Use a third projection spanning the jurisdiction
    - E.g. CA spans UTM zones 10 and 11

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Georeferencing Maps and Images

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Georeferencing / Rectification

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- Making an image fit the world
- Changes the geometry of the image
- Causes of distortion:
  - The angle that the image was taken from
  - The curvature of the earth.
  - The curvature of the lens
  - The rotation of the earth while imagery is being taken.

Registration vs. Georeferencing

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- **Registration**: assigning coordinates to pixels; assumes image is already projected

- **Georeferencing**: altering image geometry to conform to a map projection (also called warping)

A scanned map already has coordinates and only needs to be registered

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Distortion in Aerial Photography

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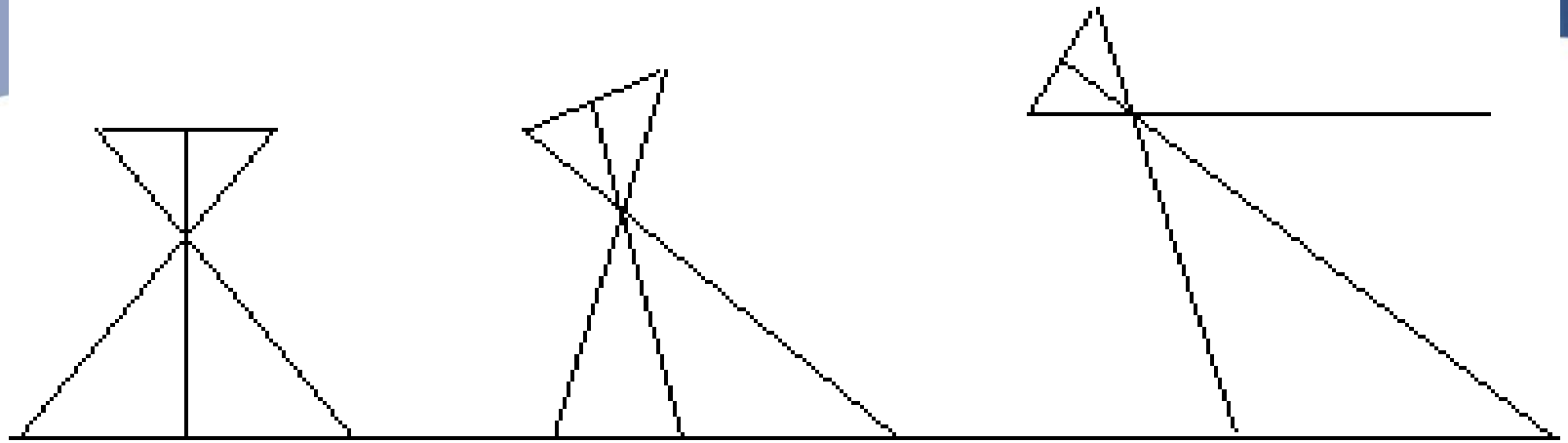
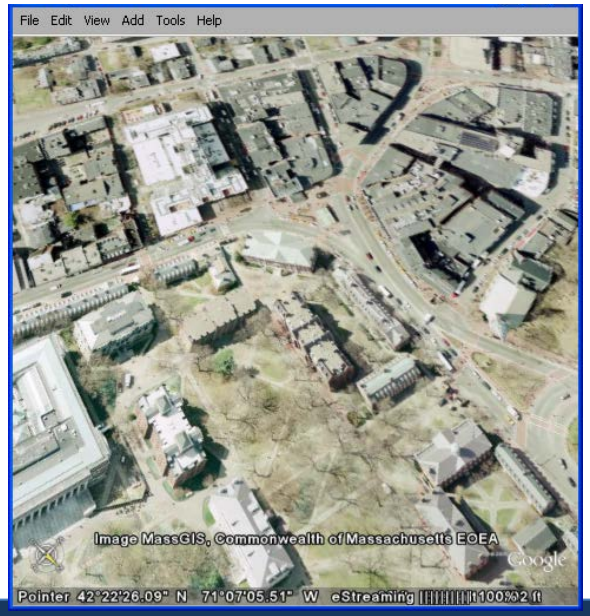


Vertical

Low Oblique

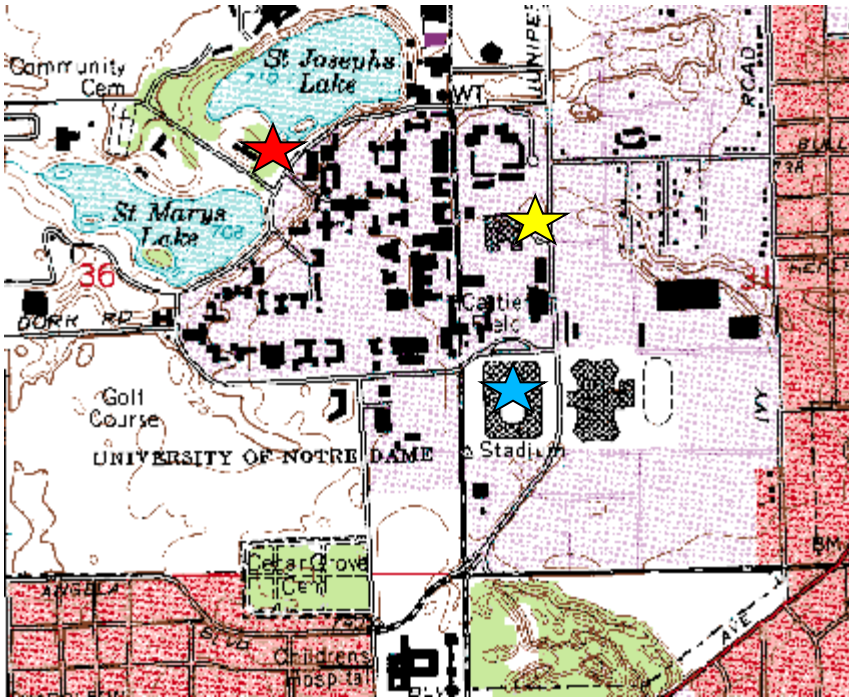
High Oblique



Rectification can allow mapping from angled photographs.

