Analytical and Computer Cartography

Lecture 3:
Review: Coordinate Systems

Geographic Coordinates

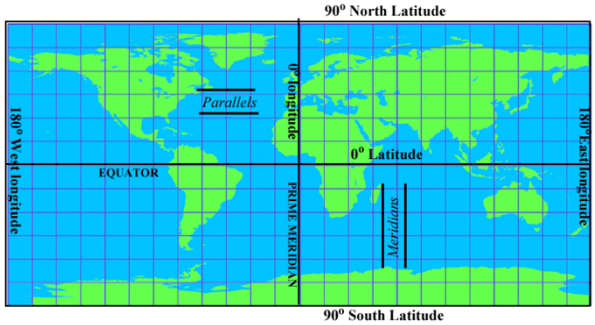


Figure 2.6 Geographic coordinates. The familiar latitude and longitude system, simply converting the angles at the earth's center to coordinates, gives the basic equirectangular projection. The map is twice as wide as high (360° east-west, 180° north-south).

Geographic Coordinates

- Geographic coordinates are the earth's latitude and longitude system, ranging from 90 degrees south to 90 degrees north in latitude and 180 degrees west to 180 degrees east in longitude.
- A line with a constant latitude running east to west is called a parallel.
- A line with constant longitude running from the north pole to the south pole is called a meridian.
- The zero-longitude meridian is called the prime meridian and passes through Greenwich, England.
- A grid of parallels and meridians shown as lines on a map is called a graticule

Measurement: Just use GPS

6 decimal places
0.000001° x 111111m
=0.11m

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
....
```

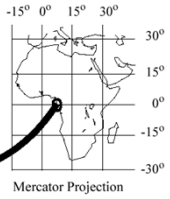


