City of Surprise Coordinate System

a Low Distortion Projection

Presented by:

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With special thanks to: Michael Dennis, PE

Project Goals

- Develop a simple map projection.
- Meet the needs of the most number of end users.

Target users:

Surveying/Engineering (Platting, Design projects)

Cartography (Flood Mapping, Ortho photography)

GIS (City mapping, Homeland Security mapping)

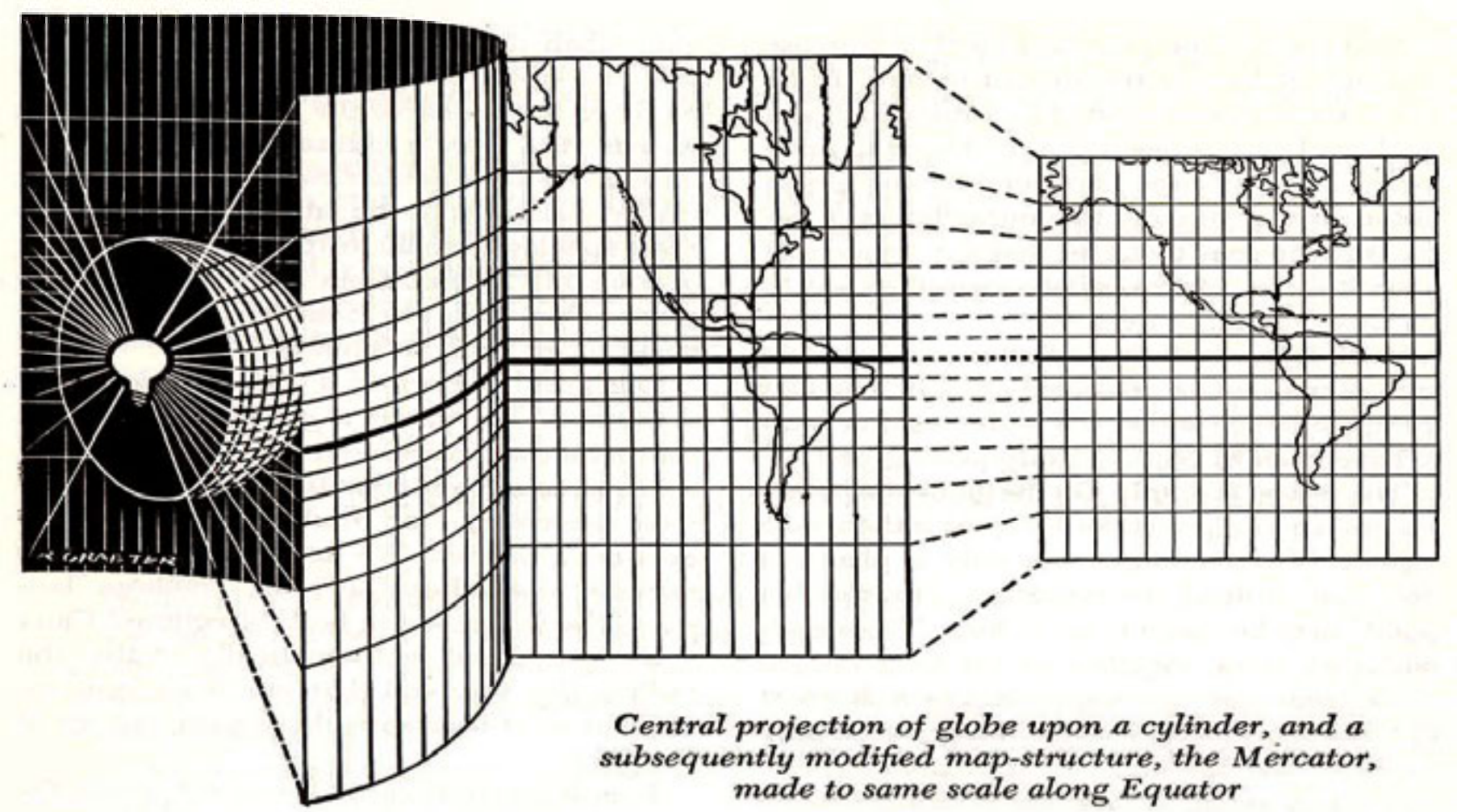
GPS/map users (Blue-stake, Google Earth™)

- Cover the largest area possible.

Map Projection Basics

- Developable surface
  - Plane
  - Cone
  - Cylinder
- Conformal
- Supported by end user's software applications
  - Google Earth
  - ESRI, Map Info
  - AutoCAD, Microstation
  - Leica, Thales, Topcon, Trimble, Sokkia, etc.

Projecting a Map

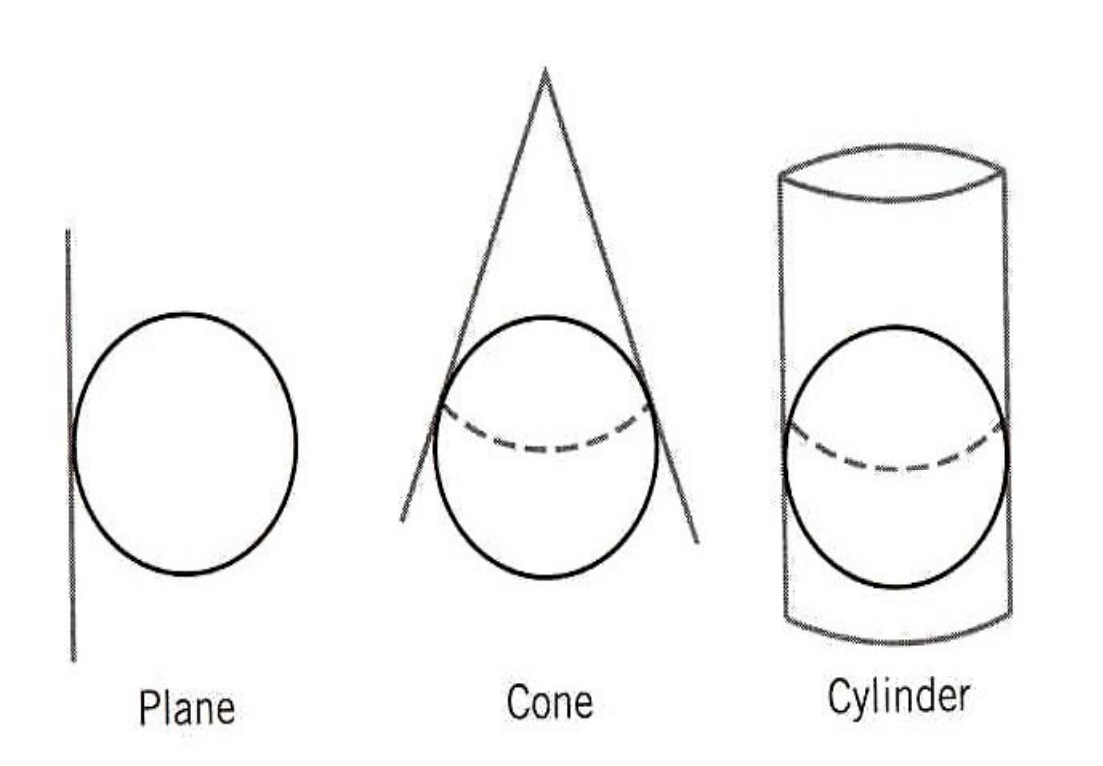


Central projection of globe upon a cylinder, and a subsequently modified map-structure, the Mercator, made to same scale along Equator

