Analytical and Computer Cartography

Lecture 3:
Review: Coordinate Systems

Geographic Coordinates

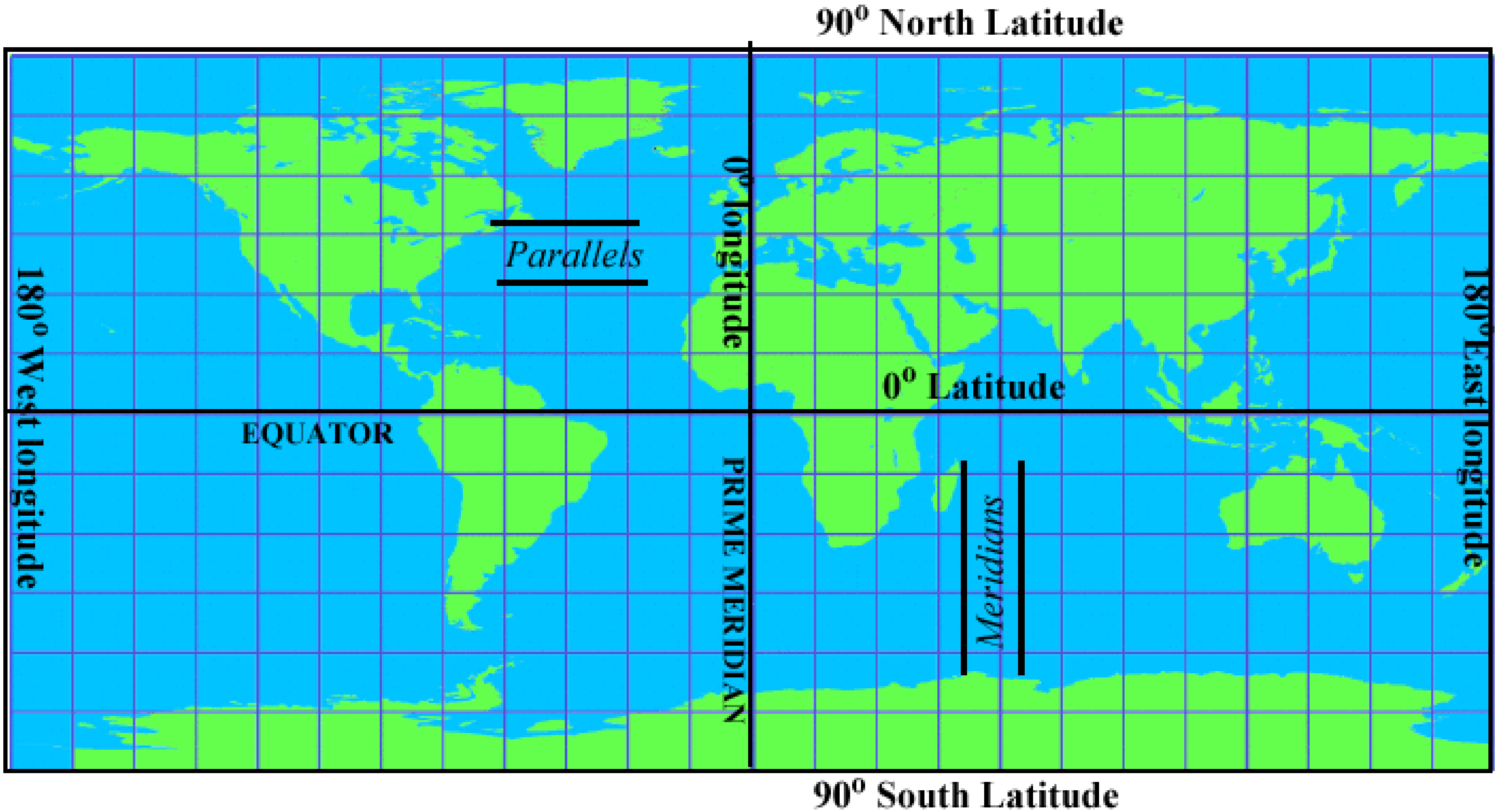

Figure 2.6 Geographic coordinates. The familiar latitude and longitude system, simply converting the angles at the earth's center to coordinates, gives the basic equirectangular projection. The map is twice as wide as high (360⁰ east-west, 180⁰ north-south).

NAD83

- NAD27 remained in use until the earth-centered international GRS80 was complete (Geodetic Reference System 1980)
- Then converted to NAD83, using GRS80 ellipsoid
- Very similar ellipsoid WGS84 was adopted by DOD and many other mapping agencies
- Meades ranch now just a historical relic

IERS

- Provides data on Earth orientation, on the International Celestial Reference System/Frame, on the International Terrestrial Reference System/Frame, and on geophysical fluids
- Maintains Conventions containing models, constants and standards
- Includes ITRS

IERS

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International Earth Rotation and Reference Systems Service

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- Analysis Coordinator
- Product Centres
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Organization

The IERS was established in 1987 by the International Astronomical Union and the International Union of Geodesy and Geophysics. According to the Terms of Reference, the IERS accomplishes its mission through the following components: Technique Centres, Product Centres, Combination Centres, Analysis Coordinator, Central Bureau, Directing Board.

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Data / Products / Tools

The IERS provides data on Earth orientation, on the International Celestial Reference System/Frame, on the International Terrestrial Reference System/Frame, and on geophysical fluids. It maintains also Conventions containing models, constants and standards.

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Publications

The IERS issues Messages to distribute news, Bulletins to provide Earth orientation data, Technical Notes to publish research results and proceedings of workshops, and Annual Reports to inform the public about its work.

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Science background

Information about Earth rotation, reference frames, and observation techniques in general - Glossary - References - List of acronyms.

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News

- History of the IERS: Several pages updated
- IERS Directing Board: list of members updated
- IERS Conventions Centre: Updated

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Meetings

- IAG Commission 4 "Positioning and Applications" Symposium
- WDS Members' Forum
- 2016 CODATA General Assembly

› More

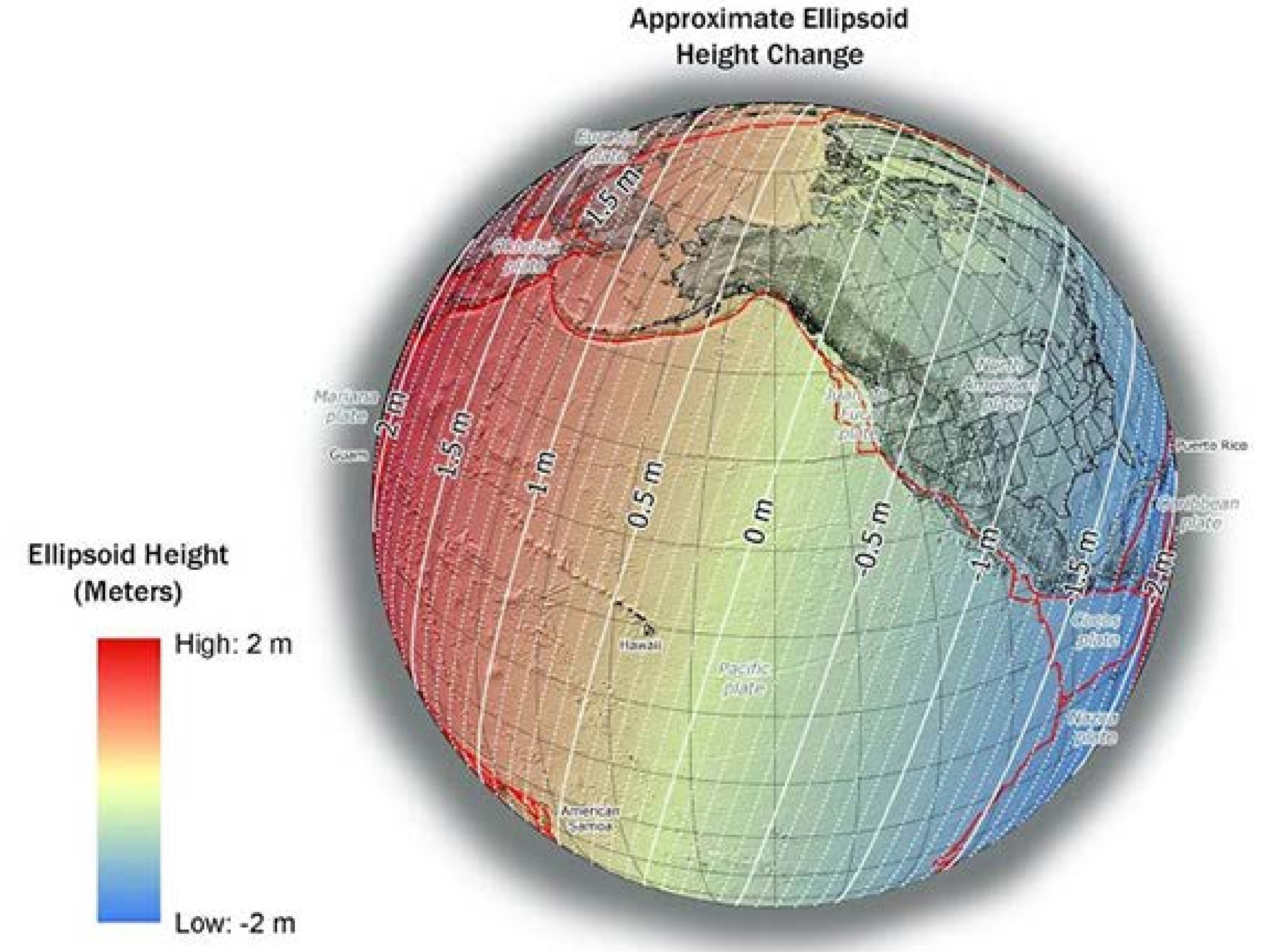
NAD2022 and NAVD2022

- North American Datum of 1983 will be replaced by a new geometric datum which provides latitude, longitude, height and time information.
- Will rely completely on the CORS network (continuously operating reference stations)
- NGS is completing a major project called Gravity for the Redefinition of the American Vertical Datum, or GRAV-D.
- The scale of the change will vary depending on your location, ranging from 0.5 to 1.5 meters in a horizontal direction, and 0 to 1.3 meters in elevation.
- Many state and other governmental entities passed laws on NAD83 that will need to be changed to reflect the new datum
- Will create the National Spatial Reference System

Resources

- http://alt.ngs.noaa.gov/web/science_edu/online_lessons/
- http://www.ngs.noaa.gov/corbin/class_description/NGS_Video_Library.shtml

NAD83 to NAD2022



Datums and Map Projections

- Assuming an earth model sets the initial surface that will be transformed
- Influences both position and height
- If projection does not document the datum, it may be irreversible
- Most GIS packages create metadata files that establish key parameters
- After NAD2022, time will be an integral part of position

Ways to Record Lat/Long

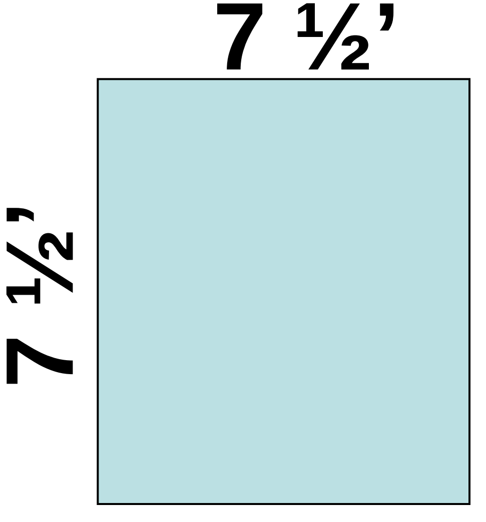
Decimal Degrees	38.8998339 -77.0463660
DMS	385359N 0770247W
Hemisphere First	N385359W0770247
Decimal Minutes	38^{o}53.98’ N 77^{o}02.78’W
Decimal Seconds	38^{o}53’98.333” N 77^{o}02’78.333”W

Problems with Geographic Coordinates

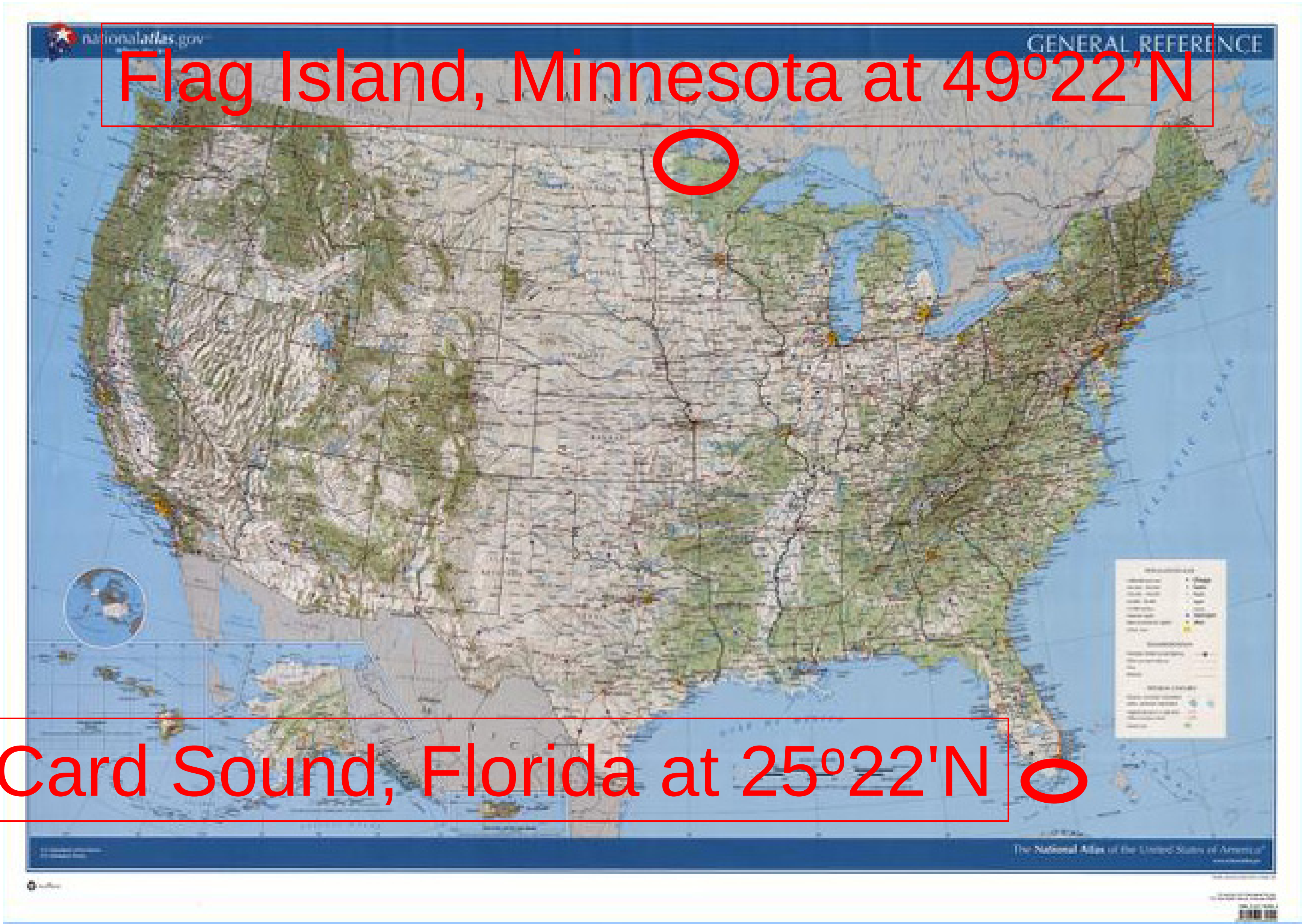
- Spherical geometry difficult, need great circle arcs for many applications
- Precision depends on mixed DMS and DD origin maps
- Axes are not orthogonal
- Difficult to use algorithms for spherical measurements e.g. simple distance in x =cos(ϕ)
- Solution: Planar geometry
- But, price is living with an imperfect projection

USGS Topographic maps

- Seven and a half minutes of longitude wide
- Seven and a half minutes of latitude high
- So why aren't they square?