Figure 2.12 Part of the World Data Bank I listing of the coordinates of the coastline of Africa. Format is geographic coordinates in decimal degrees.

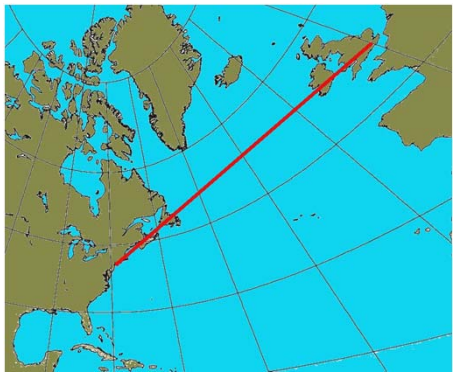
Ways to Record Lat/Long

Decimal Degrees	38.8998339 -77.0463660
DMS	385359N 0770247W
Hemisphere First	N385359W0770247
Decimal Minutes	38°53.98' N 77°02.78'W
Decimal Seconds	38°53'98.333" N 77°02'78.333"W

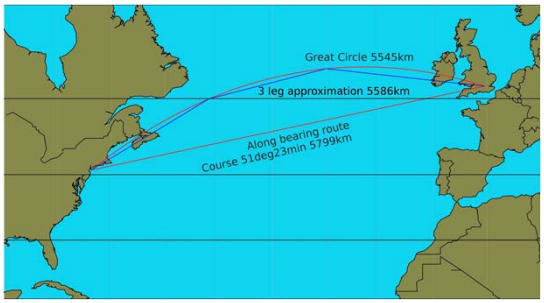
Problems with Geographic Coordinates

- Spherical geometry difficult, need great circle arcs
- Precision depends on mixed DMS and DD
- Axes are not orthogonal
- Difficult to use algorithms for measurements e.g. simple distance
- Solution: Planar geometry
- But, price is living with an imperfect projection

Great circles are straight on some conformal projections (Gnomic): Note crossing angles



JFK to LHR: Approximating a great circle on the Mercator. Only 41km farther (0.74%)



Minimizing projection error

- Use a small area
- Choose a projection to limit error
- Compute expected error amount and location
- Use secant projection
- Customize: e.g. Chile

Standard parallels