The ‘projection’ is like a shadow cast through the globe onto a piece of paper

Projected from an ***Ellipsoid*** to a ***Mapping Plane***

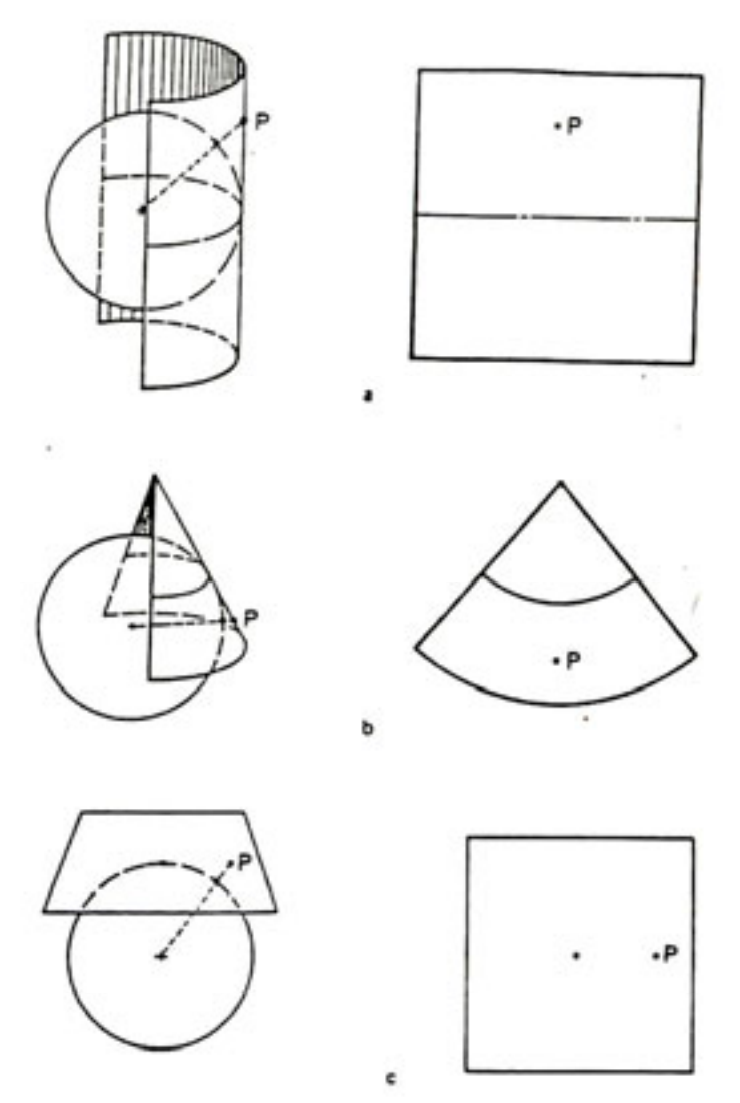
Map Projection Types



<u>Three basic types of projection:</u>

- Plane
- Cone
- Cylinder

Surface Development



<u>Cylinder and Cone projections</u> can be ‘developed’ into a flat map by cutting them and laying them out flat.

The result is a flat or planer (cartesian) surface.

- Plane surveying on a planer surface

<u>Plane projections</u> do not need to be developed

Coordinate Systems

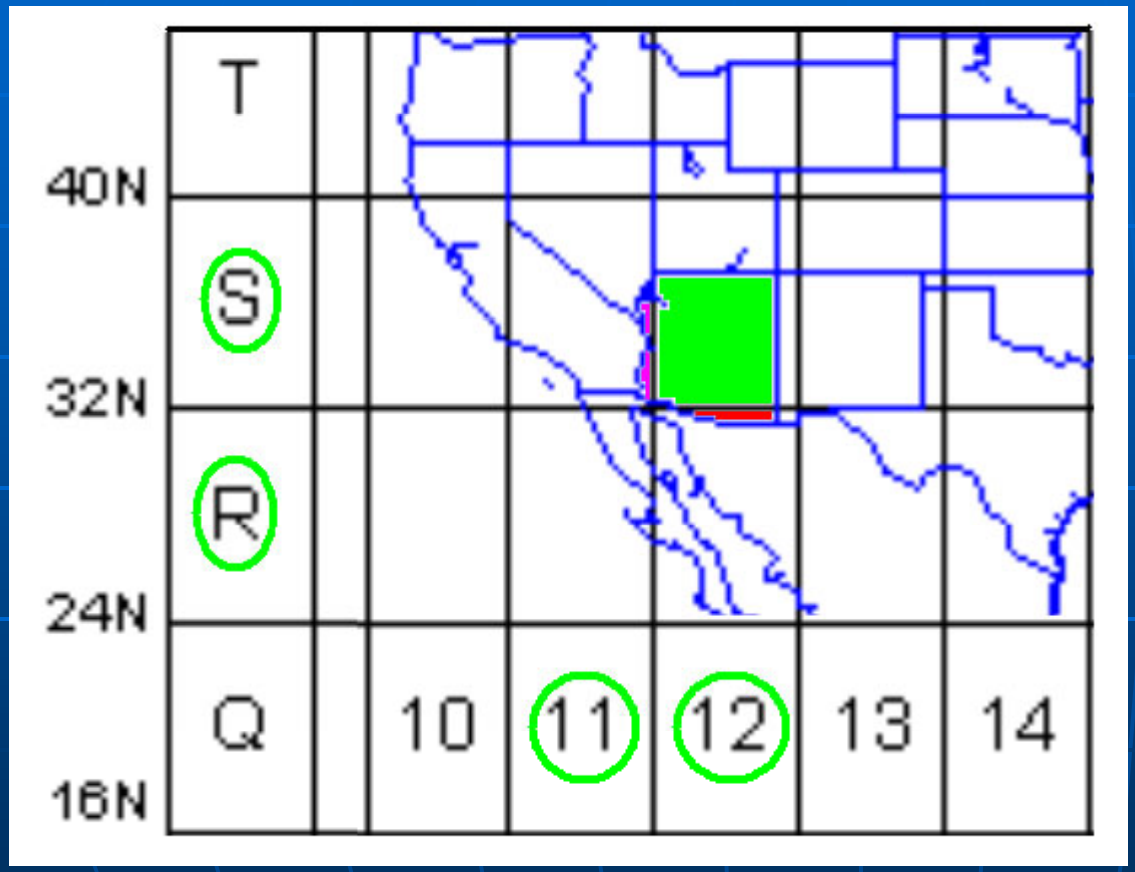
Components

- Datum Reference
- Map Projection Type
- Projection Parameters & Zones

State Plane Coordinates (SPC)
Arizona Coordinate System, Central Zone

Linear Unit: International Feet
Horizontal Geodetic Datum: NAD 1983
Projection Type: Transverse Mercator
Projection Definition:
Latitude of Grid Origin: 31° 00' North
Longitude of Central Meridian: 111° 55' West
False Northing : 0.00 feet
False Easting: 700,000.00 feet
Scale at Central Meridian: 0.9999 (exact)