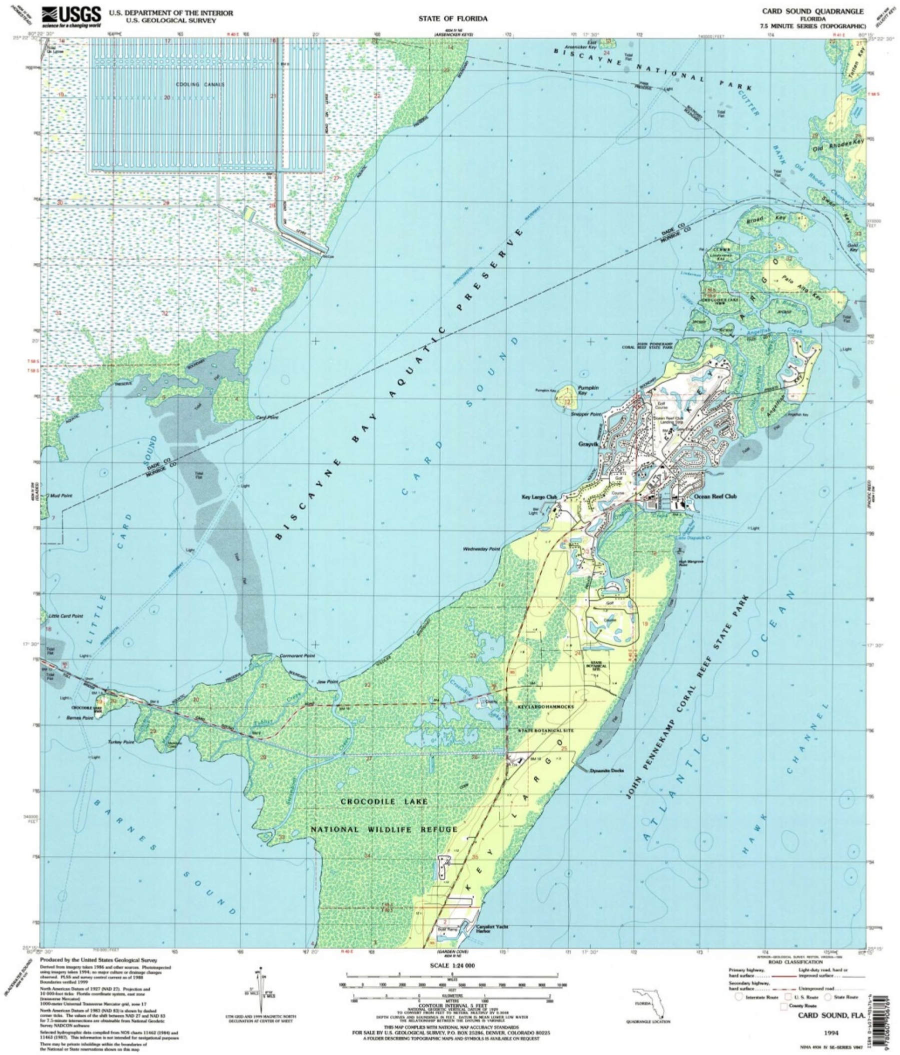
Lets check two locations



Flag Island, Minnesota at 49º22’N

Card Sound, Florida at 25º22'N

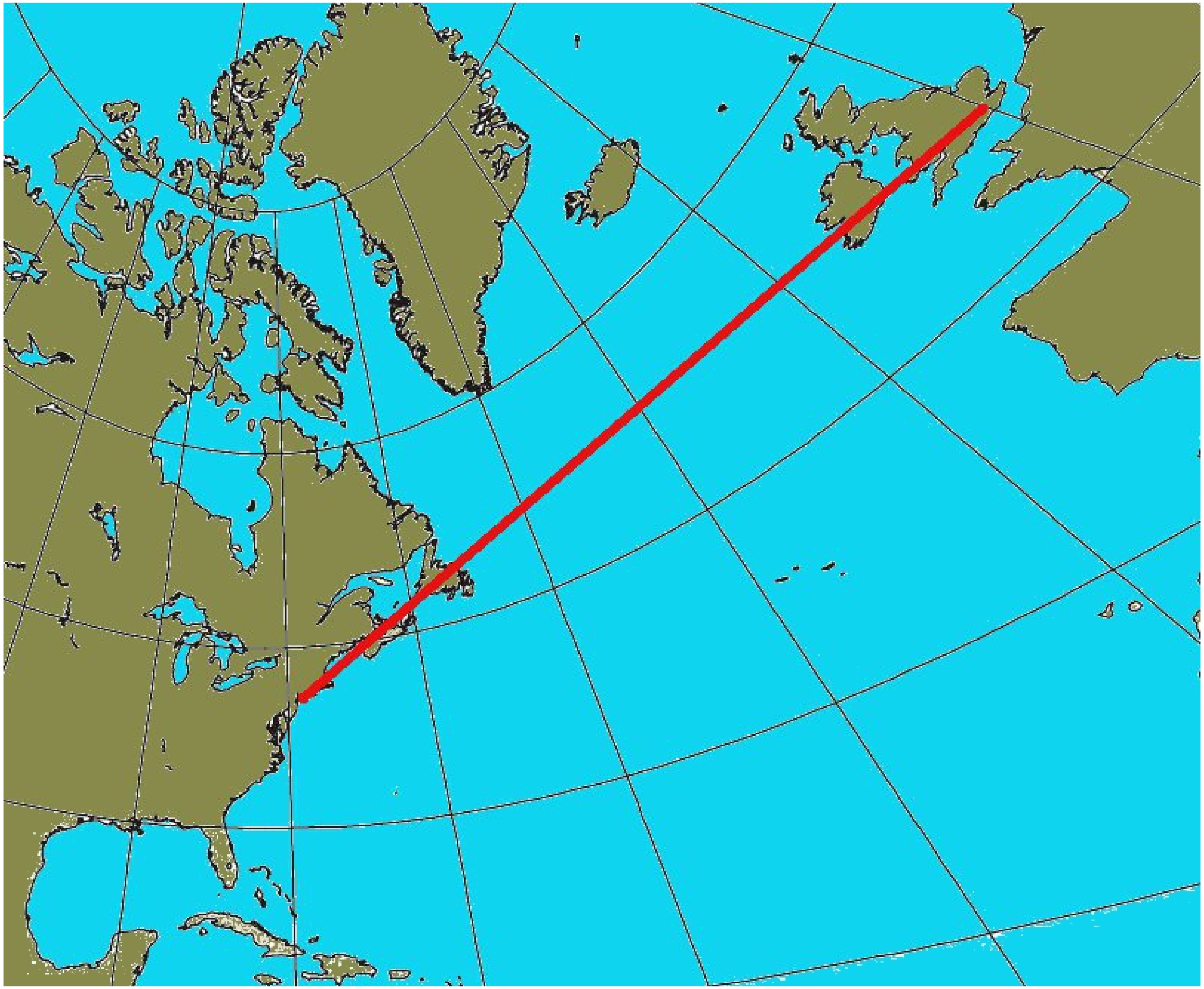
Card Sound, Florida at 25º22'N. **Flag Island, Minnesota at 49º22N.**



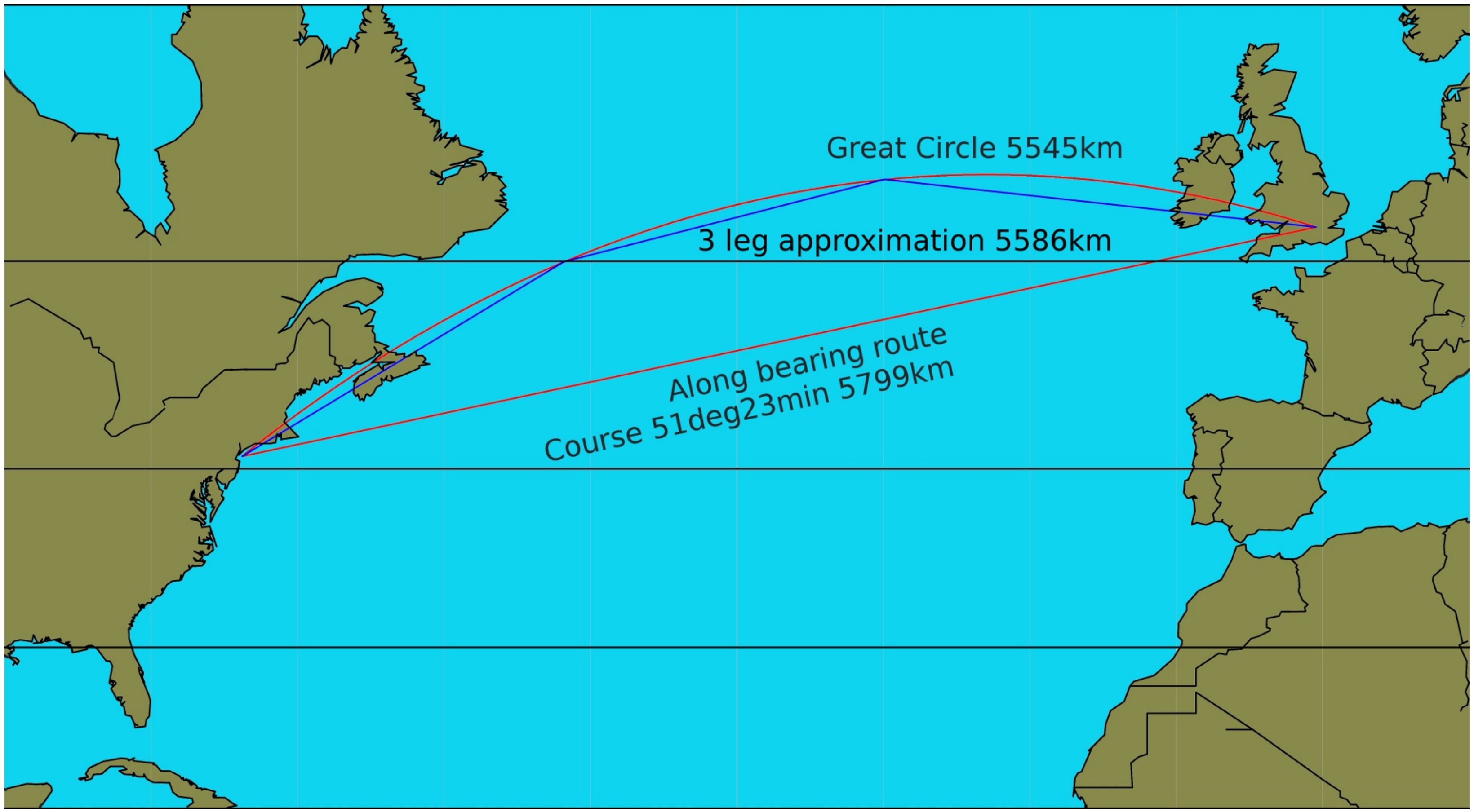
Using Projections

- Choice of projection allows control over map center, plus pattern of distortion
- Can optimize projection for map purpose, e.g. choose standard parallels
- Allows customizations for particular maps and applications, e.g. navigation
- Often chosen once then choice remains in place
- E.g. Mercator for navigation by compass

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



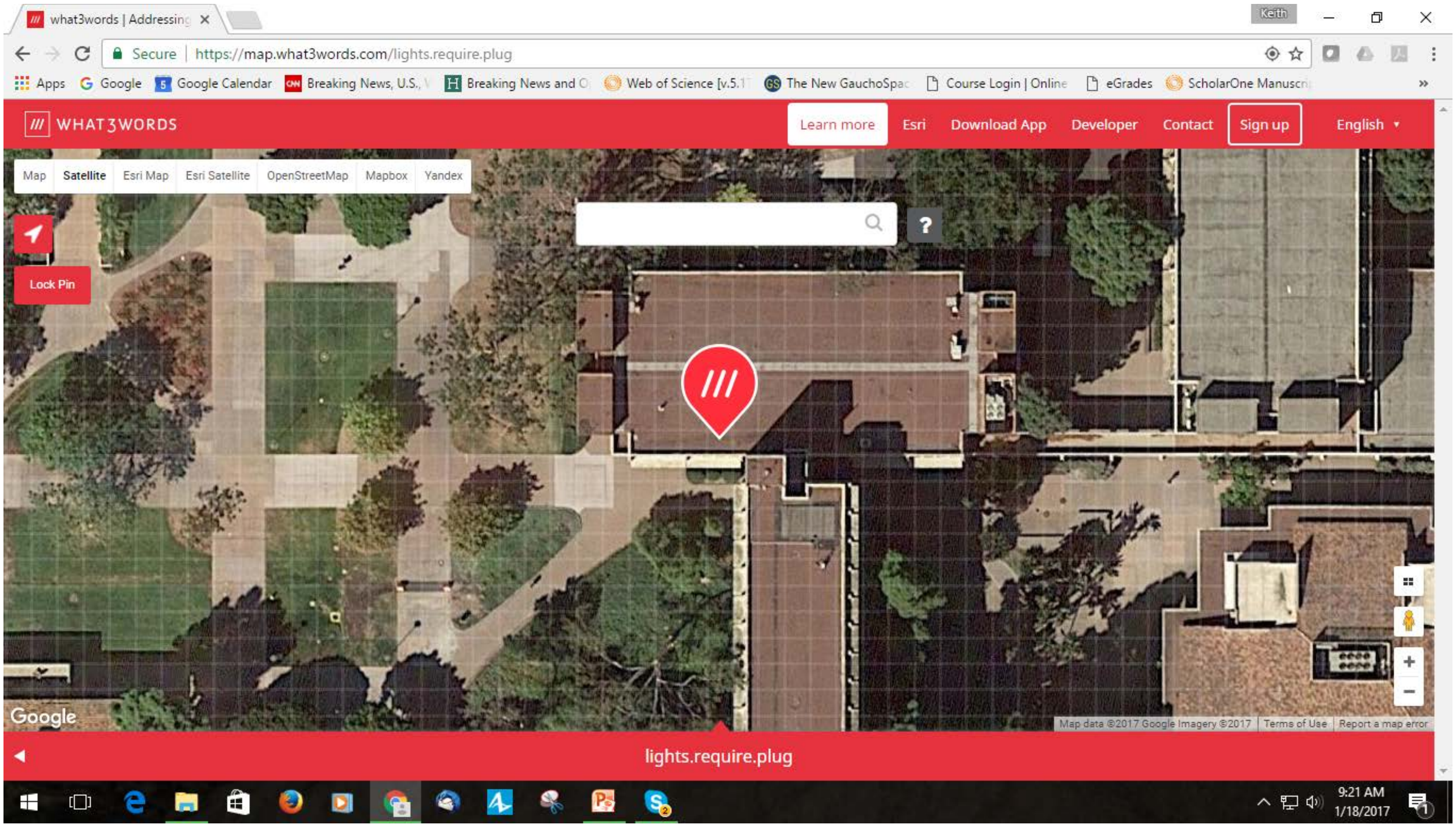
JFK to LHR: Approximating a great circle on the Mercator. Only 41km farther (0.74%)