Ground Control Points

- Physical features with known locations
- These are the points used to georeference an image
- Can be determined
  - Using GPS
  - Finding coordinates for features on a paper map
  - Finding the location on another layer



Georeferencing

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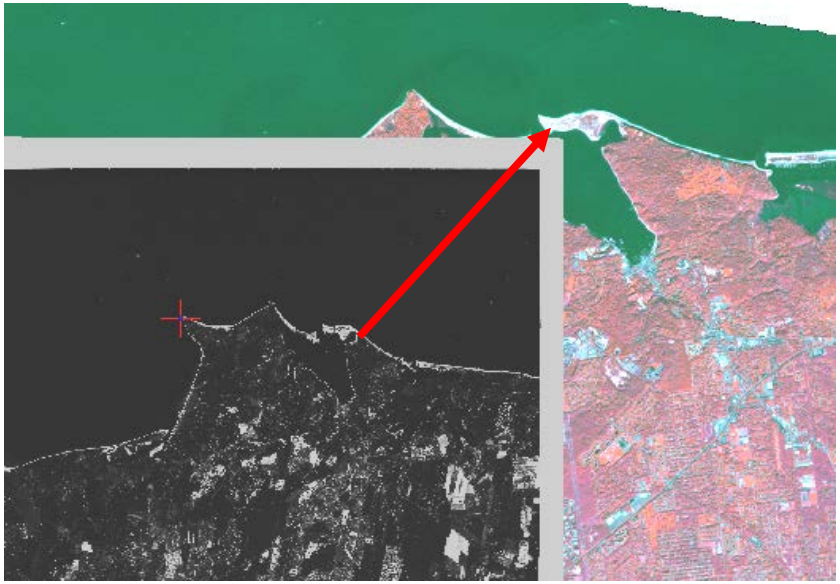
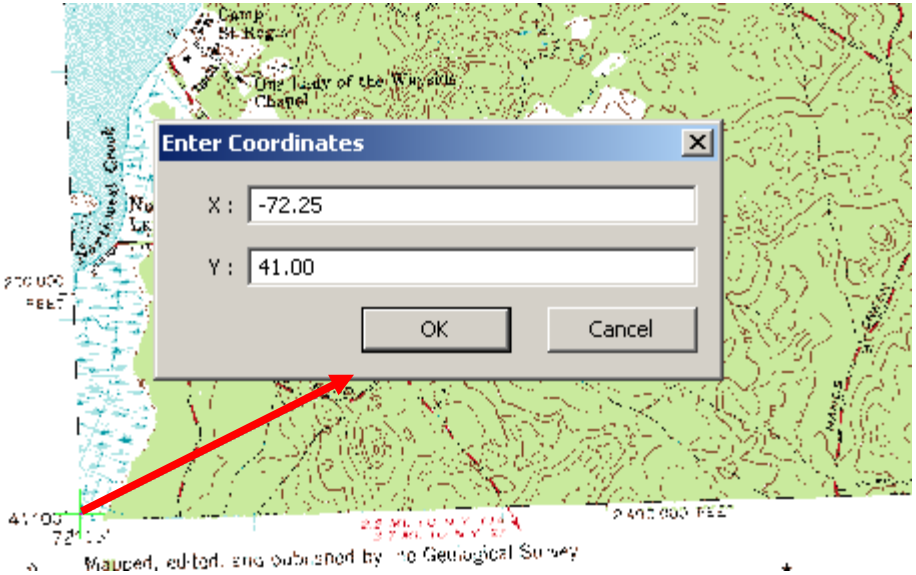
Using Ground Control Points (GCP) to tell the software where the image represents in the selected coordinate system