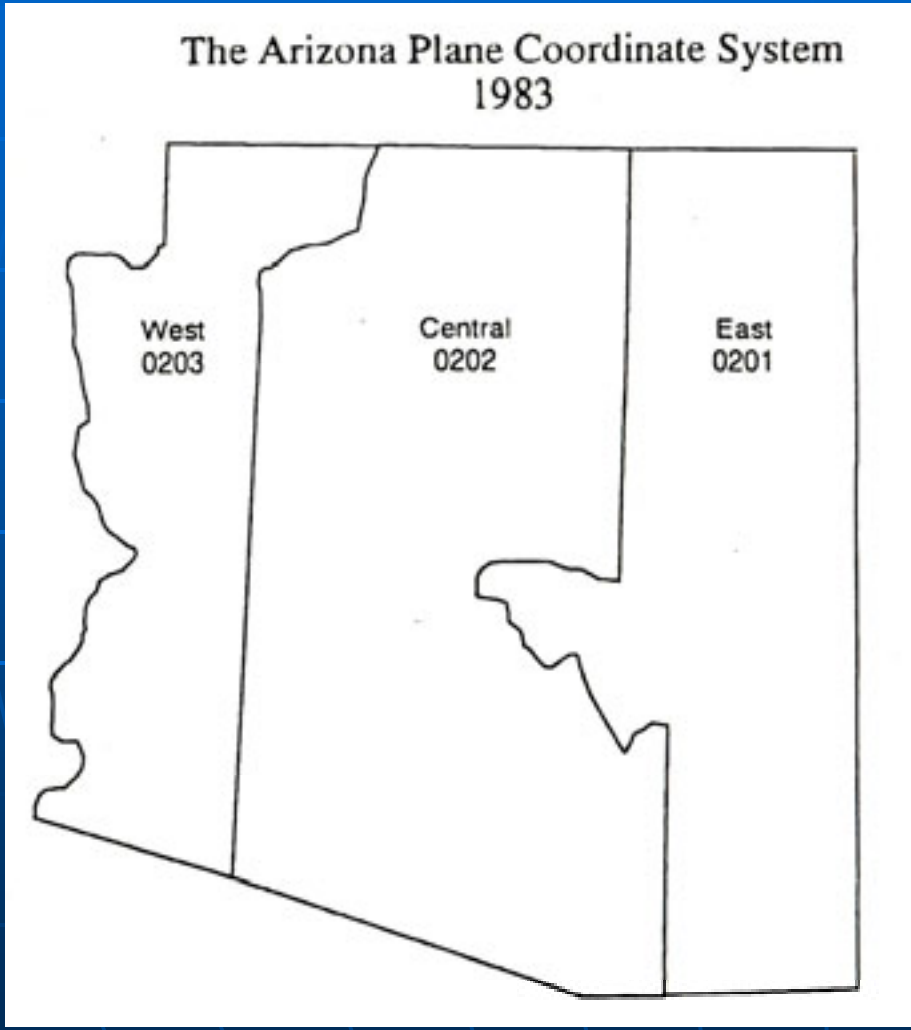
UTM Zones



- Zones defined along meridians and parallel
- Projection is the same for all zones
- Map Distortion designed at the ellipsoid (sea level) for a set zone width

1:2500 – 0.9996

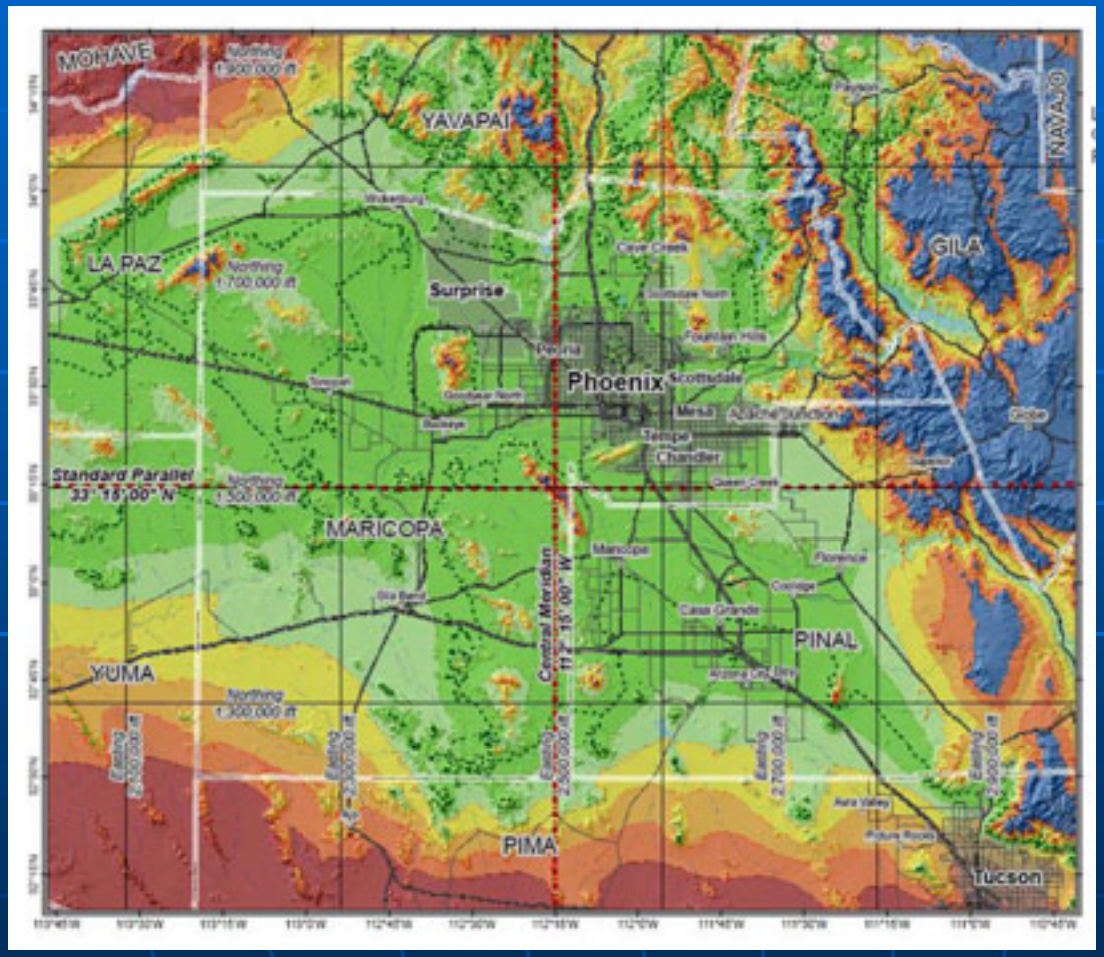
SPC Zones



- Zones defined along County/State boundaries
- Projection defined by the shape of the outer boundary of the State
- Map Distortion designed at the ellipsoid (sea level) for an 'ideal' zone width

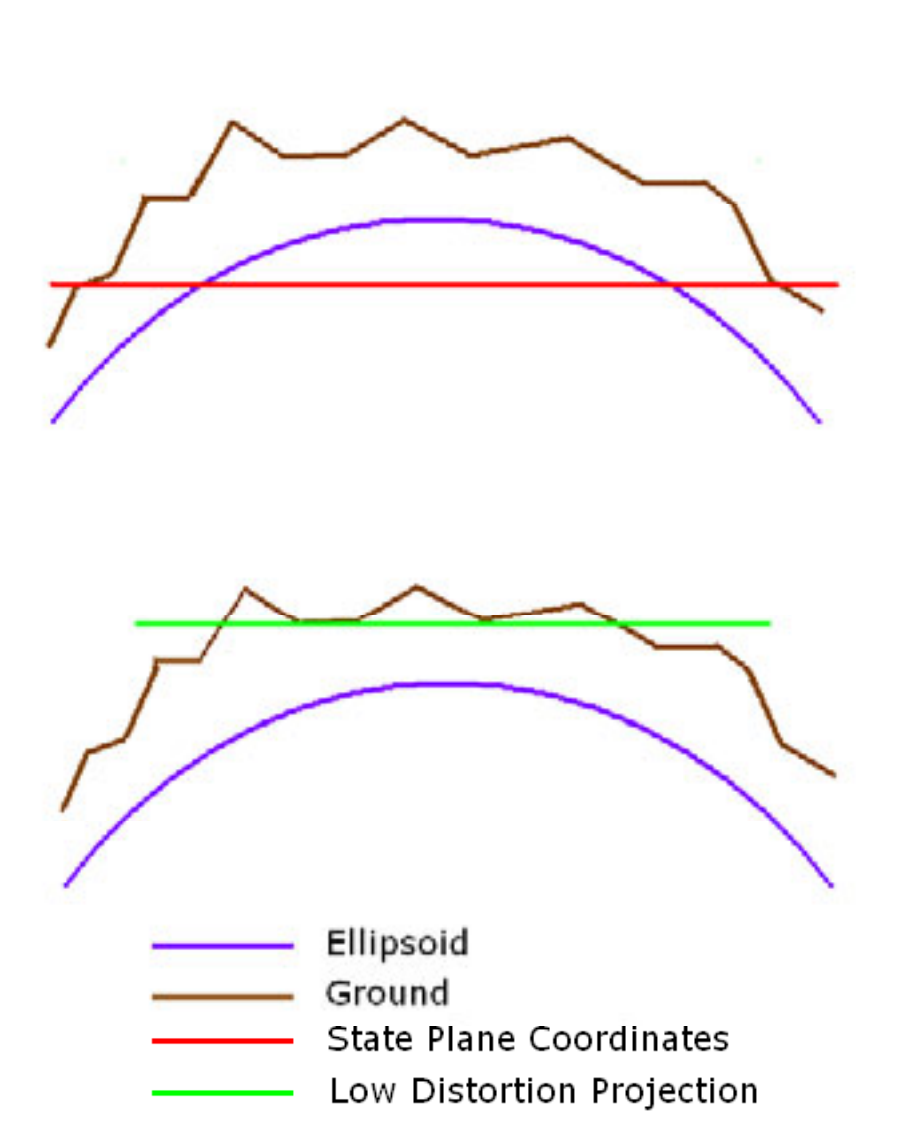
typ 1:10,000 – 0.9999

LDP Zones



- Zones defined by the 'best fit' to the topography
- Projection defined by the 'best fit' to the topography
- Map Distortion designed at the surface of the earth best fitting 'developable' land