Projection and 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*

What3words: 3 x 3m squares

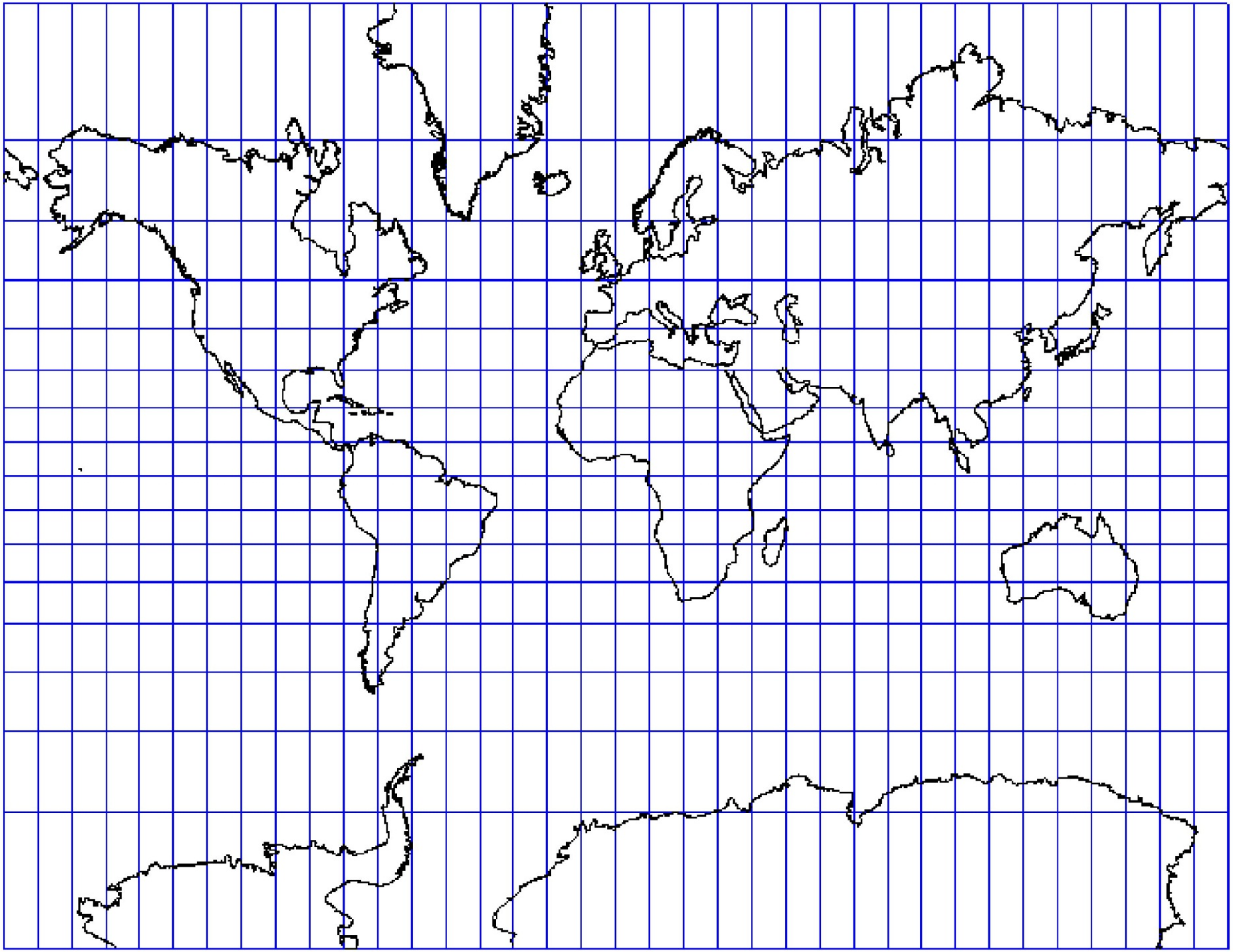


https://map.what3words.com/lights.require.plug

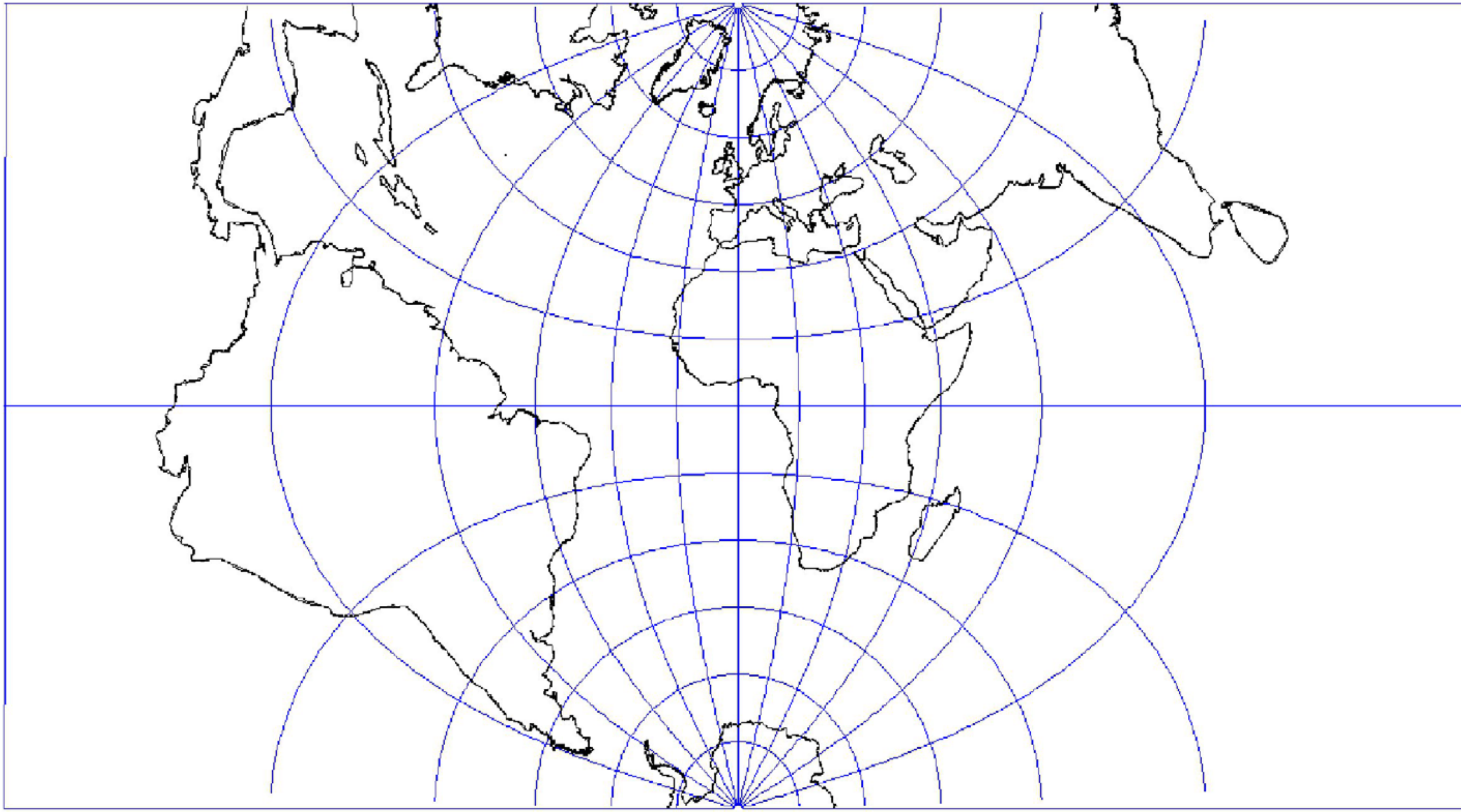
Coordinate Systems for the US

- 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.

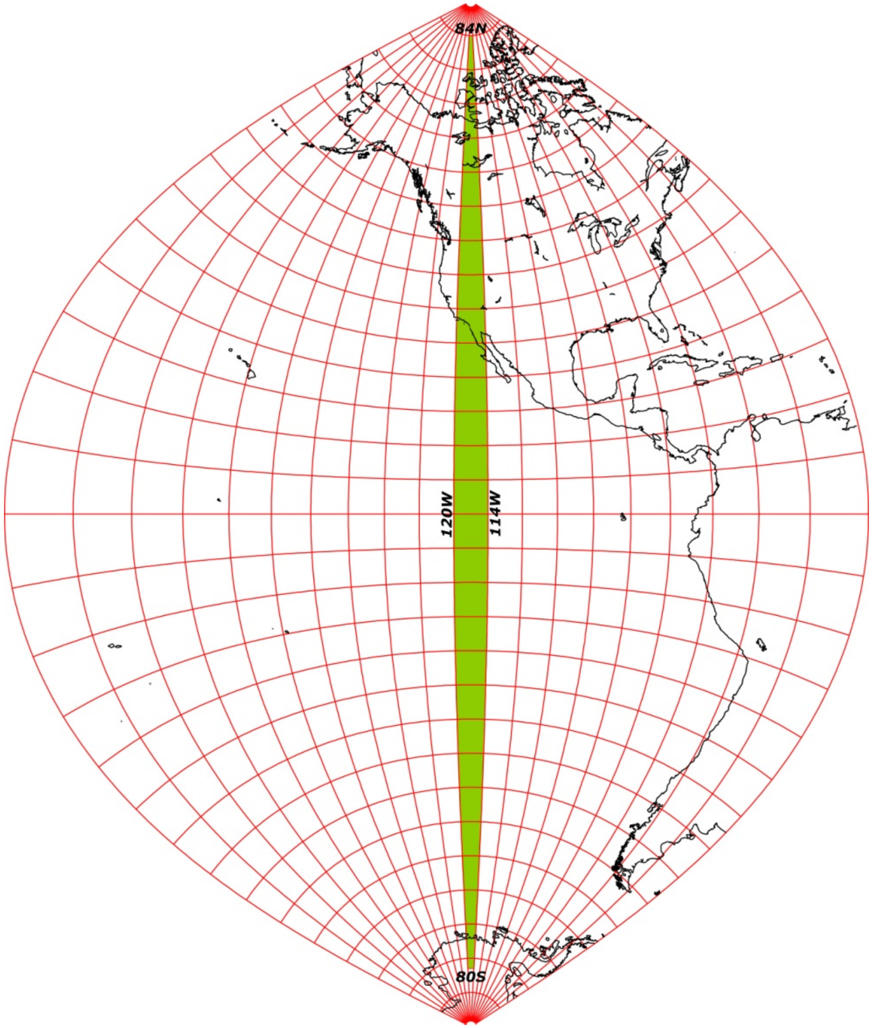
Equatorial Mercator



Transverse Mercator



The advantage of the transverse Mercator projection

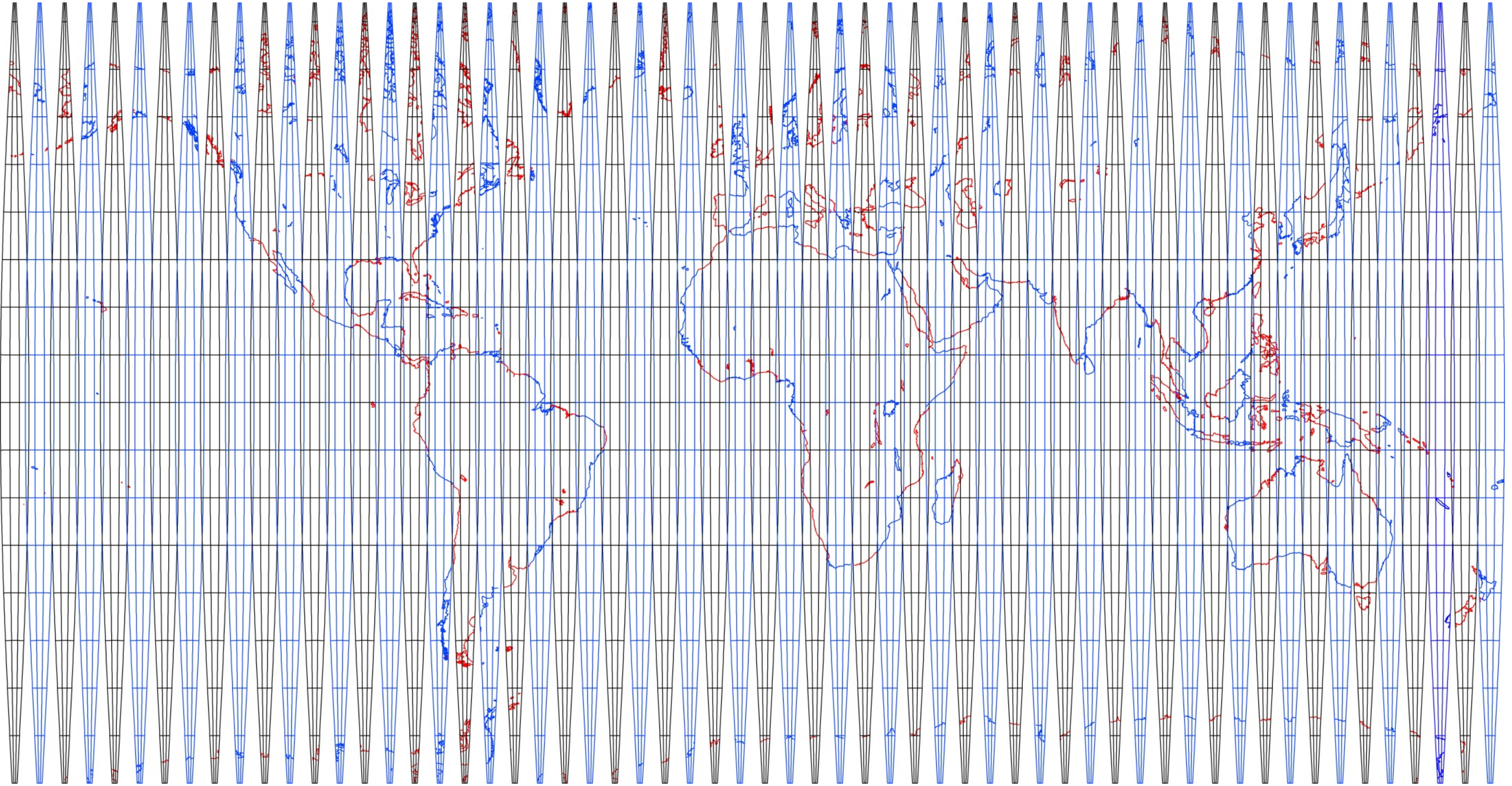


UTM

- Universal transverse Mercator coordinate system
- Basis for 3 grid systems: Civilian UTM, MGRS and US National Grid
- Used in Hybrid form by geohack
- Uses 60 projections with 6 degrees between central meridians