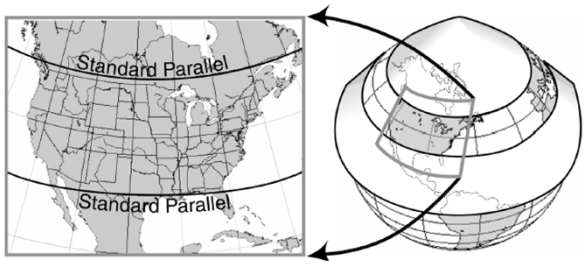
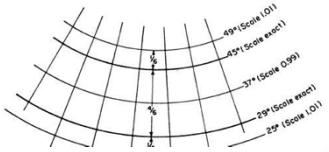
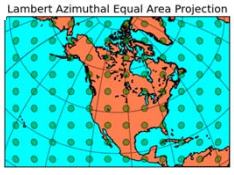


Figure 2.8 Standard parallels. The conic projection cuts through the globe, and the earth is projected both in and out onto it. This is a secant conic projection. Lines of true scale, where the cylinder and sphere touch, become standard parallels. If the touching is along one line, the projection is tangent and has one standard parallel.

Distortion on the Secant Conic Lambert conformal conic projection



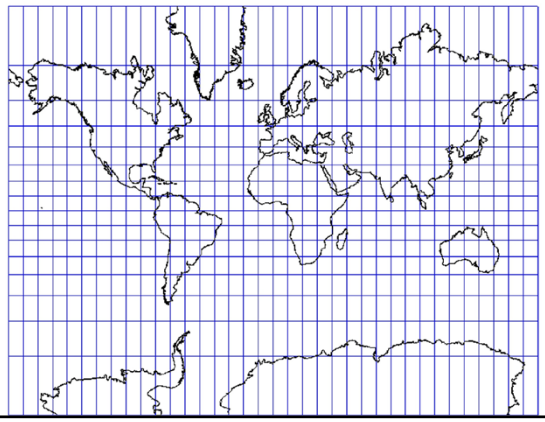
Lambert Azimuthal Equal Area Projection



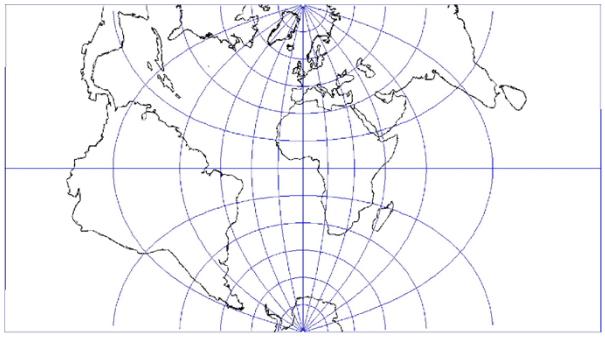
Coordinate Systems

- 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
- Can use letters, numbers
- Can interweave digits for *x* and *y*

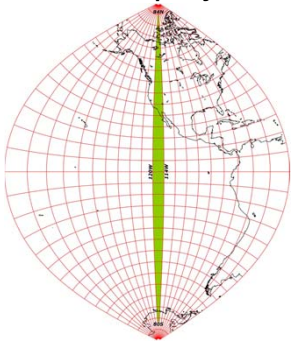
Equatorial Mercator



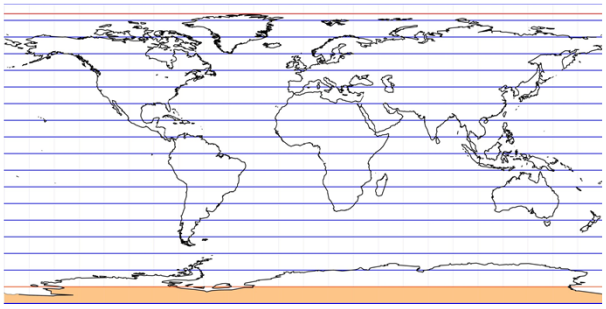
Transverse Mercator



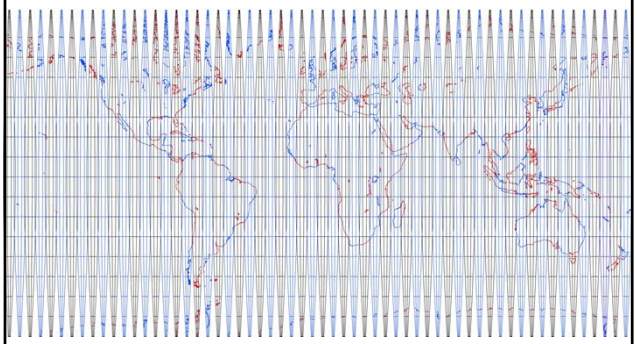
The advantage of the transverse Mercator projection



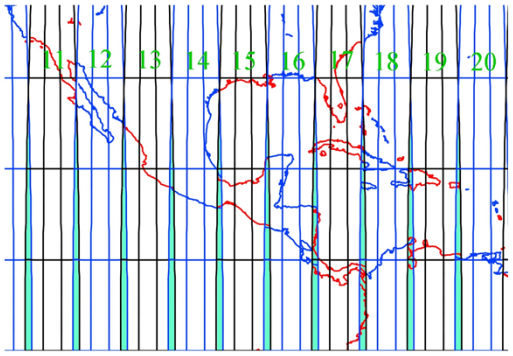
Applies 80°S to 84°N



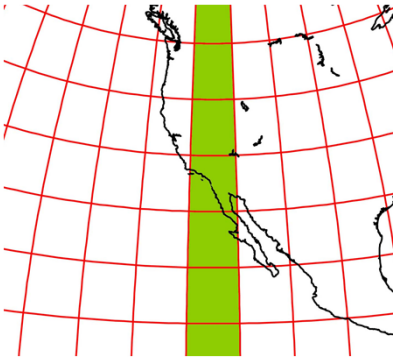