Mapping Plane Orientation



A mapping projection may be oriented to an area in several ways:

Designed at the ellipsoid (sea level)

- Historic approach (UTM, SPC)

Designed at the ground

- Modern approach (LDP)

Map Projection Distortion

three categories

- **Linear Distortion** (grid to reference surface distance caused by earth curvature and topographic relief)

- **Angular distortion** (grid north relation to central meridian)

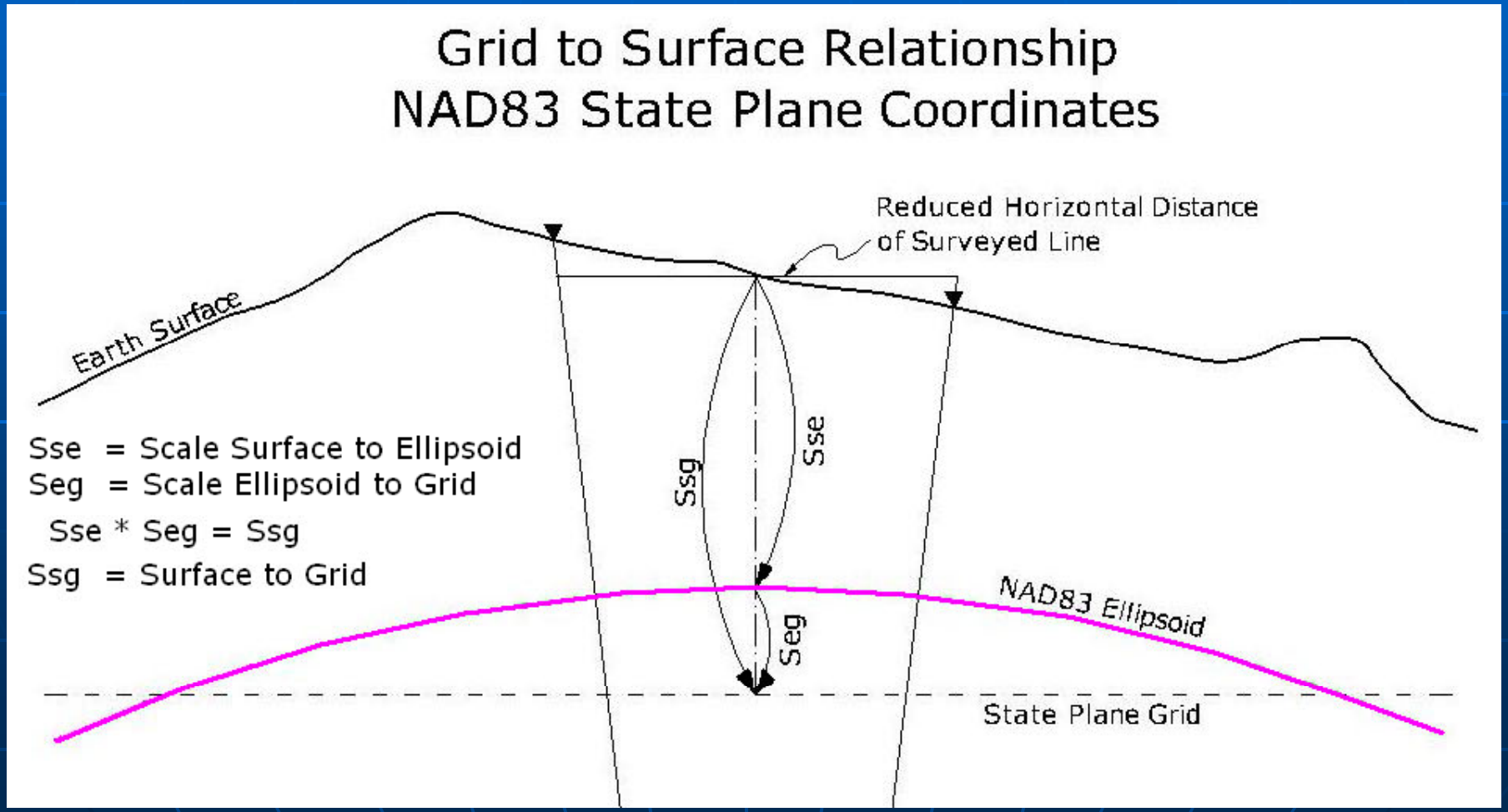
- **Arc to chord correction** (distance between points, and points location within projection zone)

Map Distortions are NOT Errors

Not accounting for or reporting map distortions may be interpreted as an error by an end user.