Applies 80^{o}S to 84^{0}N

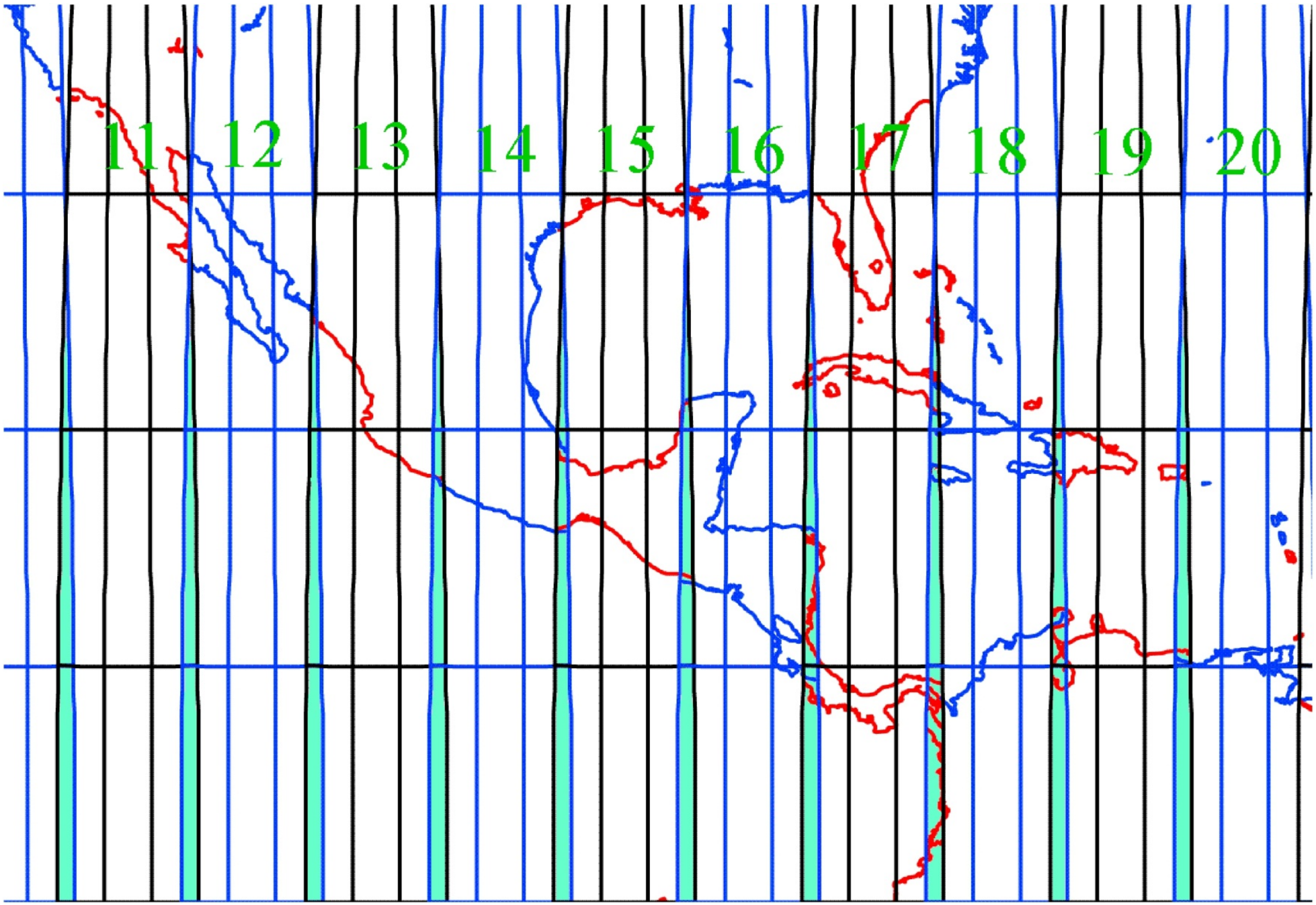
60 zones each 6º of longitude wide



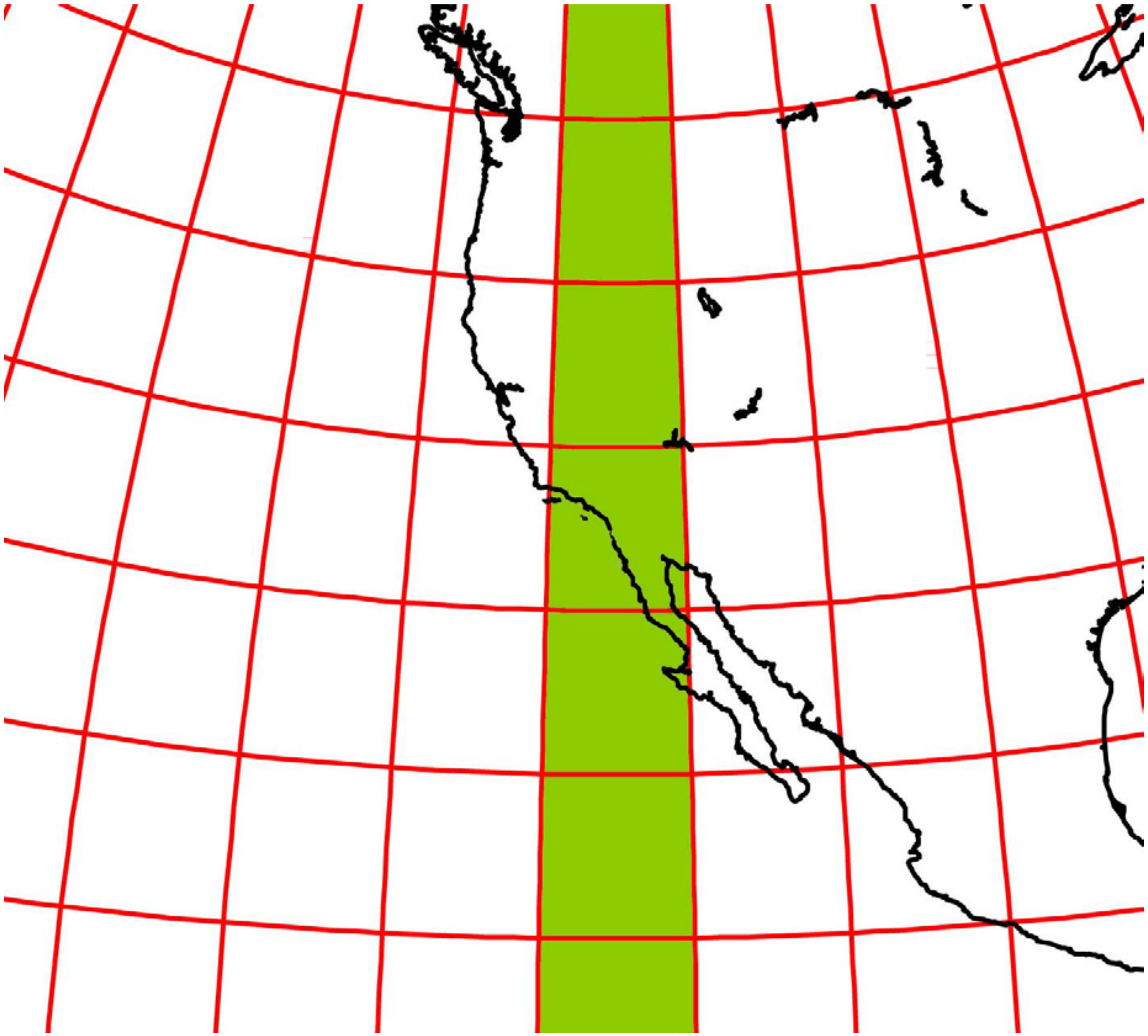
UTM Zones

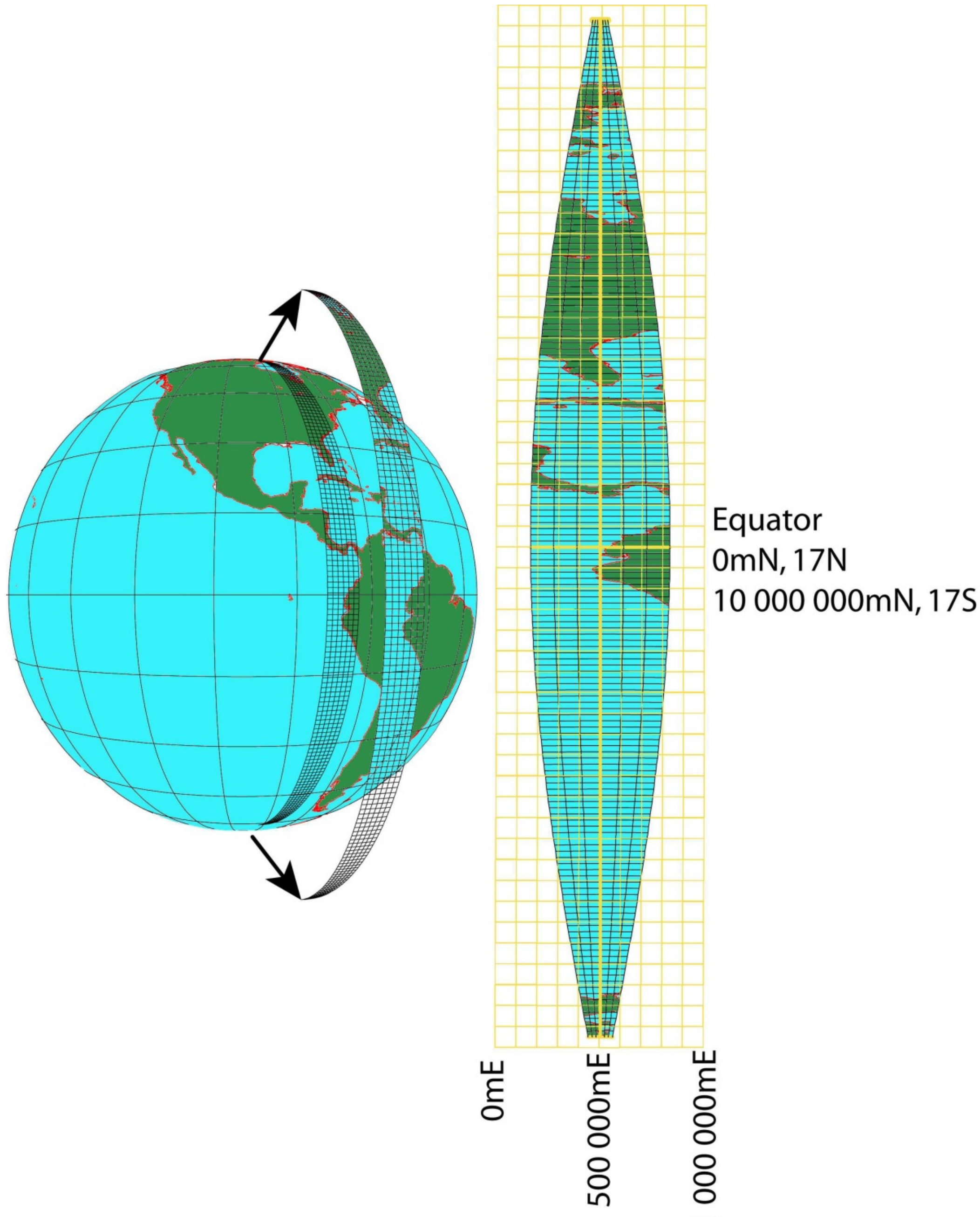
- One degree = 111,111m
- Six degrees = 666,666
- Set Zone false origin so that central meridian is 500,000m
- Gives 166,666m of overlap on each side at equator
- Overlap ends at about 25^{o}N/S