Image to Image



Coordinate based



Transformations

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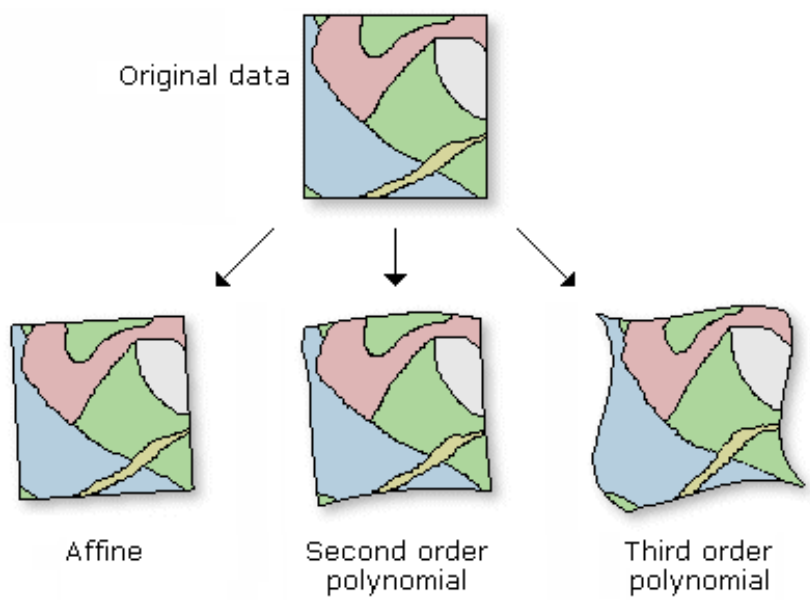
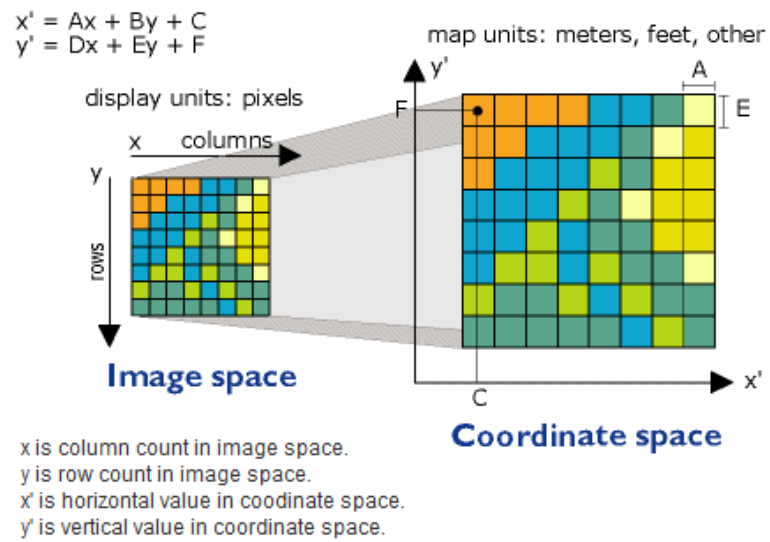
Polynomial transformations create a mathematical relationship between the image and the coordinate system





ArcGIS also has the option of a spline transformation, which interpolates all cells between GCPs

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Transformation methods

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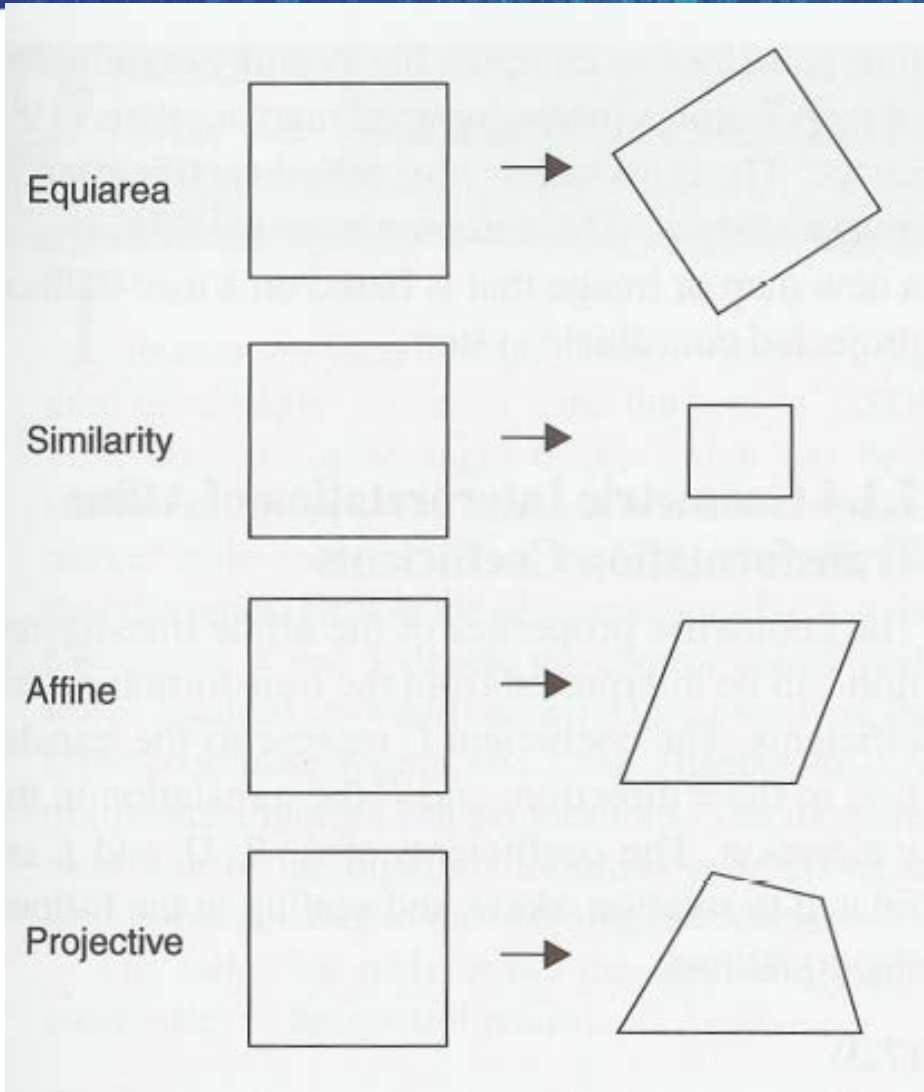
- Different methods overcome different distortions in the original image
- The Affine (first order polynomial) is the most common



Polynomial transformations:

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First Order Transformation
Affine