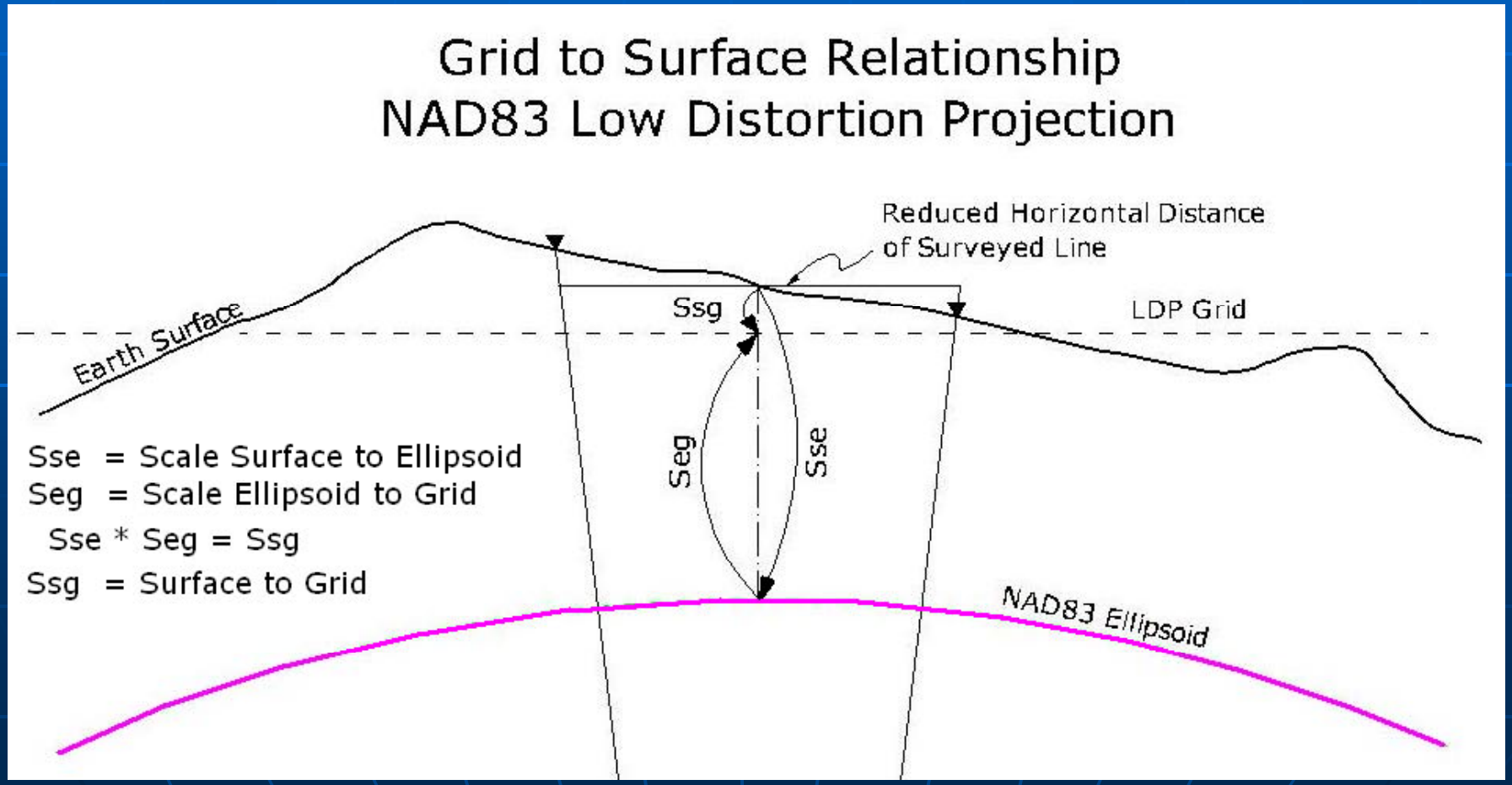
Linear Map Distortions

SPC scales are multiplicative



Linear Map Distortions

LDP scales cancel out



Linear Map Distortions Chart

Linear Ratio	Zone	Scale	PPM	Distortion in Distance (feet)			
				660	1320	2640	5280
1: 2,500	UTM	0.999 600	400	0.26	0.53	1.06	2.11
1: 6,500	SPC/Ground	0.999 846	154	0.10	0.20	0.41	0.81
1: 10,000	SPC	0.999 900	100	0.07	0.13	0.26	0.53
1: 15,000	SPC West	0.999 933	66.7	0.04	0.09	0.18	0.35
1: 25,000	LDP	0.999 960	40	0.03	0.05	0.11	0.21
1: 50,000	LDP	0.999 980	20	0.01	0.03	0.05	0.11
1: 100,000	LDP	0.999 990	10	0.01	0.01	0.03	0.05
1: 500,000	ppm/mile	0.999 998	2	0.00	0.00	0.01	0.01
1: 1,000,000	ppm/mile	0.999 999	1	0.00	0.00	0.00	0.005

The good the bad and the ugly

(aka: LDP, SPC and modified SPC)

The good

Low Distortion Projections (LDP)

LDP allow the user to **fully control** all aspects of a map in relation to the target goals of the project.

Simple Definition

Easy data sharing

Reduction or elimination of additional computations with terrestrial survey data

Low Distortion Projection (LDP)
Maricopa County, Arizona

Linear Unit: International Feet
Horizontal Geodetic Datum: NAD 1983
Projection Type: Lambert Conic (single parallel)
Projection Definition:
Latitude of Grid Origin/Central Parallel: 33° 15' North
Longitude of Central Meridian: 112° 15' West
False Northing : 1,500,000.00 feet
False Easting: 2,500,000.00 feet
Scale at Central Parallel: 1.000 045 (exact)

The bad

State Plane Coordinates (SPC) & UTM

SPC has the advantage of being *published* and commonly defined in drop down menus, but the disadvantage of not matching the surface of the earth and/or a target project area in an optimal way.

Additional data reductions required for terrestrial survey data

State Plane Coordinates (SPC)
Arizona Coordinate System, Central Zone

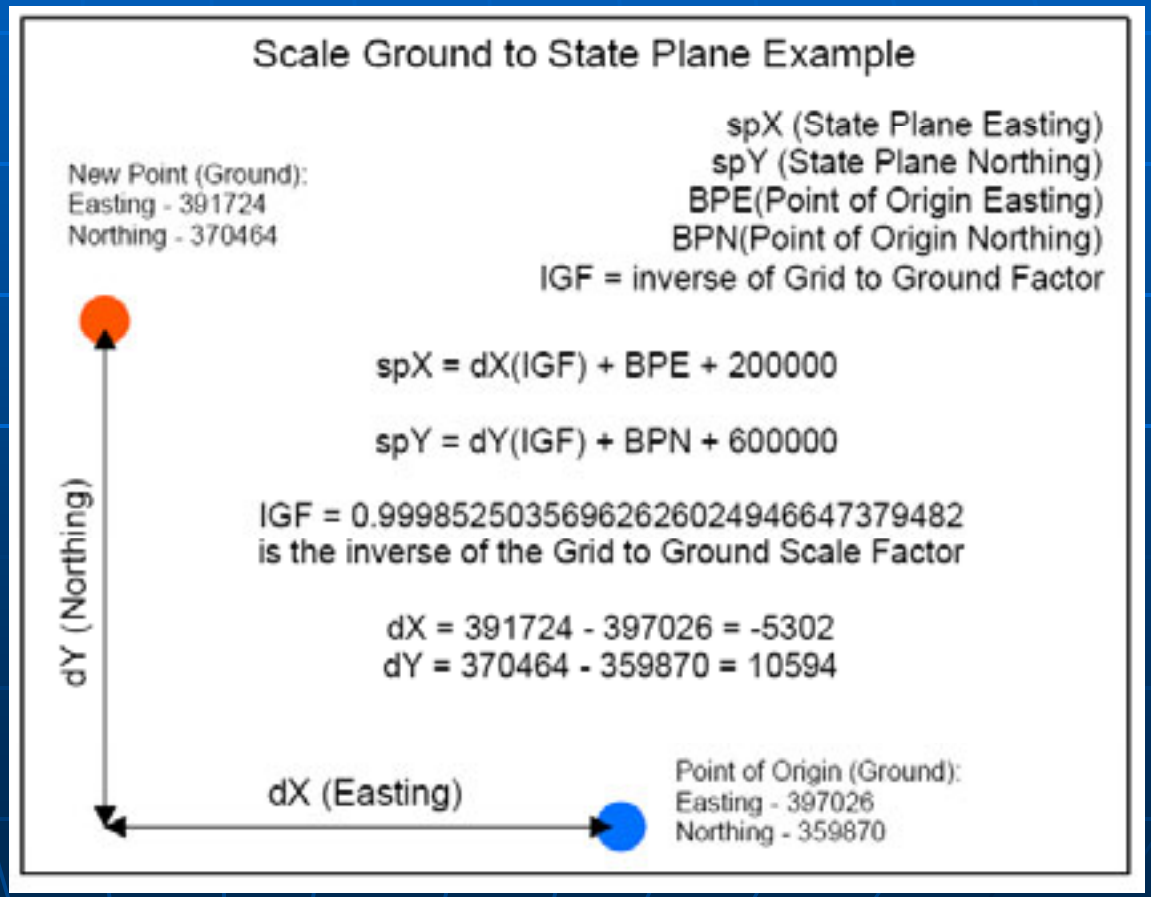
Linear Unit: International Feet
Horizontal Geodetic Datum: NAD 1983
Projection Type: Transverse Mercator
Projection Definition:
- Latitude of Grid Origin: 31° 00' North
- Longitude of Central Meridian: 111° 55' West
- False Northing : 0.00 feet
- False Easting: 700,000.00 feet
- Scale at Central Meridian: 0.9999 (exact)

And the ugly

Modified SPC

Modified SPC has all the disadvantages of SPC, and the projection definition becomes needlessly complicated.

Modified SPC also will not integrate freely with various software/field data collection devises.



The ugly
Part II
Localization Calibration

Localization/Calibrations

<u>Helmert Similarity Transformation</u> with GPS or GIS processing software.