Zones overlap slightly when 1million meters wide



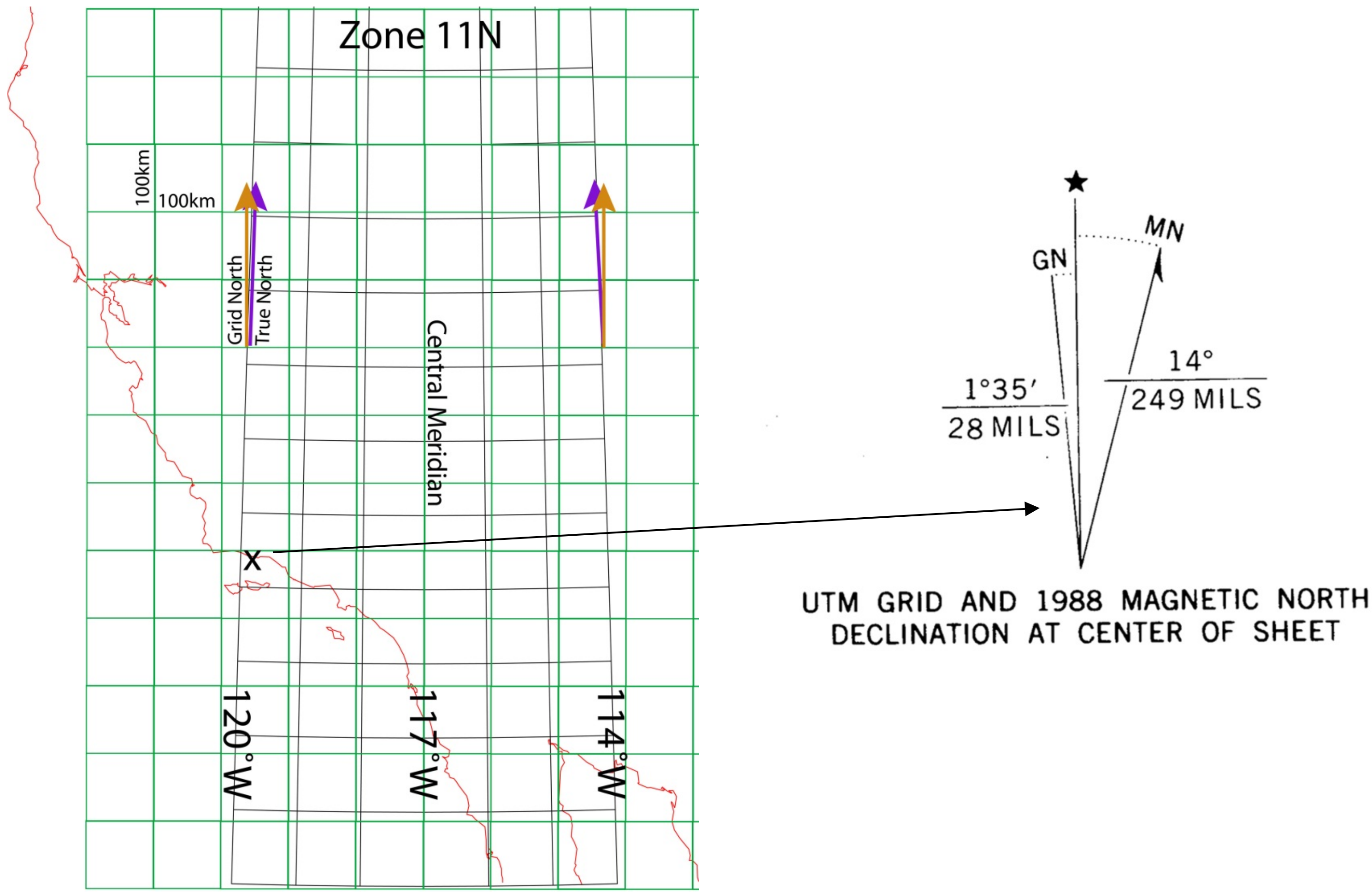
Zone 11N



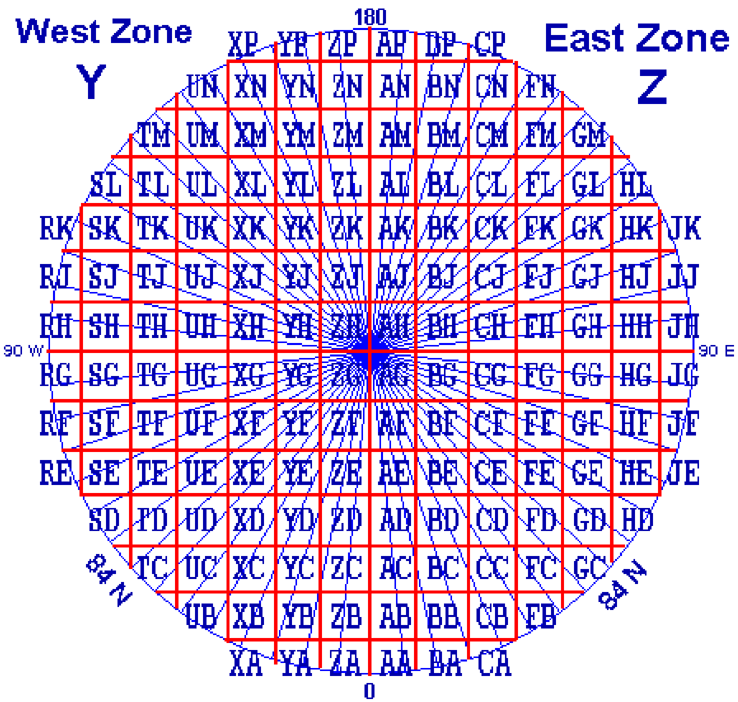


Equator
0mN, 17N
10 000 000mN, 17S
0mE
500 000mE
1 000 000mE

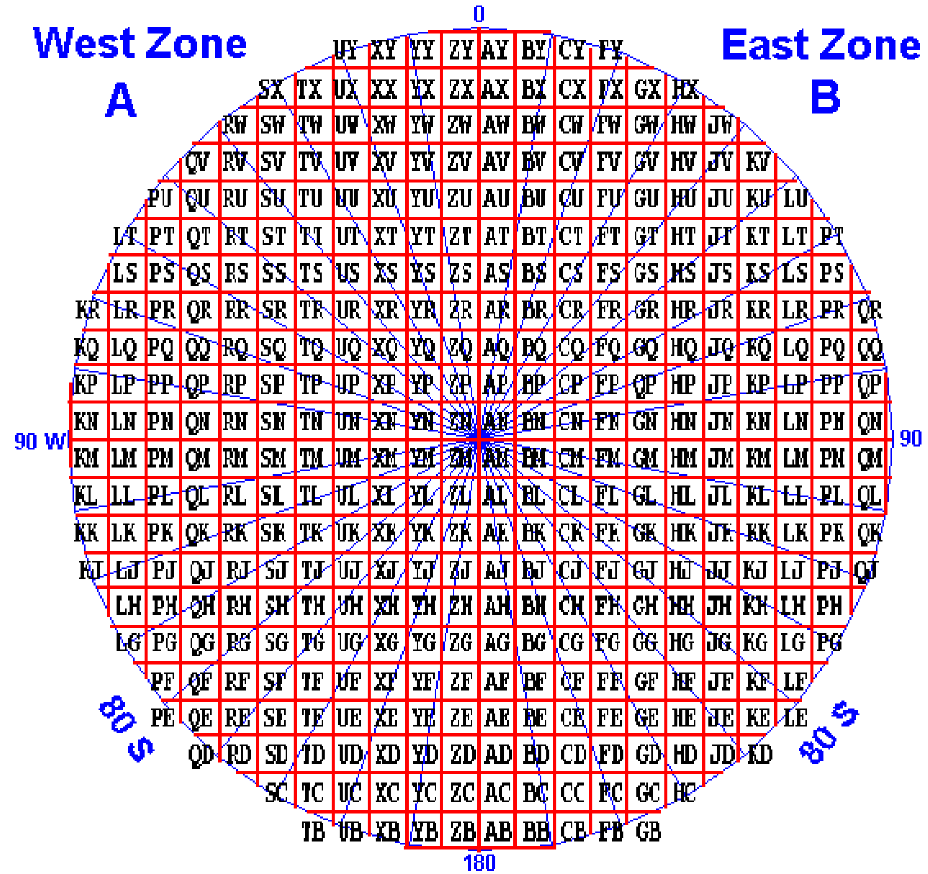
Grid north and the Zone



Universal Polar Stereographic (UPS)