60 zones each 6° of longitude wide



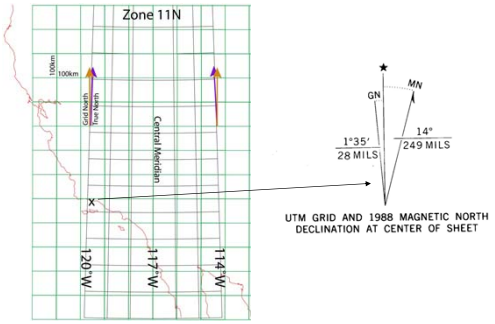
Zones overlap slightly when 1million meters wide

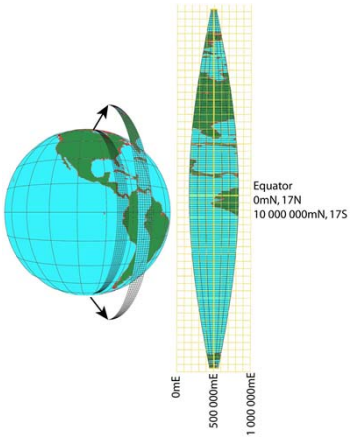


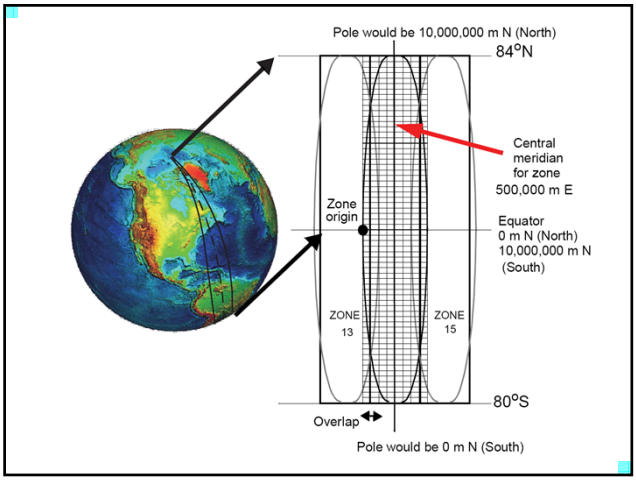
Zone 11N



Grid north and the Zone

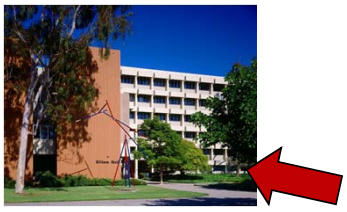




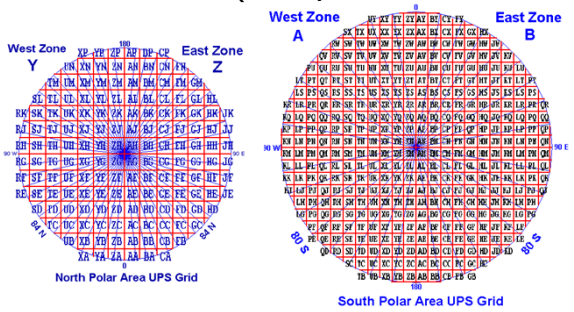


Example, GPS fix

238499E; 3811905N 11, N



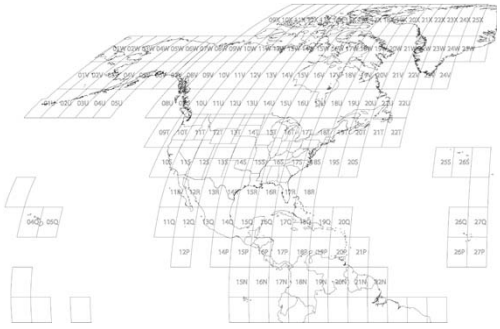
Universal Polar Stereographic (UPS)



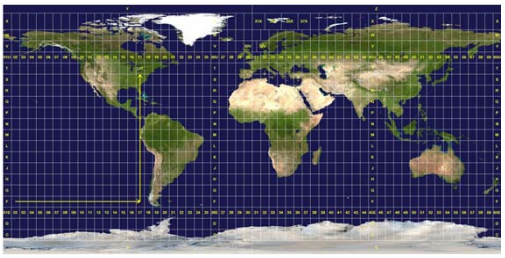
Coordinate Systems for the US

- Some standard coordinate systems used in the United States are
  - geographic coordinates
  - universal transverse Mercator system
  - military grid/MGRS/National grid
  - state plane
- To compare or edge-match, both maps MUST be in the same coordinate system.

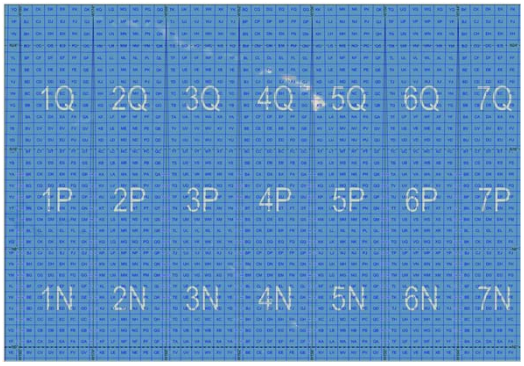
UTM zones in the USA



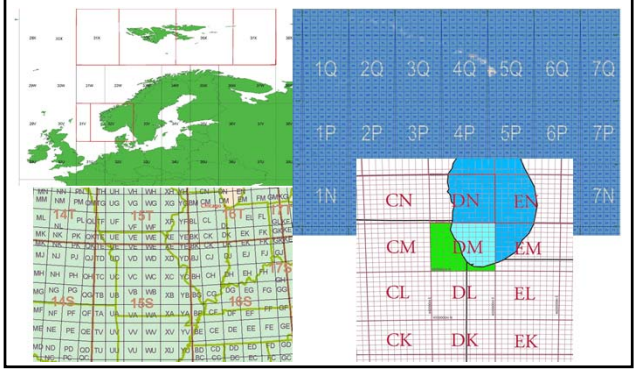
Military Grid Coordinates First Reference (6 x 8 degrees)



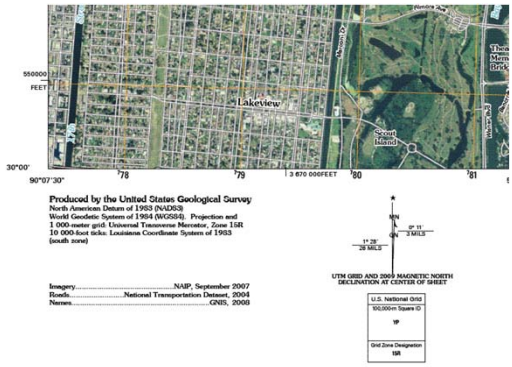
USMG: 2nd Reference 100,000m cells



MGRS Grid designators

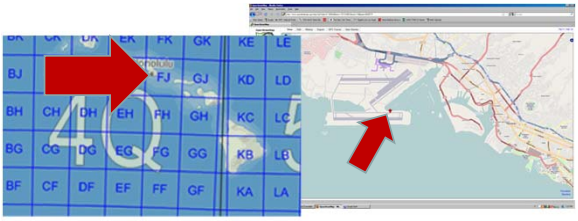


MGRS/National Grid



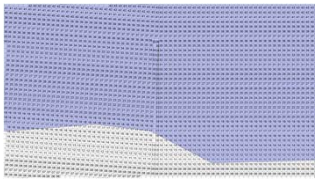