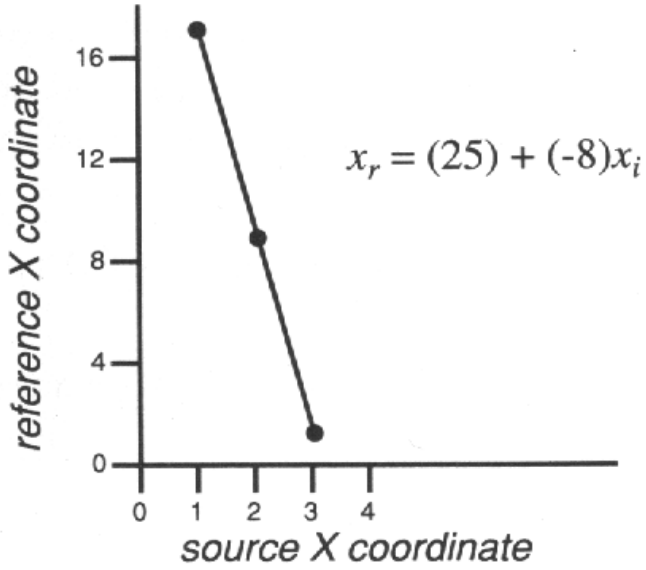
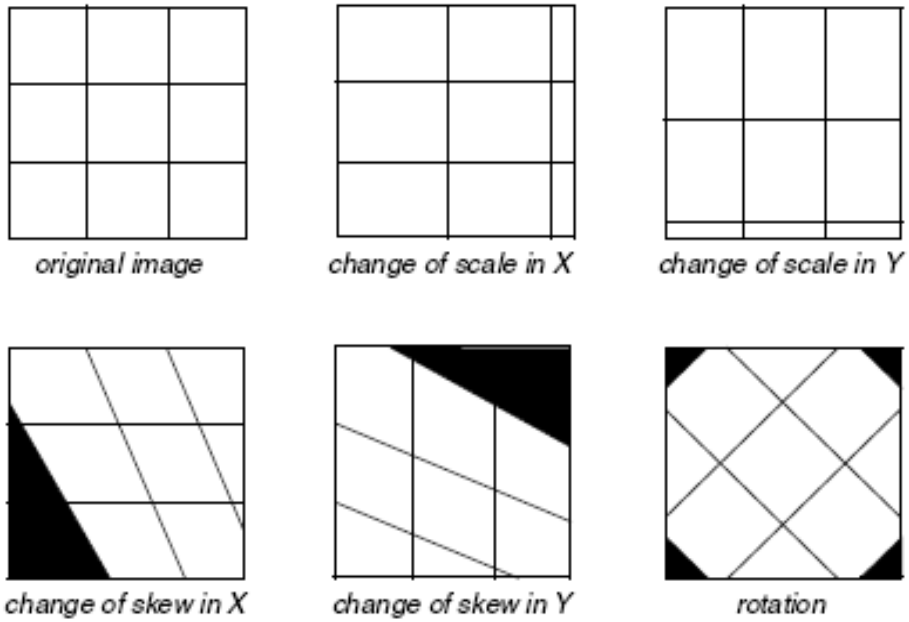


Figure 10-2: Linear Transformations



First order transformation

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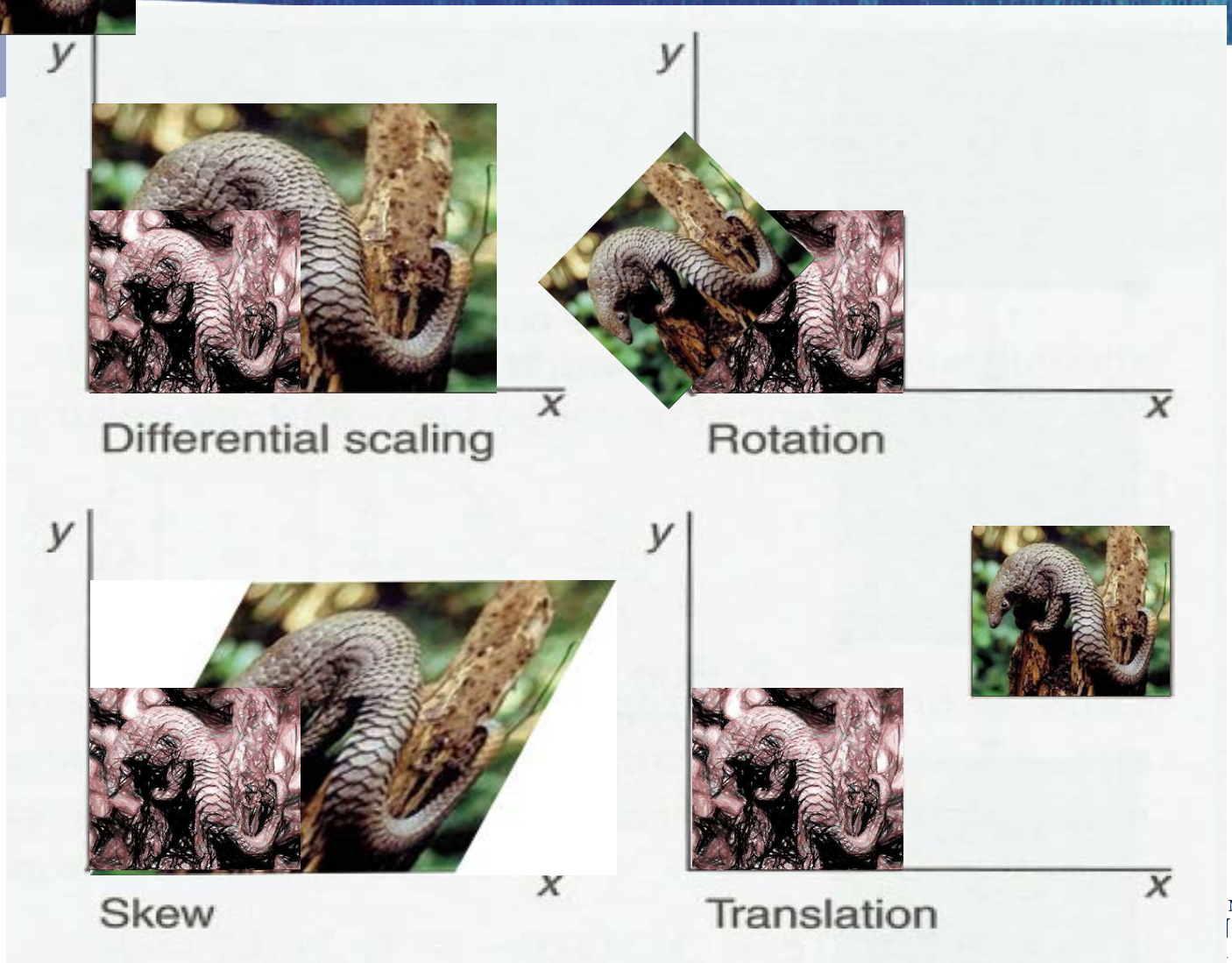