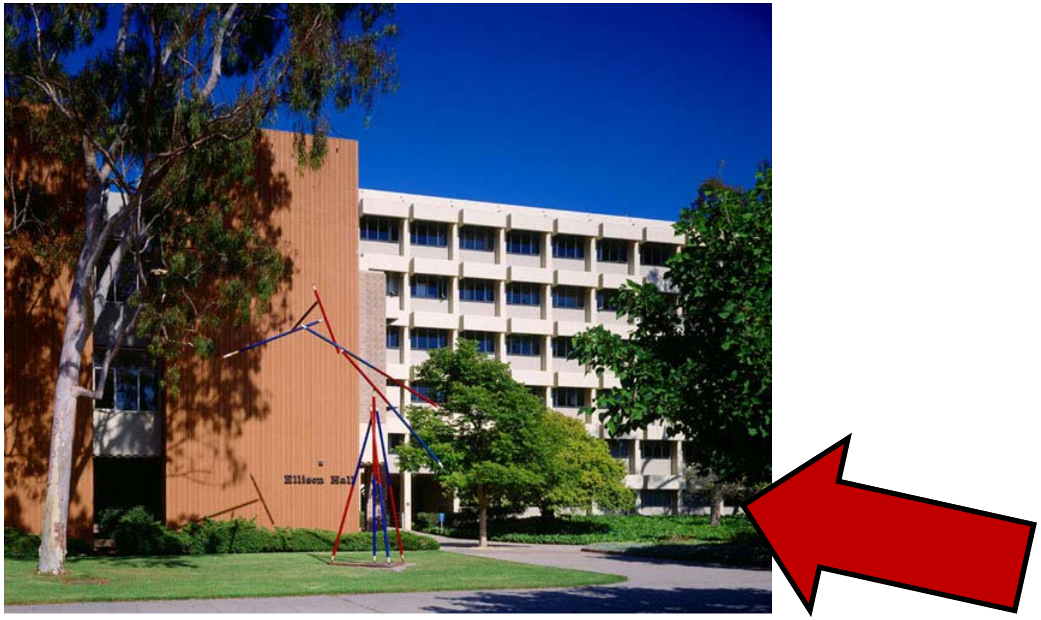
North Polar Area UPS Grid



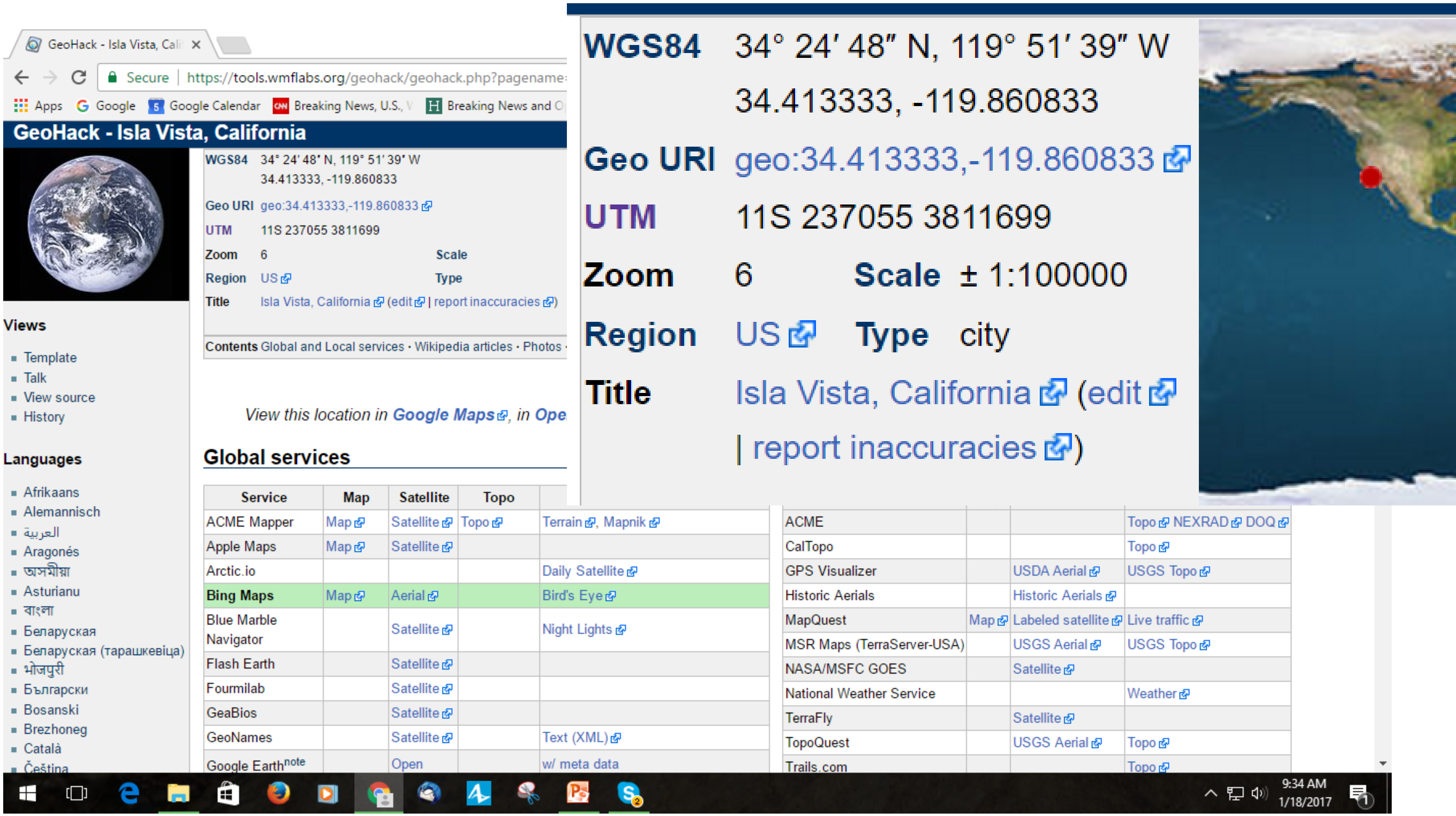
South Polar Area UPS Grid

Example, GPS fix

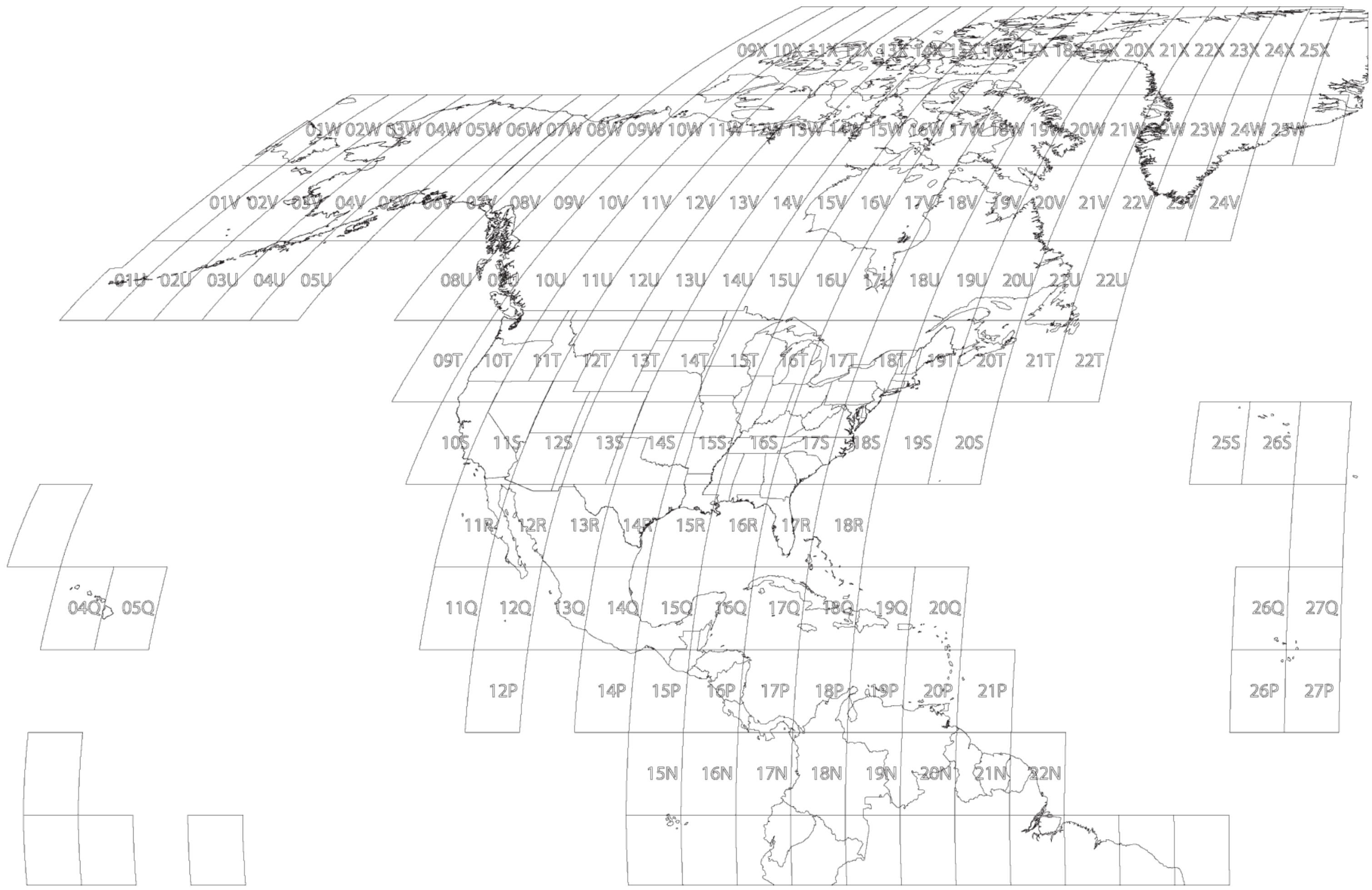
238499E; 3811905N 11, N



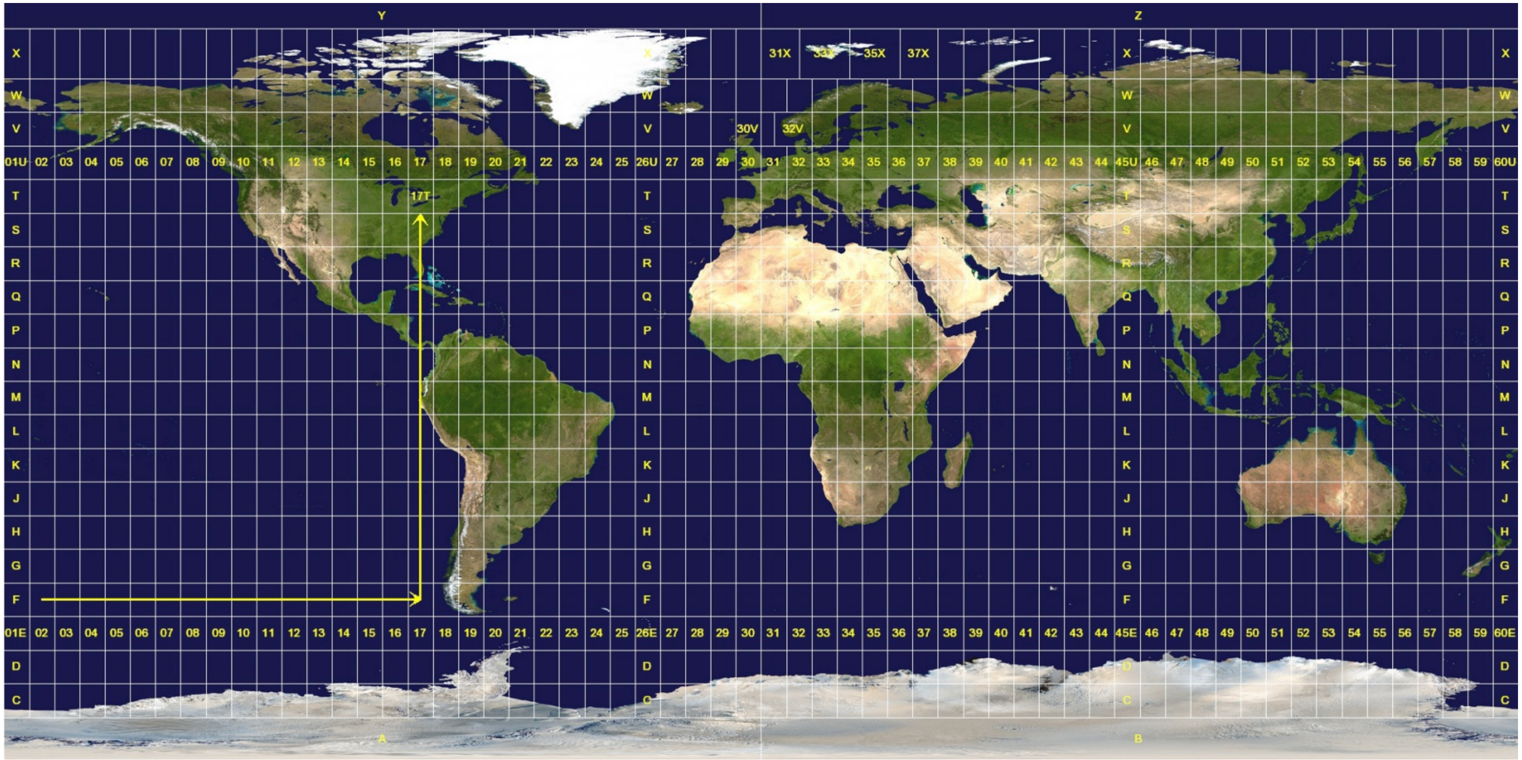
Geohack Isla Vista



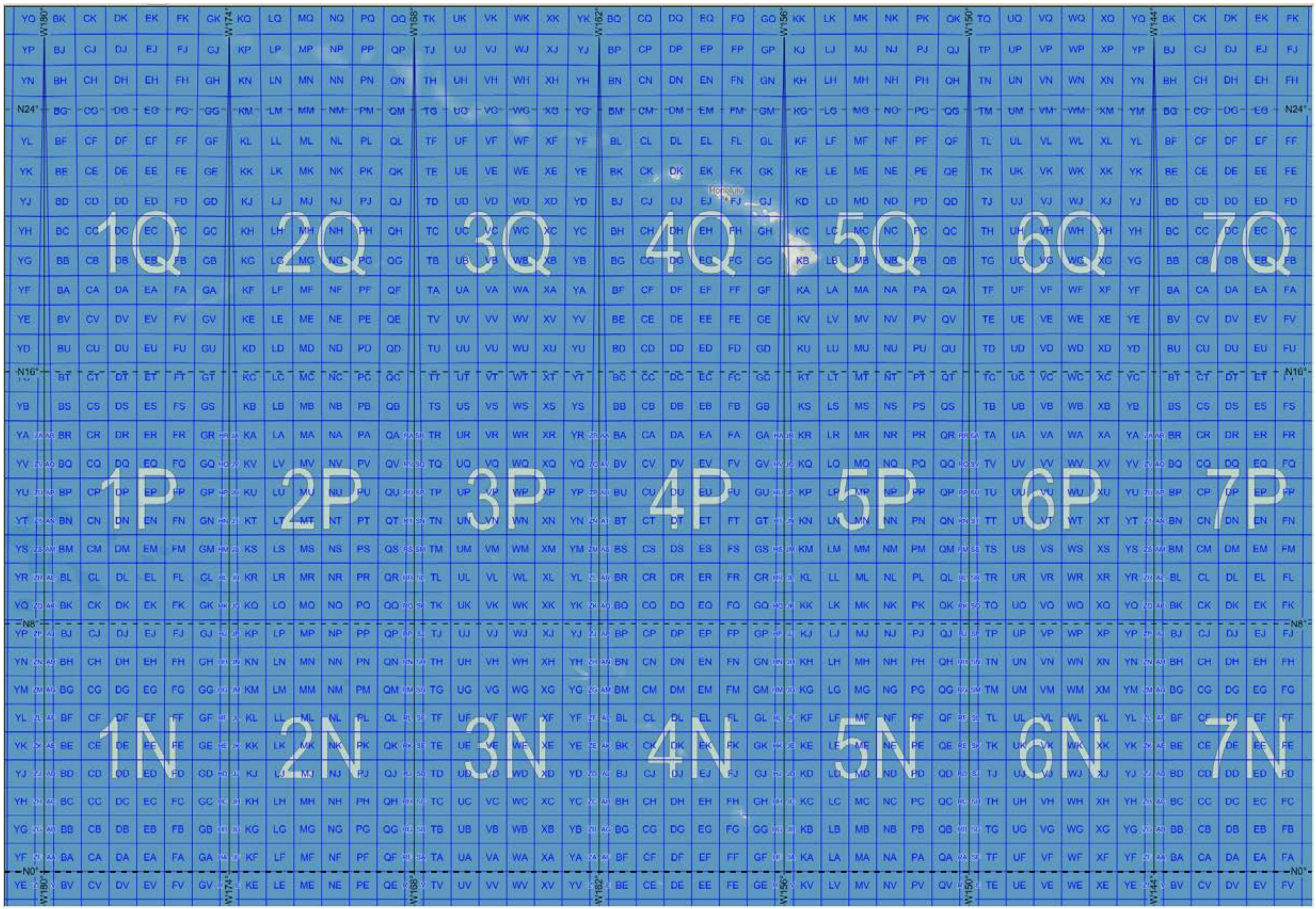
UTM zones in the USA



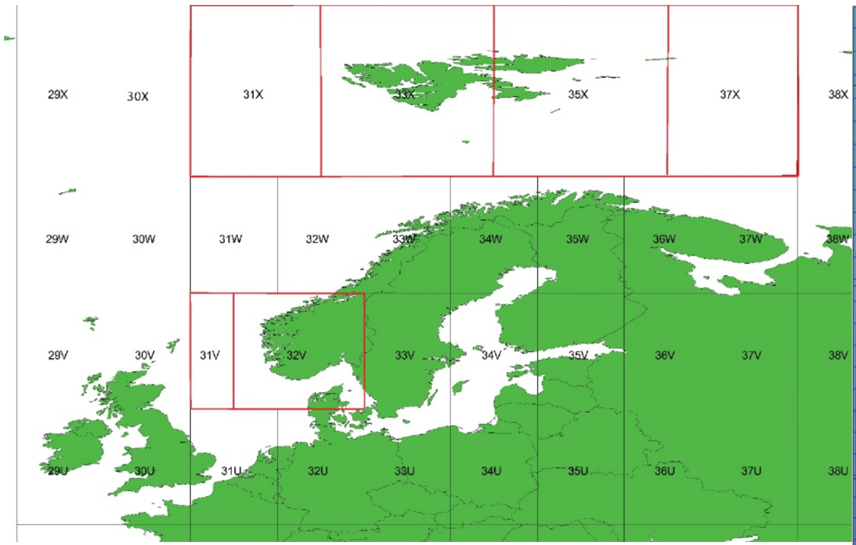
Military Grid Coordinates
First Reference (6 x 8 degrees)

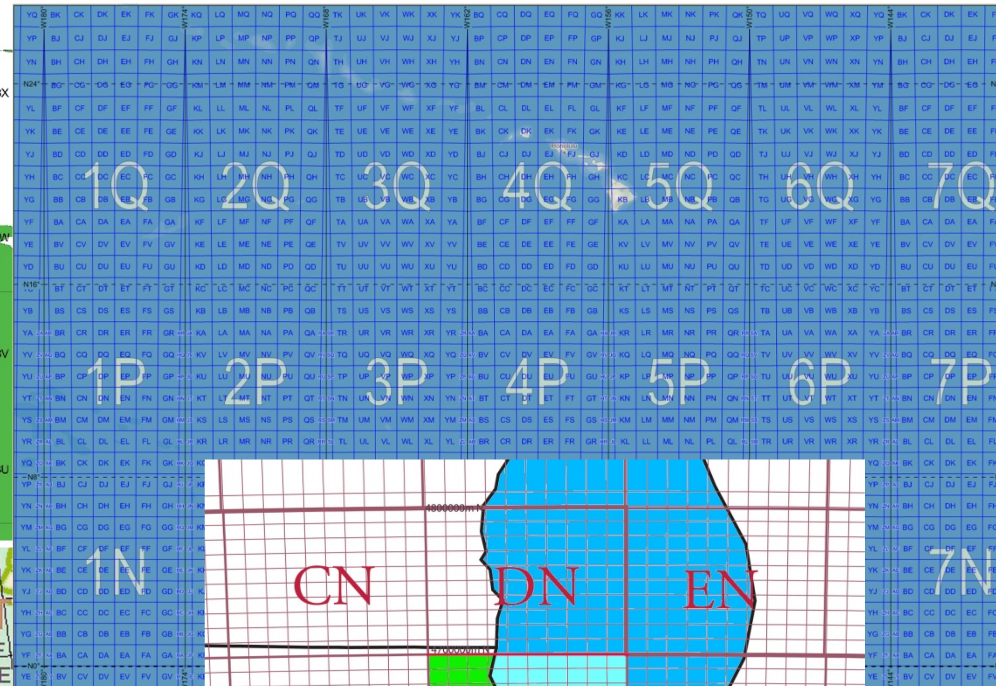


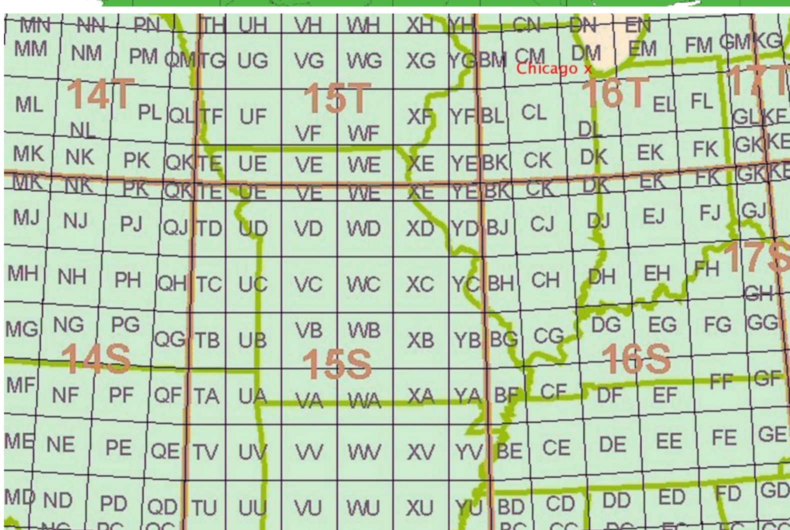
USMG: 2nd Reference 100,000m cells

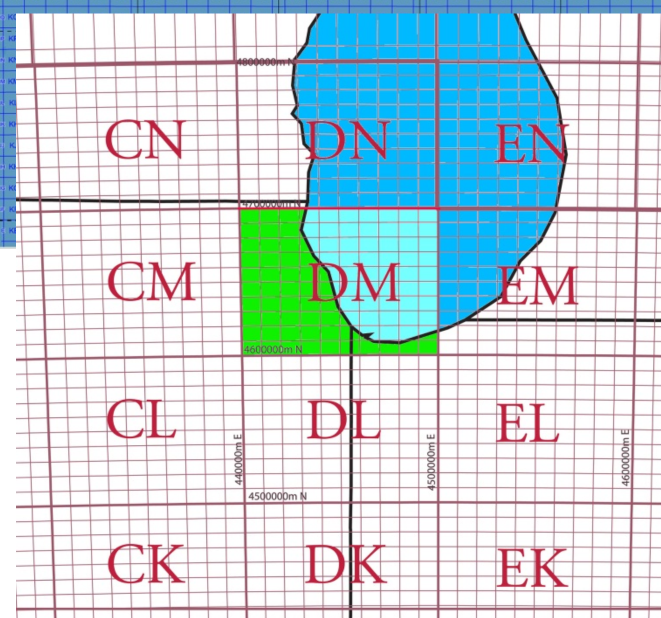


MGRS Grid Cell Designators





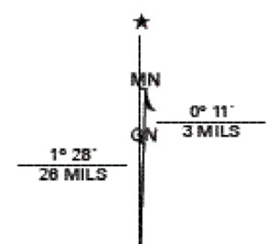




MGRS/National Grid

Produced by the United States Geological Survey
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1 000-meter grid: Universal Transverse Mercator, Zone 15R
10 000-foot ticks: Louisiana Coordinate System of 1983
(south zone)

Imagery..NAIP, September 2007
Roads.......................National Transportation Dataset, 2004
Names..GNIS, 2008