Anatomy of a MGRS coordinate

4Q .....GZD only, precision level 6° × 8° (in most cases)
4QFJ .....GZD and 100 km SQ_ID, precision level 100 km
4QFJ16 .....precision level 10 km
4QFJ1267 .....precision level 1 km
4QFJ123678 .....precision level 100 m
4QFJ12346789 .....precision level 10 m
4QFJ1234567890 .....precision level 1 m

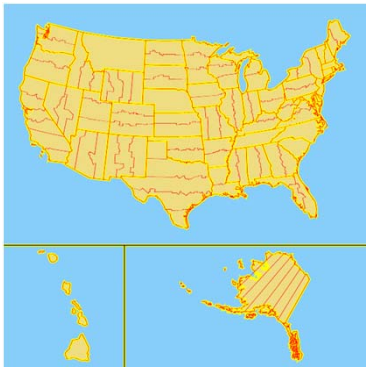


USNG: The National Grid

Same as the MGRS except uses NAD83
Maximum difference only c 2m worldwide
Supported in National Map
Some problems at cell boundaries

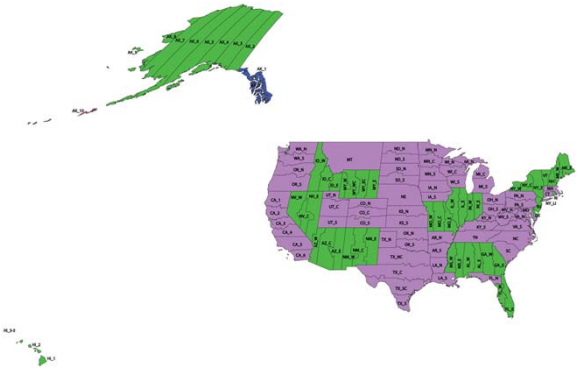


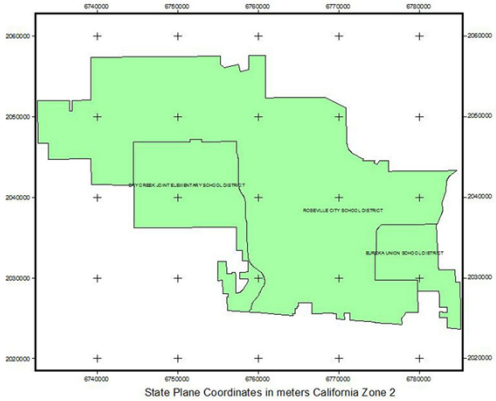
State Plane Coordinates



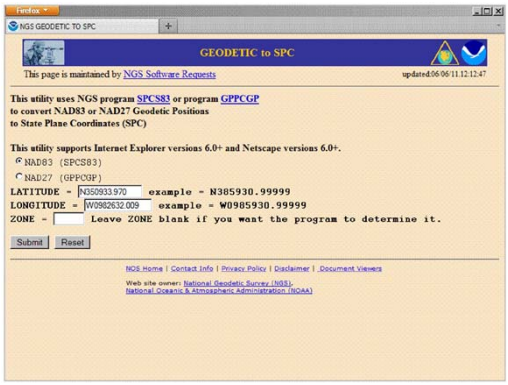
Zones:

Lambert Conformal Conic vs. Transverse Mercator

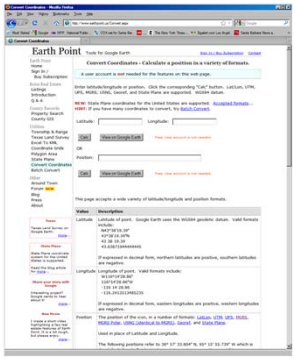




Converting

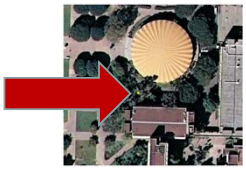


www.earthpoint.us



Coordinate examples

- 238,479 mE; 3,811,950 mN; 11, N
- 11SKU3847911950
- N 34º24’57.24” W 119º50’42.9”
- 603153 1830382 CA 5



Degree of digit variation in a line

- 4QFJ12345 67890
- 4QFJ12347 67897
- 4QFJ12349 67899
- 4QFJ12352 67903
- 4QFJ12355 67907