Typically proprietary

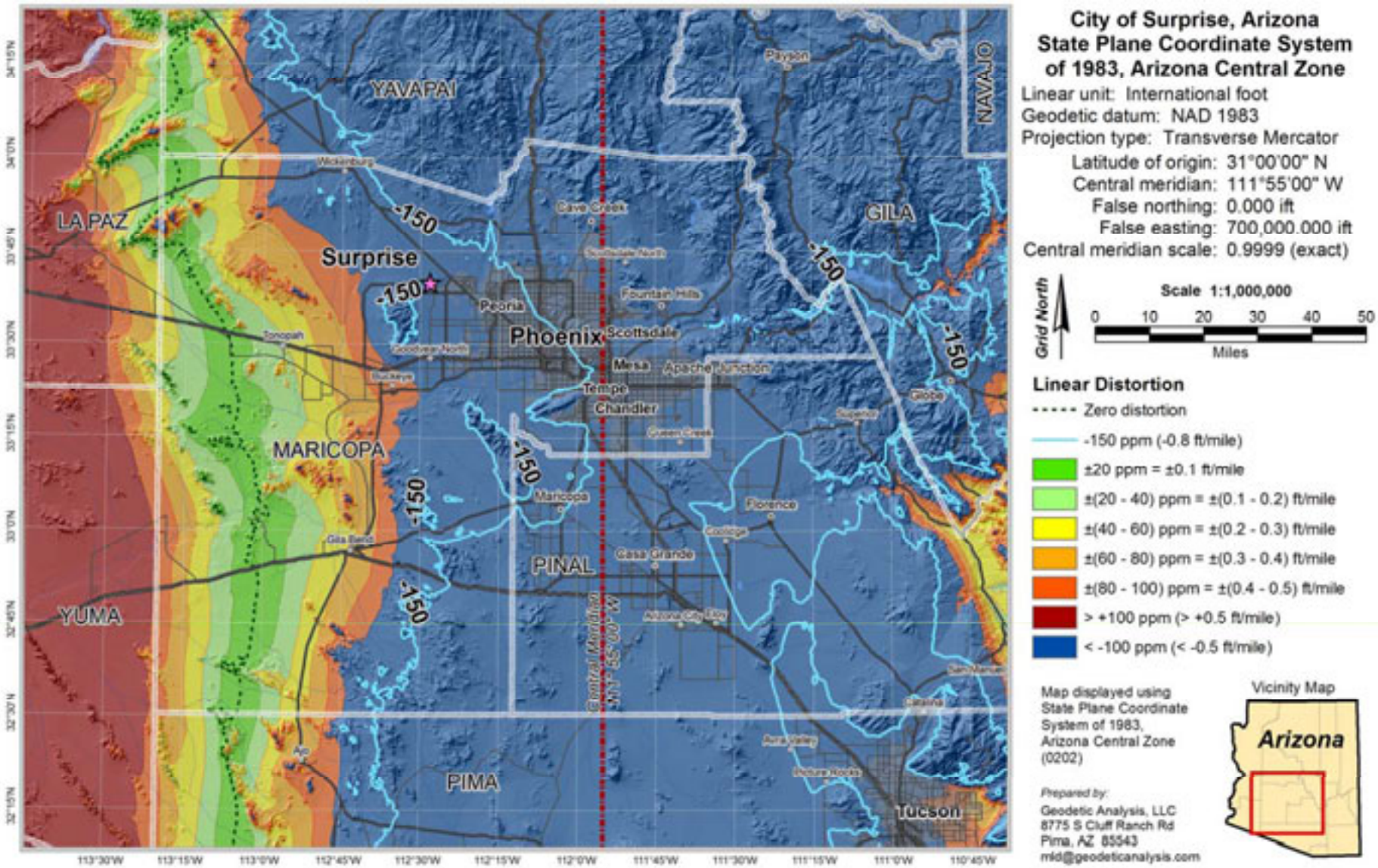
Limited transferability

Coordinate System Details

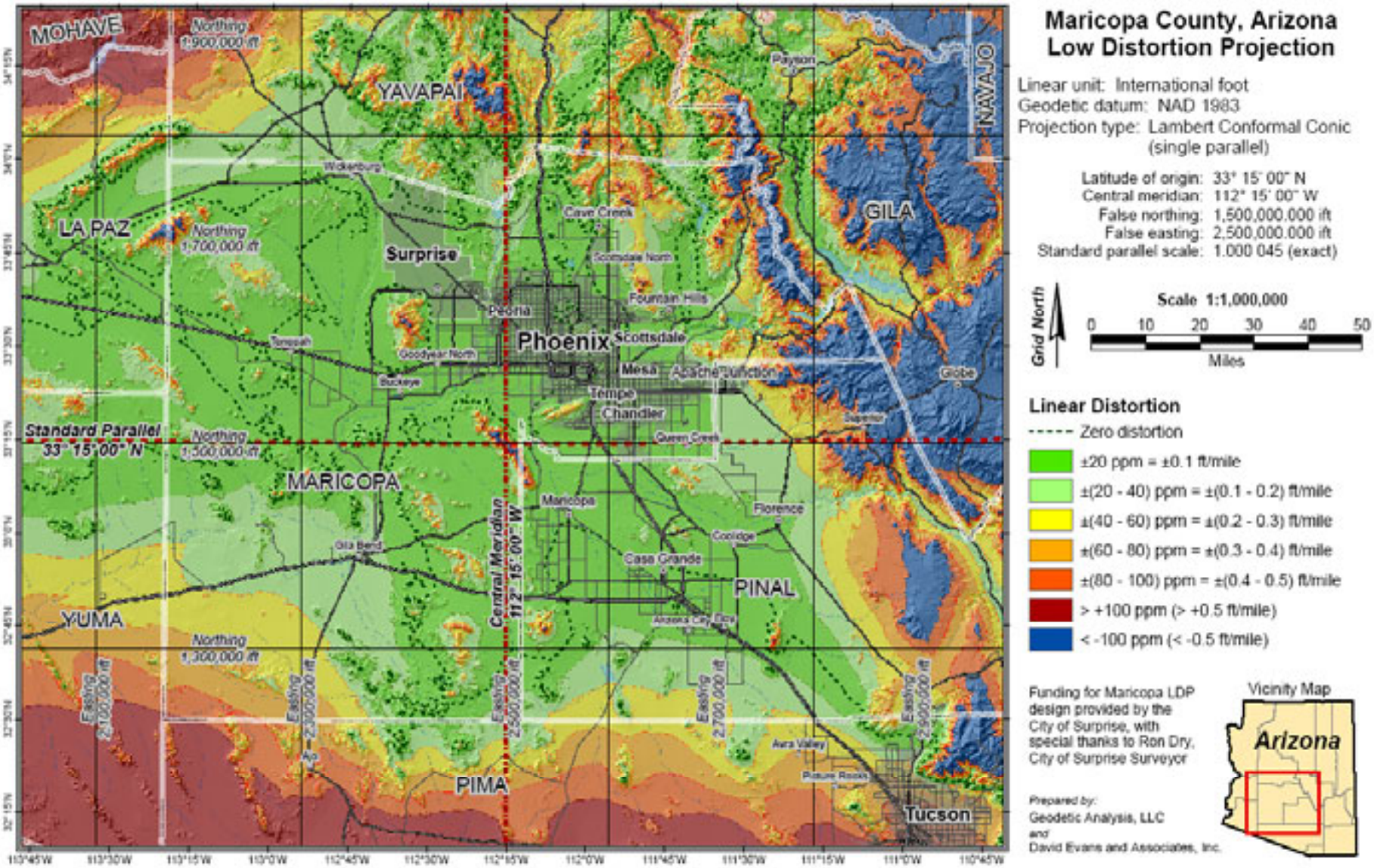
Project : SP27

```
Coordinate System
 Coordinate System : US State Plane 1983
 Zone              : Arizona Central 0202
 Datum             : calibration
 Ellipsoid Name    : Geodetic Ref System 1980
 Geoid Model       : GEOID99 (Conus)
 Site              : Default
Ellipsoid
 Ellipsoid Name   : Geodetic Ref System 1980
 Flattening 1/f   : 298.257
 Semi Major Axis  : 20925646.325ift
Datum Transformation : Three Parameter
 WGS84 to Geodetic Ref System 1980
 Translation X    :  53.425ift
 Translation Y    : -99.006ift
 Translation Z    :   5.276ift
 Scale Factor     :        N/A ppm
Transverse Mercator Projection
 Projection Origin                        False Origin
 Latitude      :   31°00'00.00000"N       False Northing  : 0.000ift
 Longitude     :  111°55'00.00000"W       False Easting   : 700000.000ift
 Scale Factor  :   0.99990000
 Project height              :        1300.000ift
GPS Site Calibration Details
 Horizontal Adjustment
 North Origin  :    756843.943ift  Translation North  :  0.000ift
 East Origin   :    588662.255ift  Translation East   :  0.000ift
 Scale         :    1.00000000     Rotation    :  0°00'00.443105"
Vertical Adjustment
 North Origin                        :    759472.760ift
 East Origin                         :    585995.230ift
 Vertical constant correction        :       -37.388ift
 Slope North                         :        11.090ppm
 Slope East                          :         8.170ppm
```