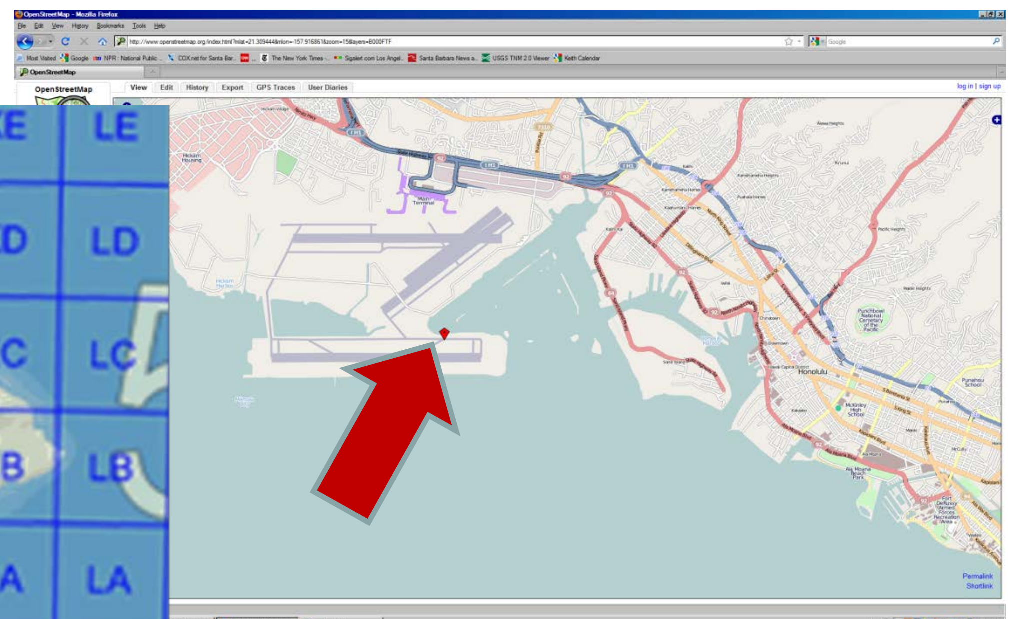


UTM GRID AND 2009 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

U.S. National Grid
100,000-m Square ID YP
Grid Zone Designation 15R

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



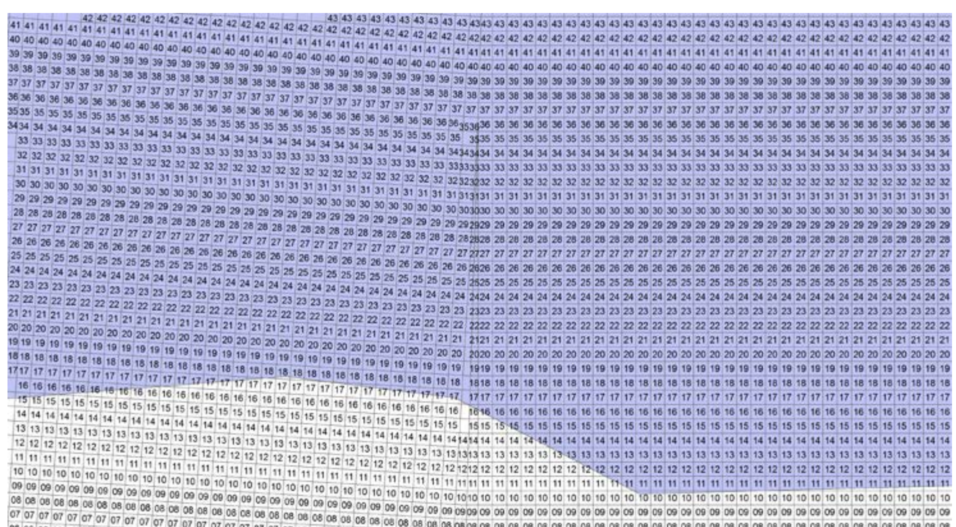
USNG: The National Grid

Same as the MGRS except uses NAD83

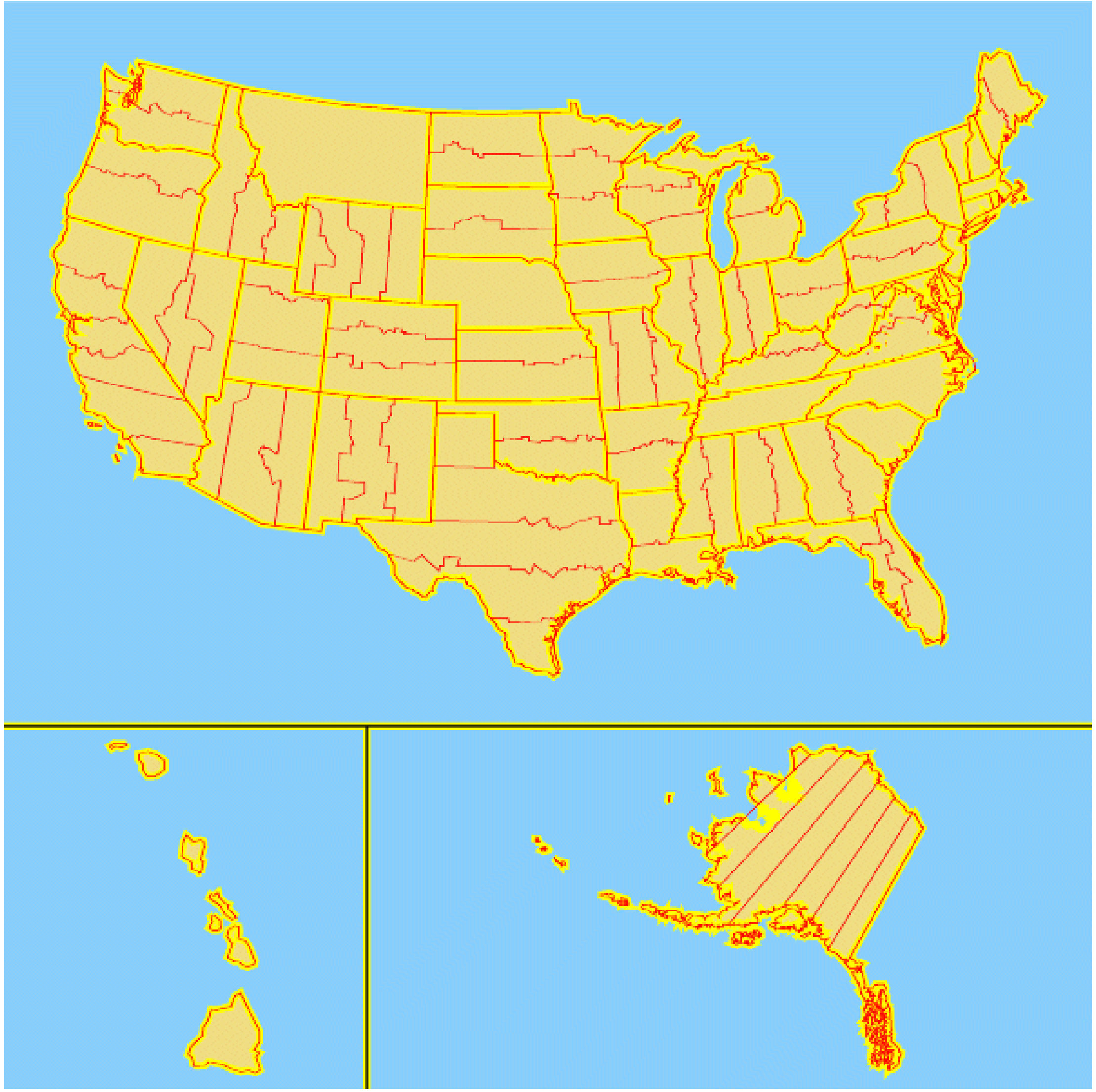
Maximum difference only c 2m worldwide

Supported in National Map

Some problems at cell boundaries

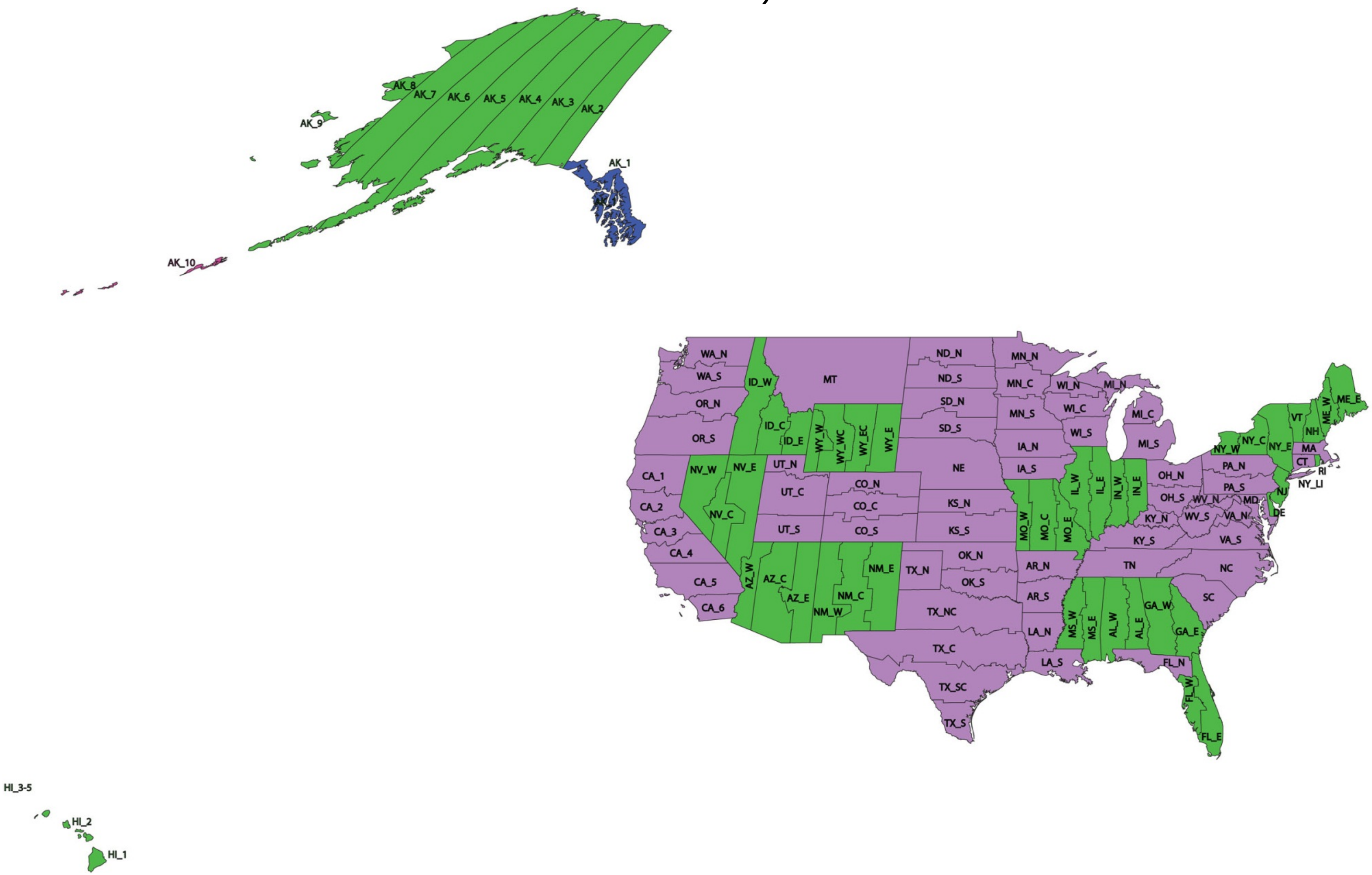


State Plane Coordinates

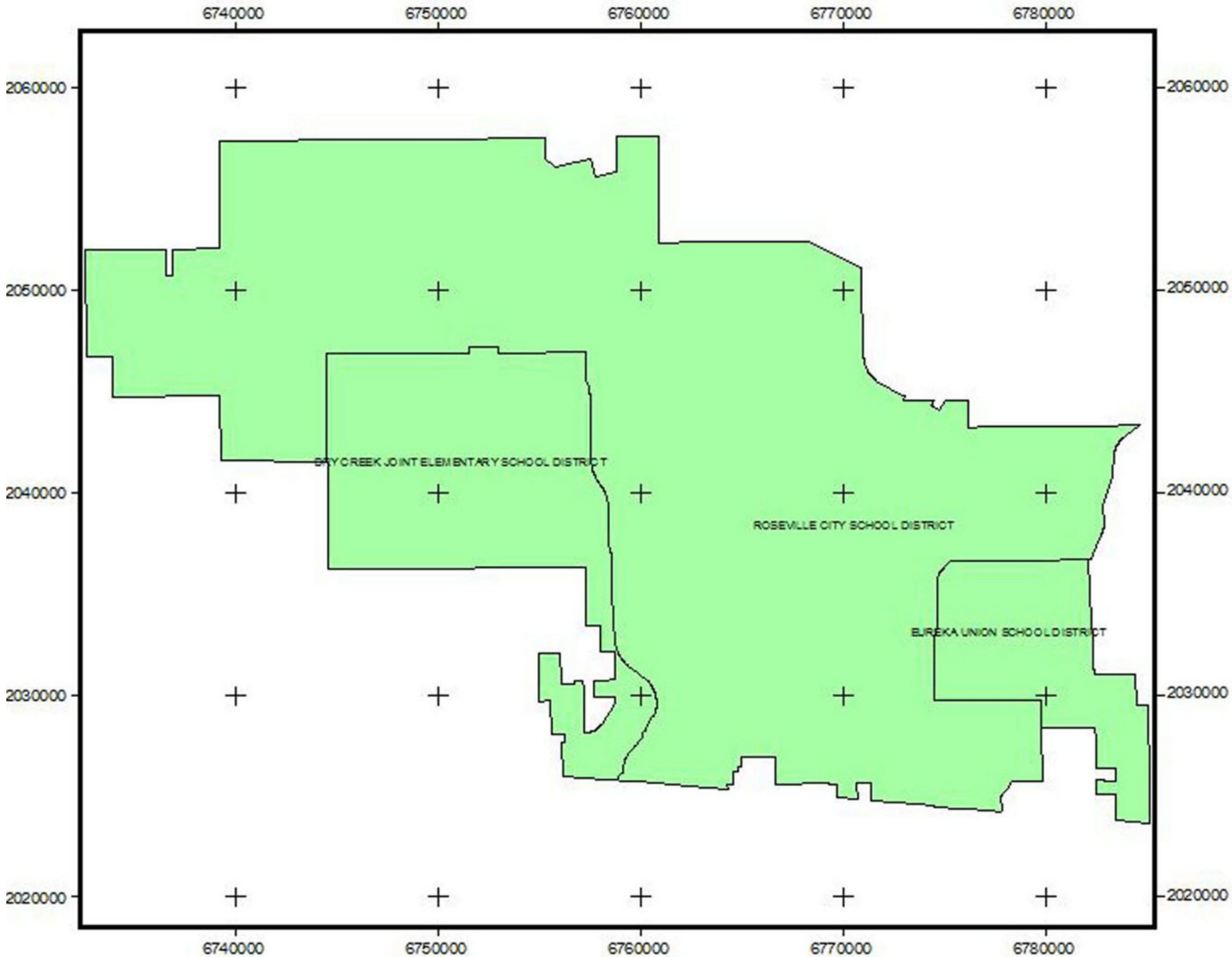


Zones:

Lambert Conformal Conic vs. Transverse Mercator (Plus one Hotine Oblique Mercator)