Polynomial transformations:

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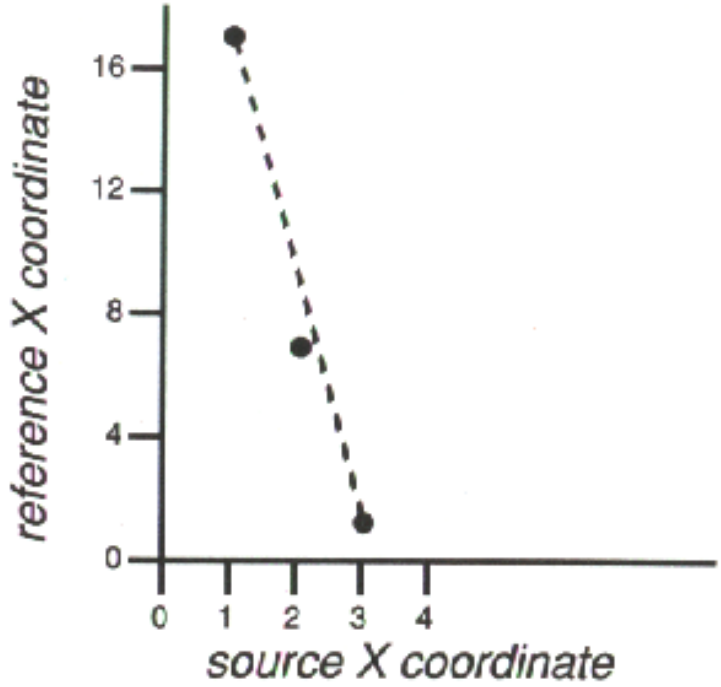
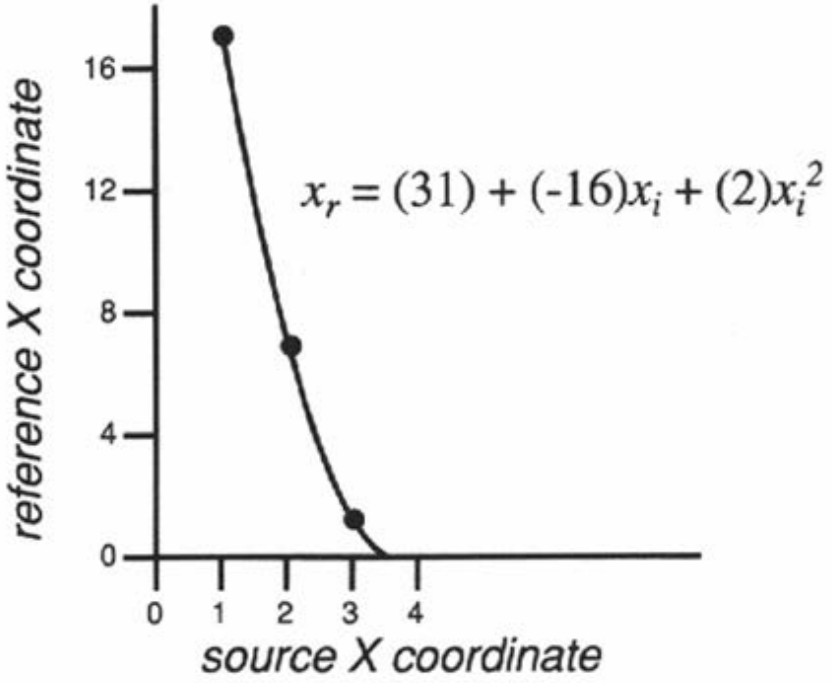
Second Order Transformation





Polynomial transformations:

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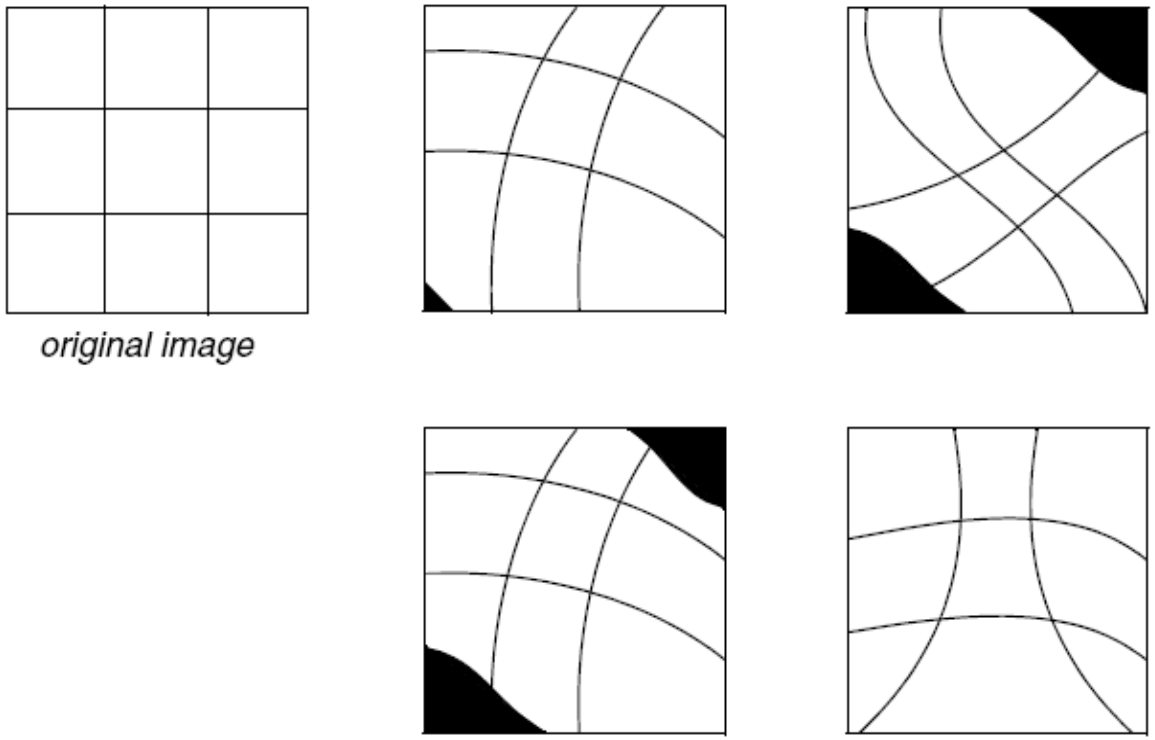
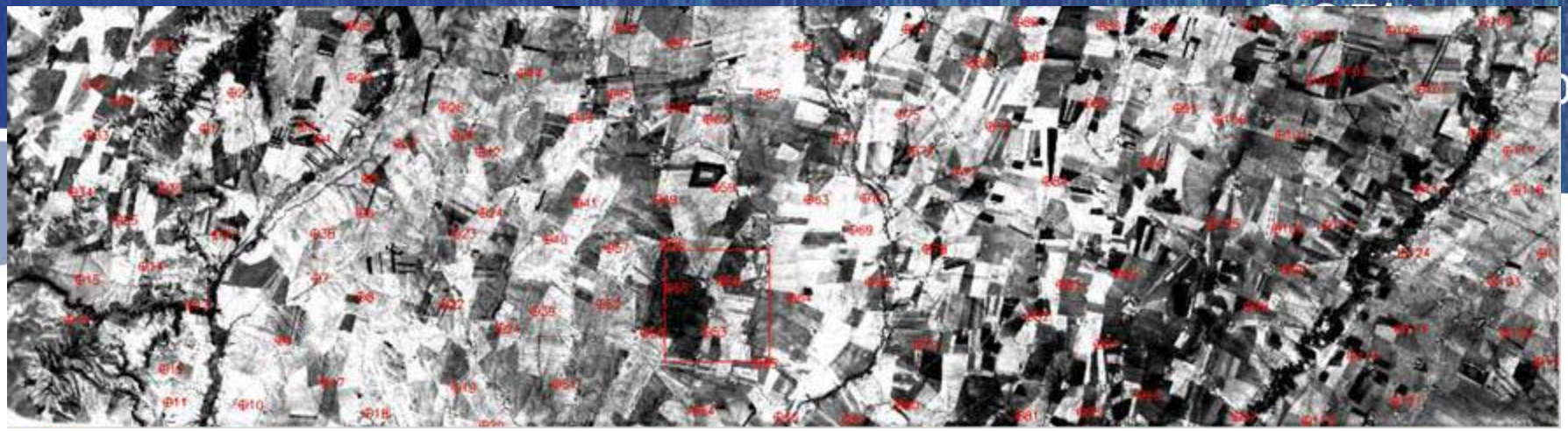
Second Order Transformation