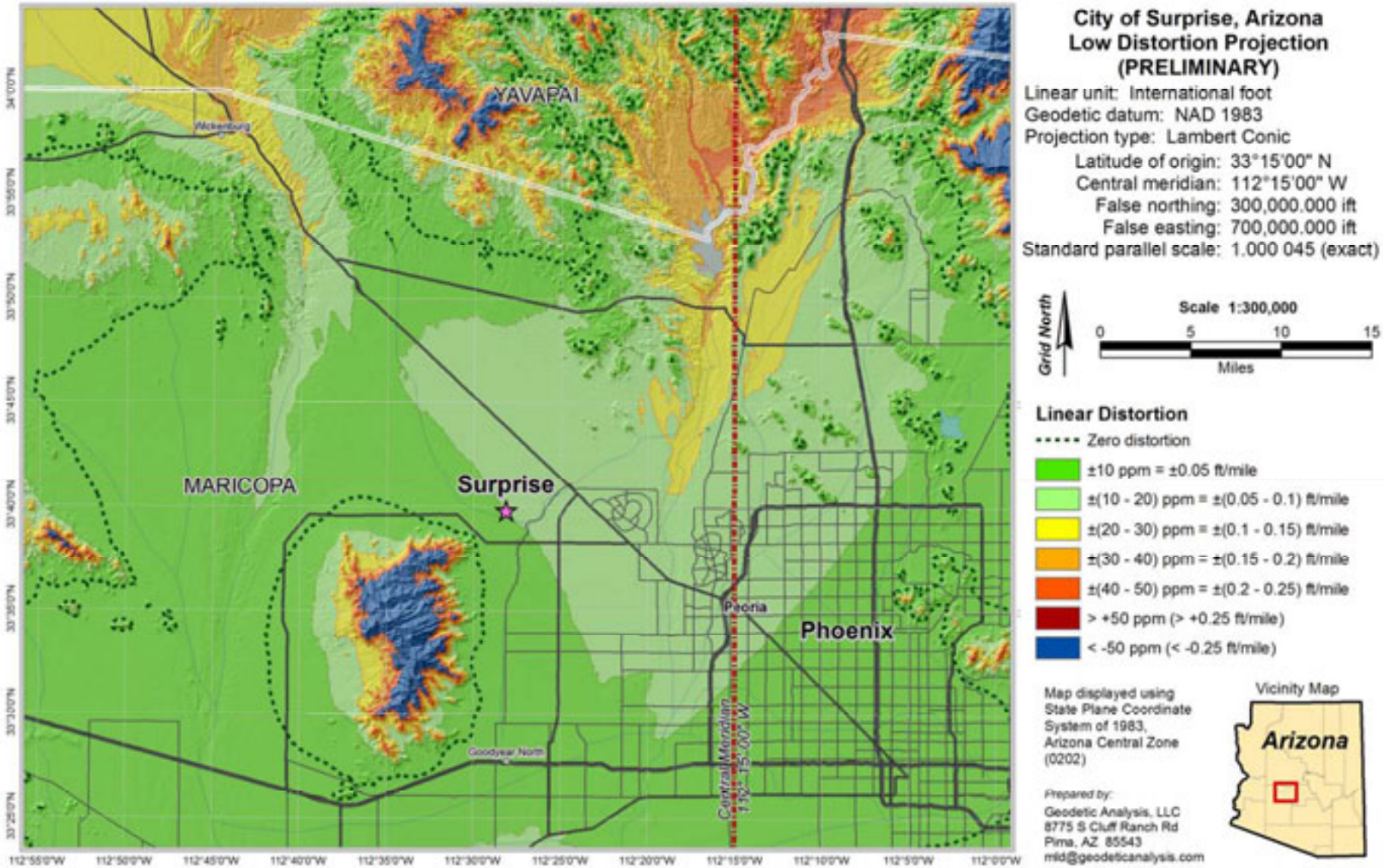
SPCS83_AZ_C_20ppm



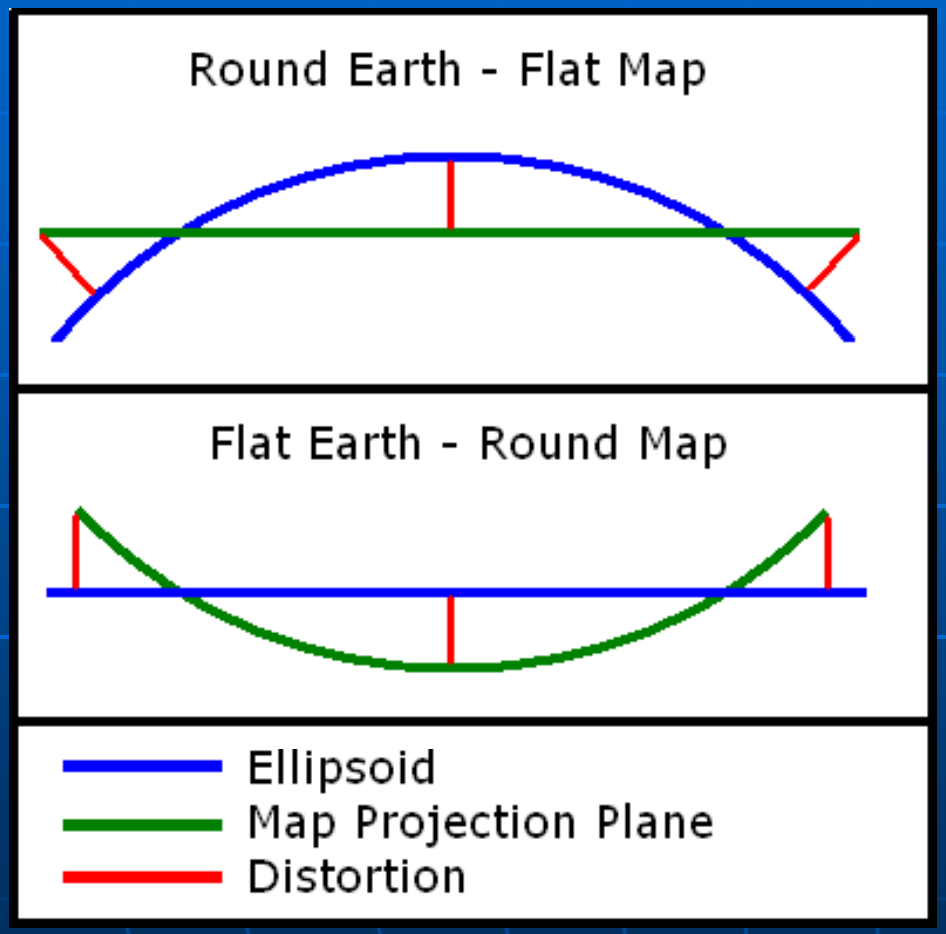
Surprise Final LDP



LC_SP3315_k1000045_10ppm

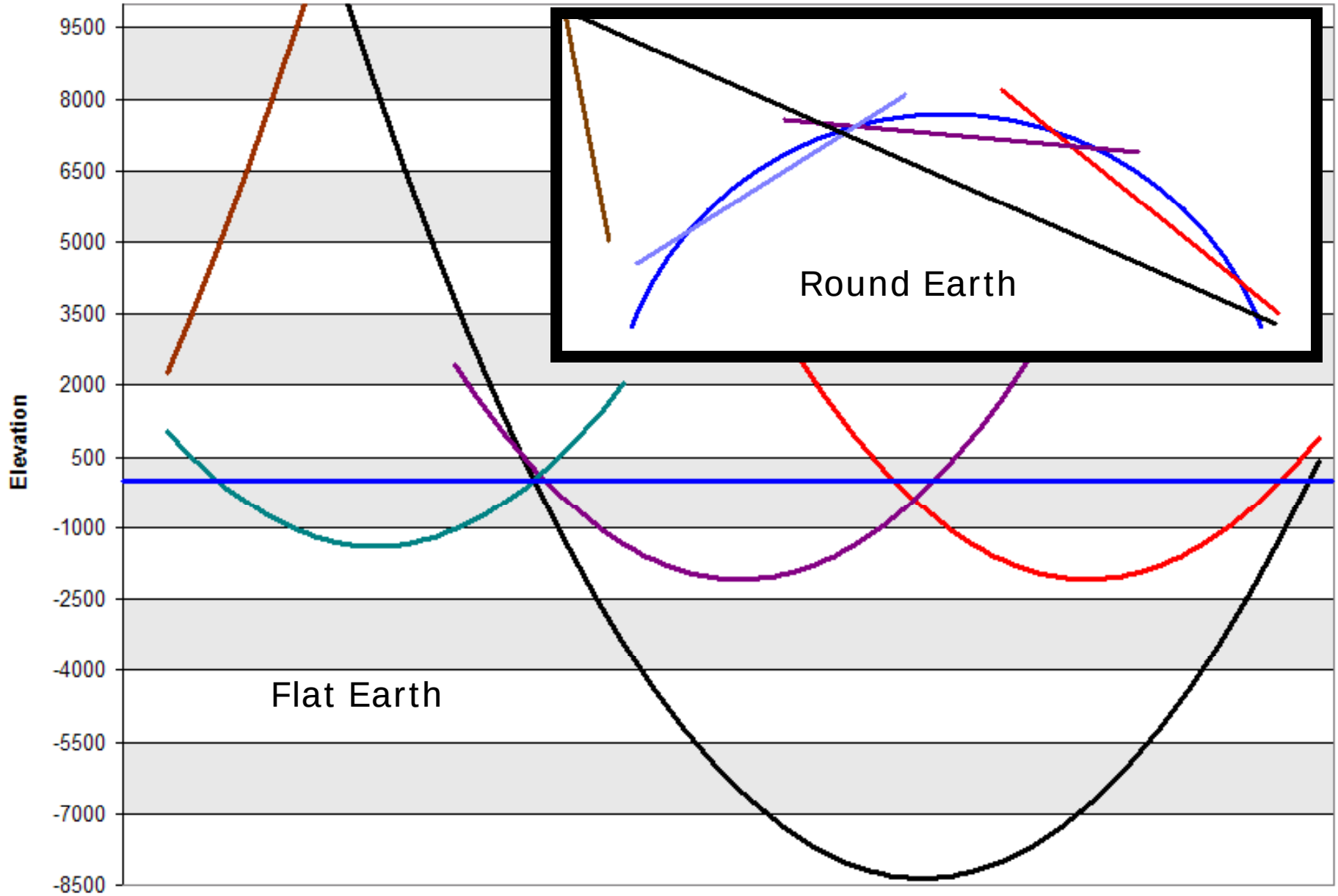