Roseville, CA School Districts

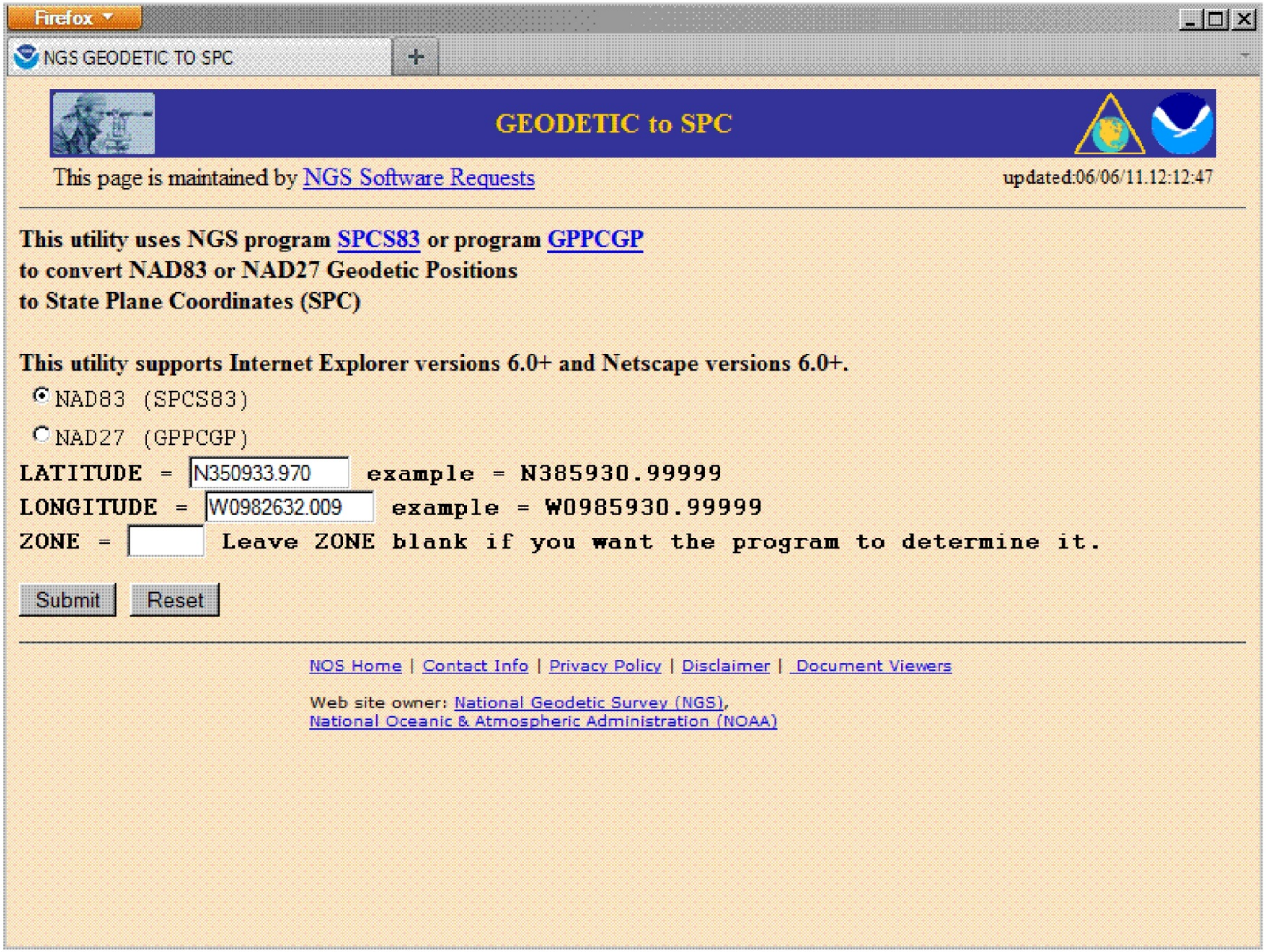


State Plane Coordinates in meters California Zone 2

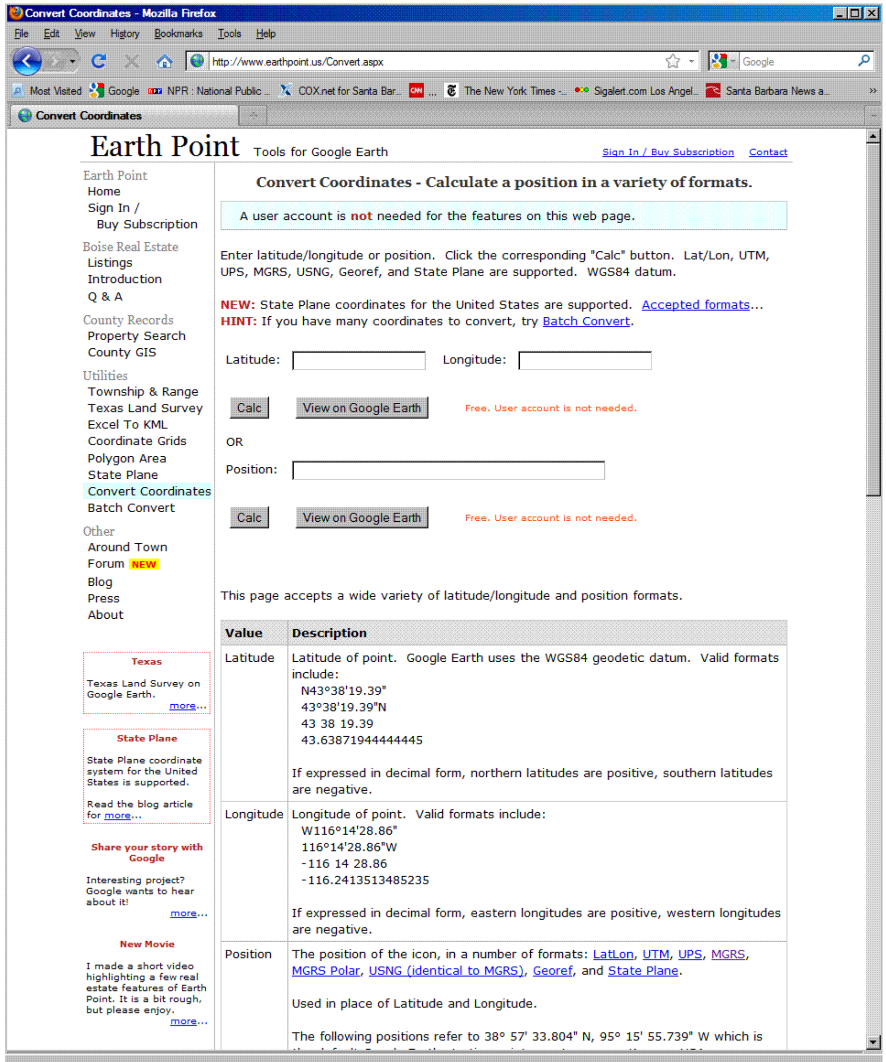
Measurement: Just use GPS

6 decimal places
0.000001^{o} x 111111m
=0.11m

Converting

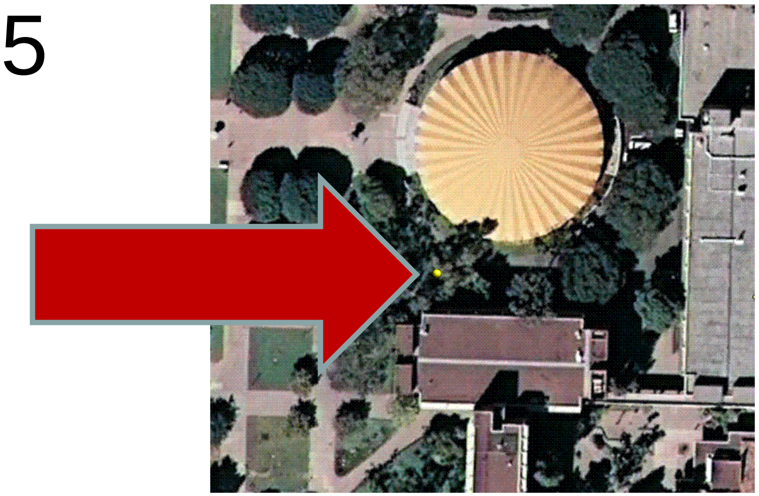

Firefox
NGS GEODETIC TO SPC
GEODETIC to SPC
This page is maintained by NGS Software Requests
updated:06/06/11.12:12:47
This utility uses NGS program SPCS83 or program GPPCGP
to convert NAD83 or NAD27 Geodetic Positions
to State Plane Coordinates (SPC)
This utility supports Internet Explorer versions 6.0+ and Netscape versions 6.0+.
NAD83 (SPCS83)
NAD27 (GPPCGP)
LATITUDE = N350933.970 example = N385930.99999
LONGITUDE = W0982632.009 example = W0985930.99999
ZONE = Leave ZONE blank if you want the program to determine it.
Submit
Reset
NOS Home | Contact Info | Privacy Policy | Disclaimer | Document Viewers
Web site owner: National Geodetic Survey (NGS),
National Oceanic & Atmospheric Administration (NOAA)

www.earthpoint.us



Coordinate examples

- 238,479 mE; 3,811,950 mN; 11, N
- 11SKU3847911950
- 11SKU3847911950 NAD83
- N 34^{o}24’57.24” W 119^{o}50’42.9”
- 603153 1830382 CA 5



Code Libraries

- Matthew's Map Projection Software http://www.users.globalnet.co.uk/~arcus/mmps/
- PROJ.4 https://trac.osgeo.org/proj/
- GEOTRANS http://earth-info.nga.mil/GandG/geotrans/
- Java Map projection Library http://javamapprojlib.sourceforge.net/

Sarah E. Battersby, Daniel “daan” Strebe & Michael P. Finn (2016) Shapes on a plane: evaluating the impact of projection distortion on spatial binning, *Cartography and Geographic Information Science*, http://dx.doi.org/10.1080/15230406.2016.1180263

- Issue: Much social data is “binned” by lat/long grid cells, not taking into account projection distortion
- Suggest ways that cells can be equalized: using hexagons and binning by equal areas

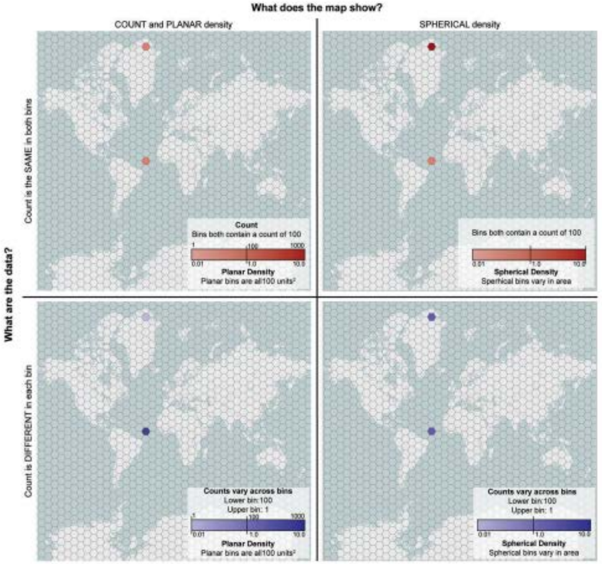


Figure 1. Regular spatial bins on a nonequal area projection (Web Mercator in this example) present challenges for users to appropriately estimate both quantity and density in the same visualization. If the reader assumes that the spatial bins represent the same area, the assumed density values will also be equivalent for both locations (left column). However, if spherical area is (more appropriately) used to calculate density, as seen in the right column, it is apparent that the density is different.

Fits distortion analysis tradition

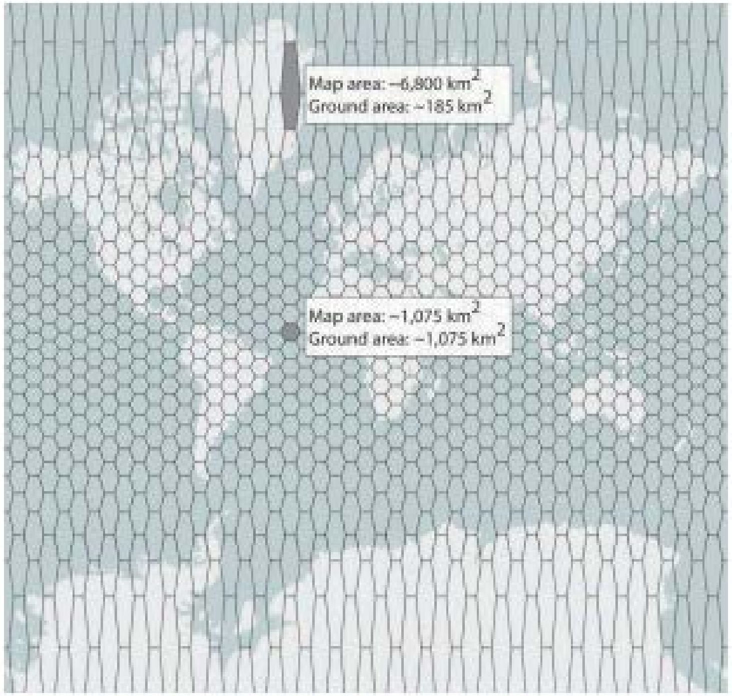


Figure 6. Hexagonal bins defined as 10° side on a plate carrée projection, and projected onto a Web Mercator base map. Measurements listed provide relative map area and ground area.

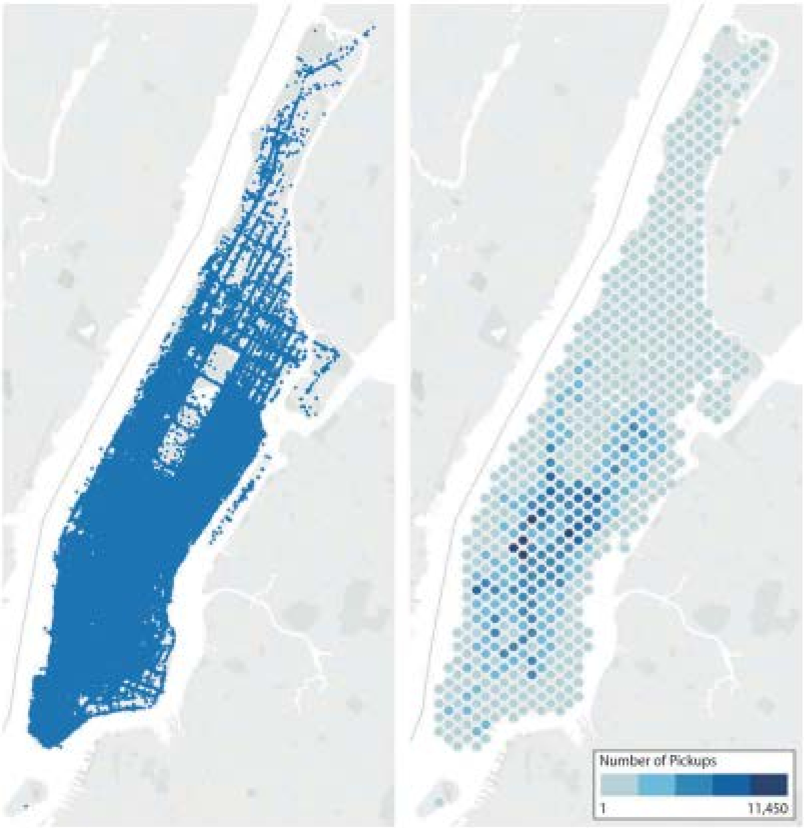


Figure 3. Taxi cab pickup locations in Manhattan as raw point locations (left) and as counts after being binned into a hexagonal grid (data from Andres Monroy – http://www.andresmh.com/nyctaxitrips/).

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
Blue digits 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

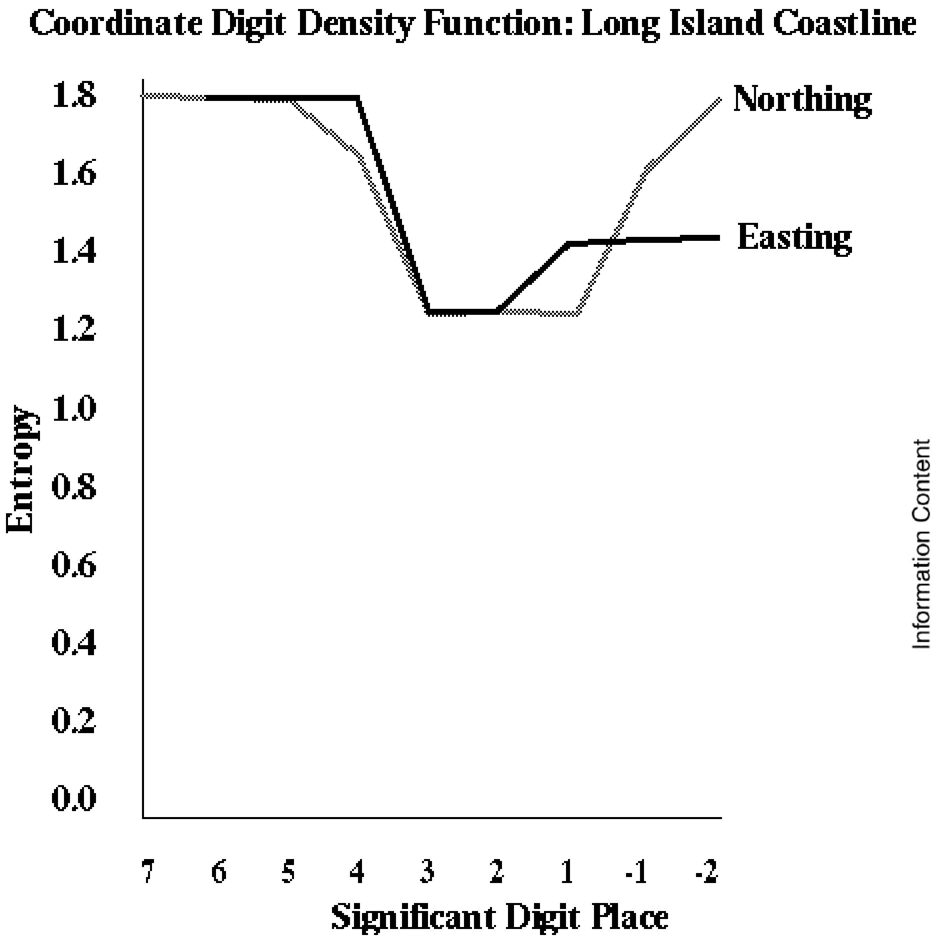
Information content

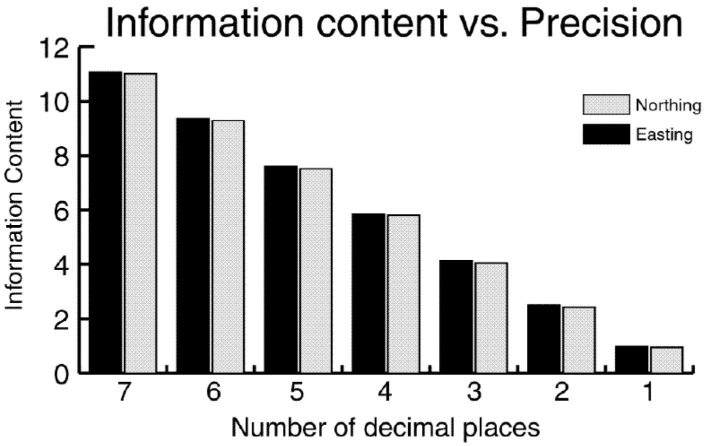
- For any digit *n* at any one significant digit location out of *N* possible digit values or states (10 for decimal), *I* is defined, where:

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

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 Reference System allows positions to be described
- 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
- To merge and overlap maps, they must be in the same map projection, datum and coordinate system