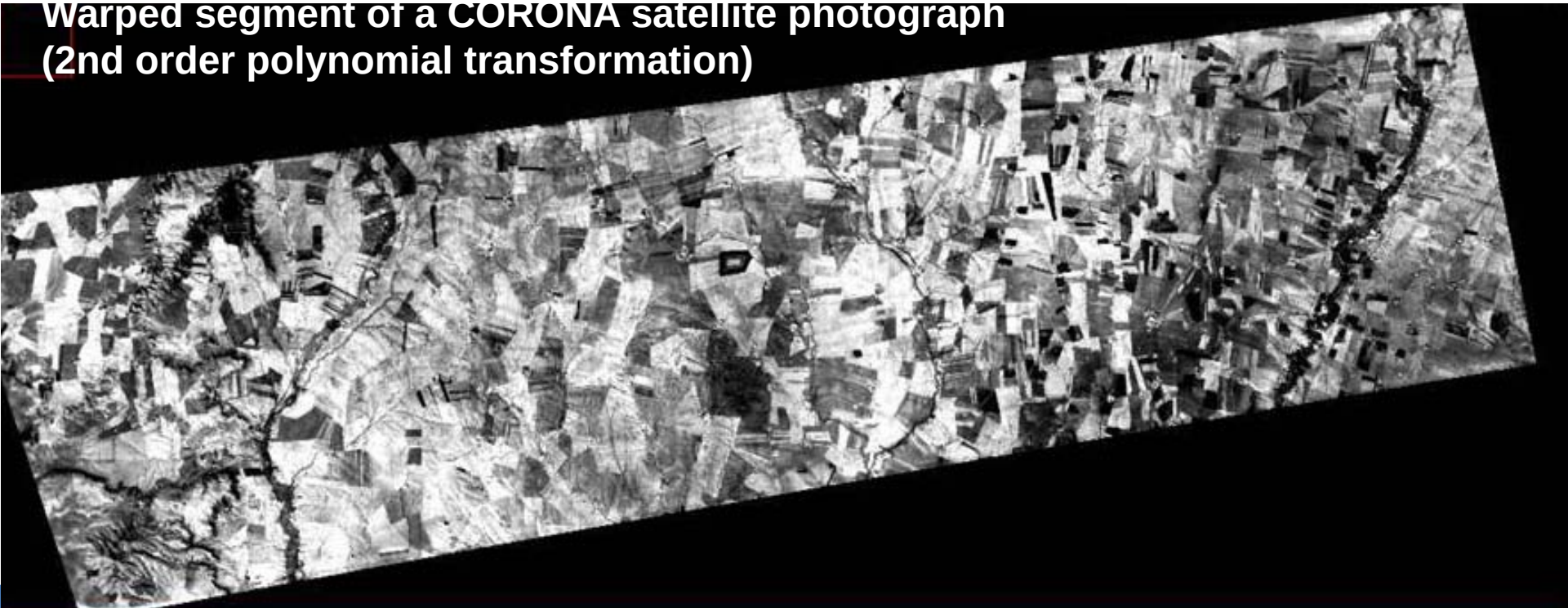
Figure 10-3: Nonlinear Transformations



Unwarped segment of a CORONA satellite photograph



Warped segment of a CORONA satellite photograph
(2nd order polynomial transformation)



Polynomial transformations:

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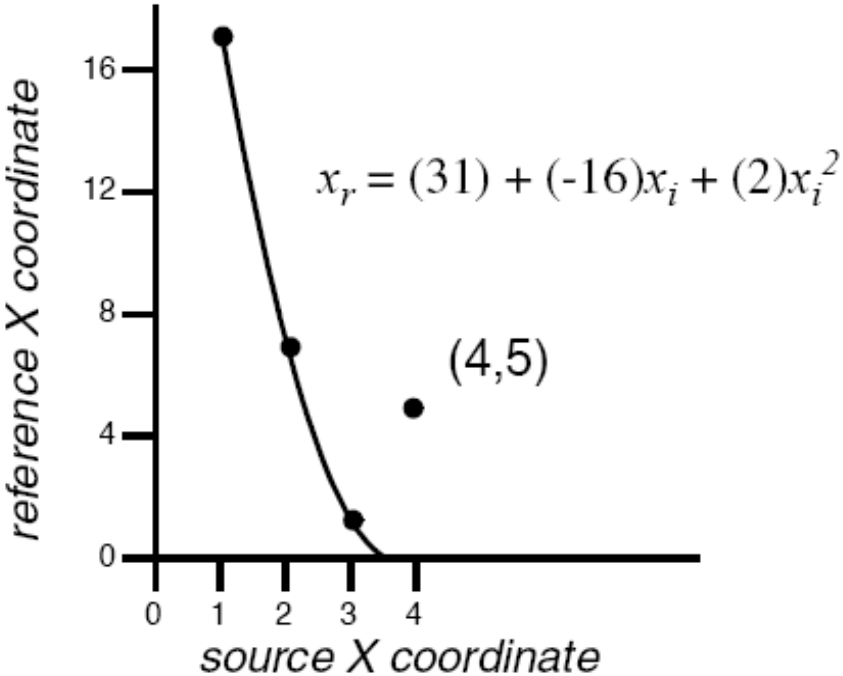
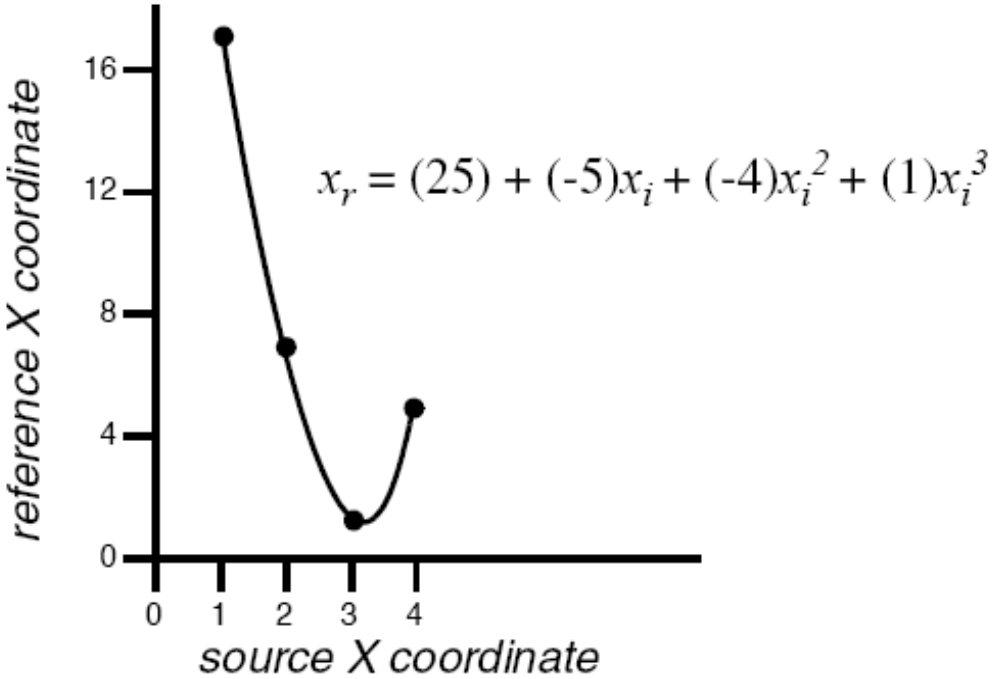
Third Order Transformation