- 4QFJ12356 67910

Red values do not change
Green values are 2 of 10 possible values
Purple digits are 5 of 10 possible values

Suspicious

- 4QFJ12345 67890
- 4QFJ12340 67897
- 4QFJ12340 67899
- 4QFJ12355 67903
- 4QFJ12355 67907
- 4QFJ12360 67910

Always 0 or 5, rounded? But only in the Easting

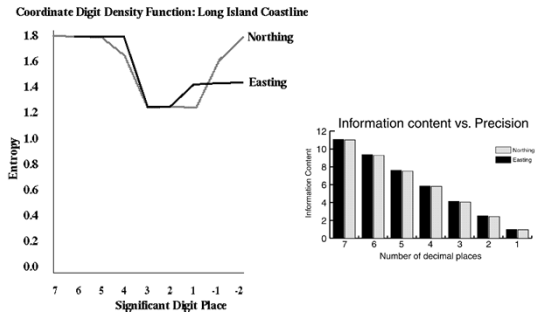
Information content

- For any digit *n* at any one significant digit location out of *N* possible digit values or states (10 for decimal), *I* is defined, where:

$$I_n = \sum_{1}^{N} \left| \frac{D}{\Sigma D_n} - \frac{1}{N} \right|$$

First digit of the coordinates are all "4" so nine digits would have no occurrence (0.0 - 0.1 x 9 = -0.9) and one digit would occur alone (1.0 - 0.1 = 0.9), which sums to 1.8.
If all values are equally represented, I = 0.0

The Coordinate Digit Density Function



Summary

- Geographic coordinates are not planar
- Euclidean coordinates need a plane, and orthogonal axes
- Many standard coordinate systems are in use e.g. State Plane, UTM, MGRS, National Grid
- We can compute information content for sets of coordinates
- Coordinate digits can be redundant to random