Used when the relationship is even more complicated

Resampling Methods

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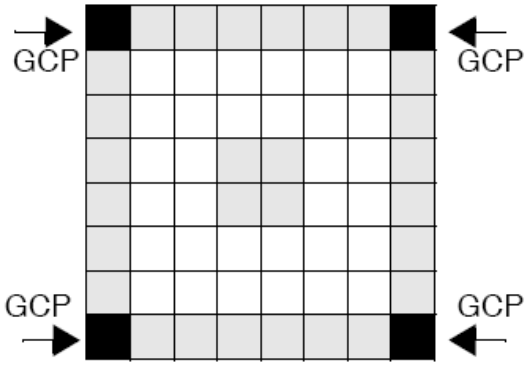
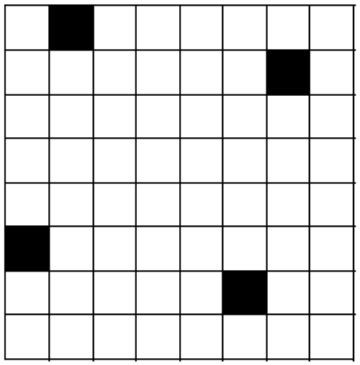
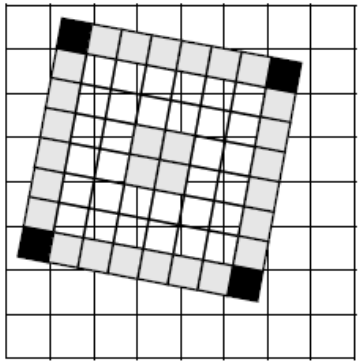


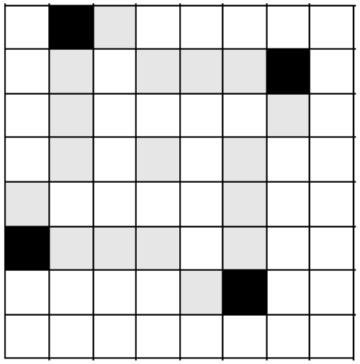
1. The input image with source GCPs.



2. The output grid, with reference GCPs shown.



3. To compare the two grids, the input image is laid over the output grid, so that the GCPs of the two grids fit together.



4. Using a resampling method, the pixel values of the input image are assigned to pixels in the output grid.

The method used to give each geographic area its value

- Nearest Neighbor
- Bilinear Interpolation
- Cubic Convolution

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“Error” in Polynomial Equations

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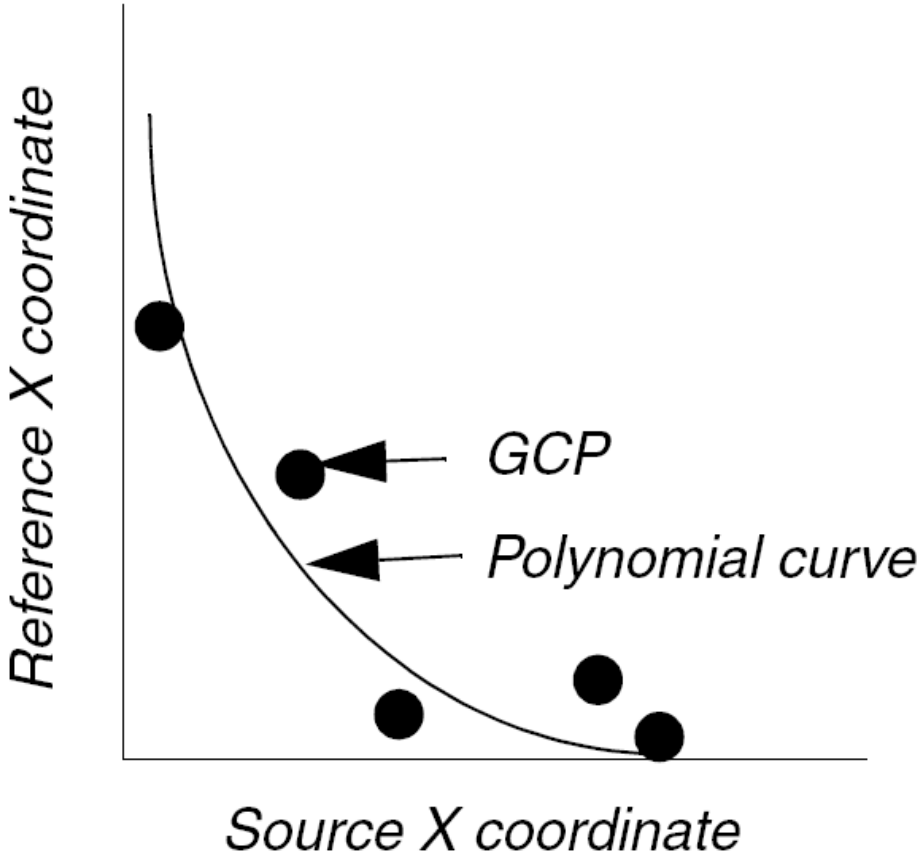

ArcGIS uses Root Mean Squares (rms) to evaluate the error in GCP

General Steps for Georeferencing in ArcGIS

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1. Obtain a digital or scanned imagery/map
2. Obtain either a layer with a known coordinate system or control points that represent locations/objects visible in image
3. Create displacement links that link pixel locations to real world coordinates
4. Look at the link table for acceptable residual on each point and total RMS error.
5. Select transformation method.
6. Rectify the map by selecting a resampling method (optional in ArcMap). Rectifying will create a new image file