The Earth is Flat?

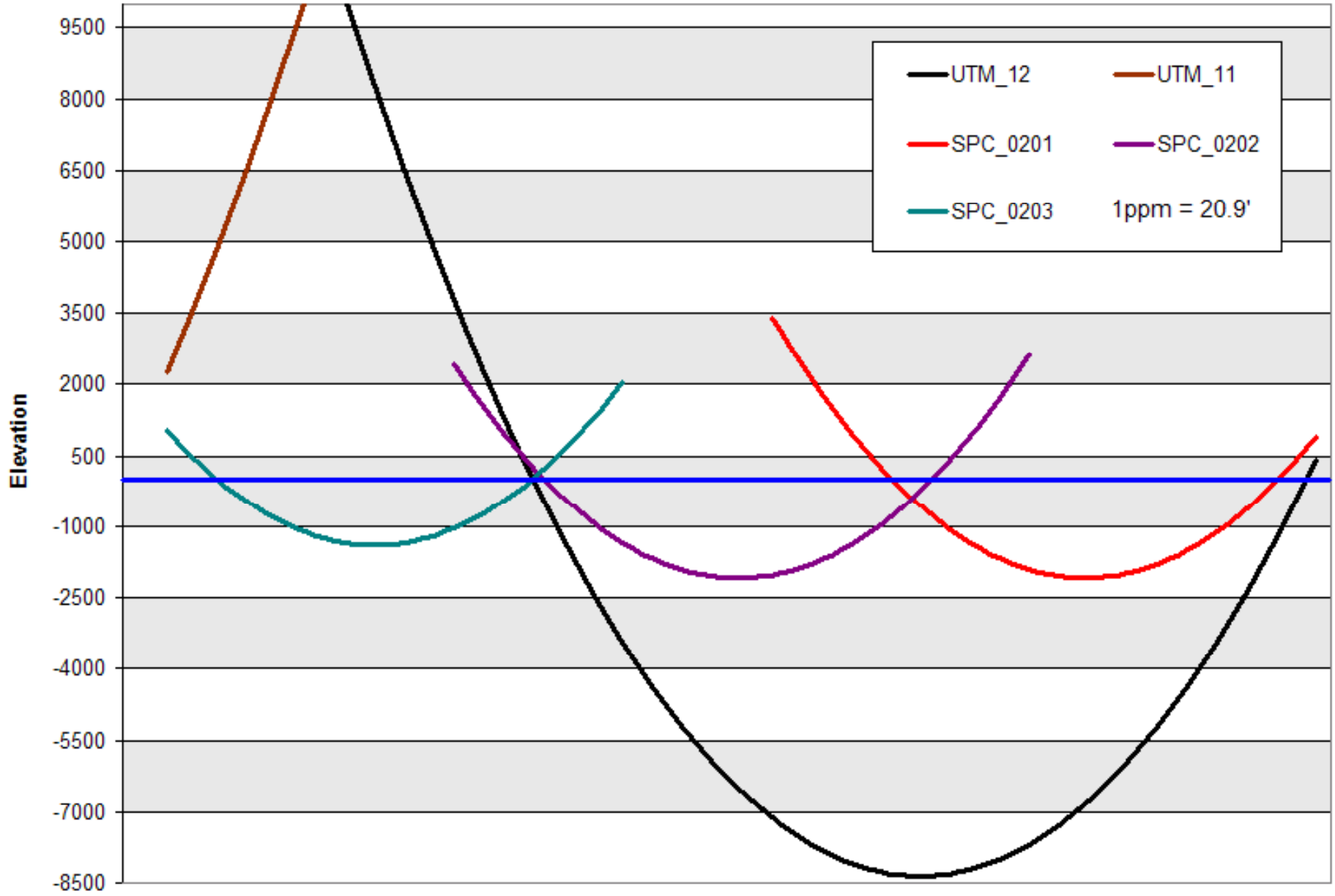


In order to understand map projections, and how they relate to one another we need to take a different look at the world

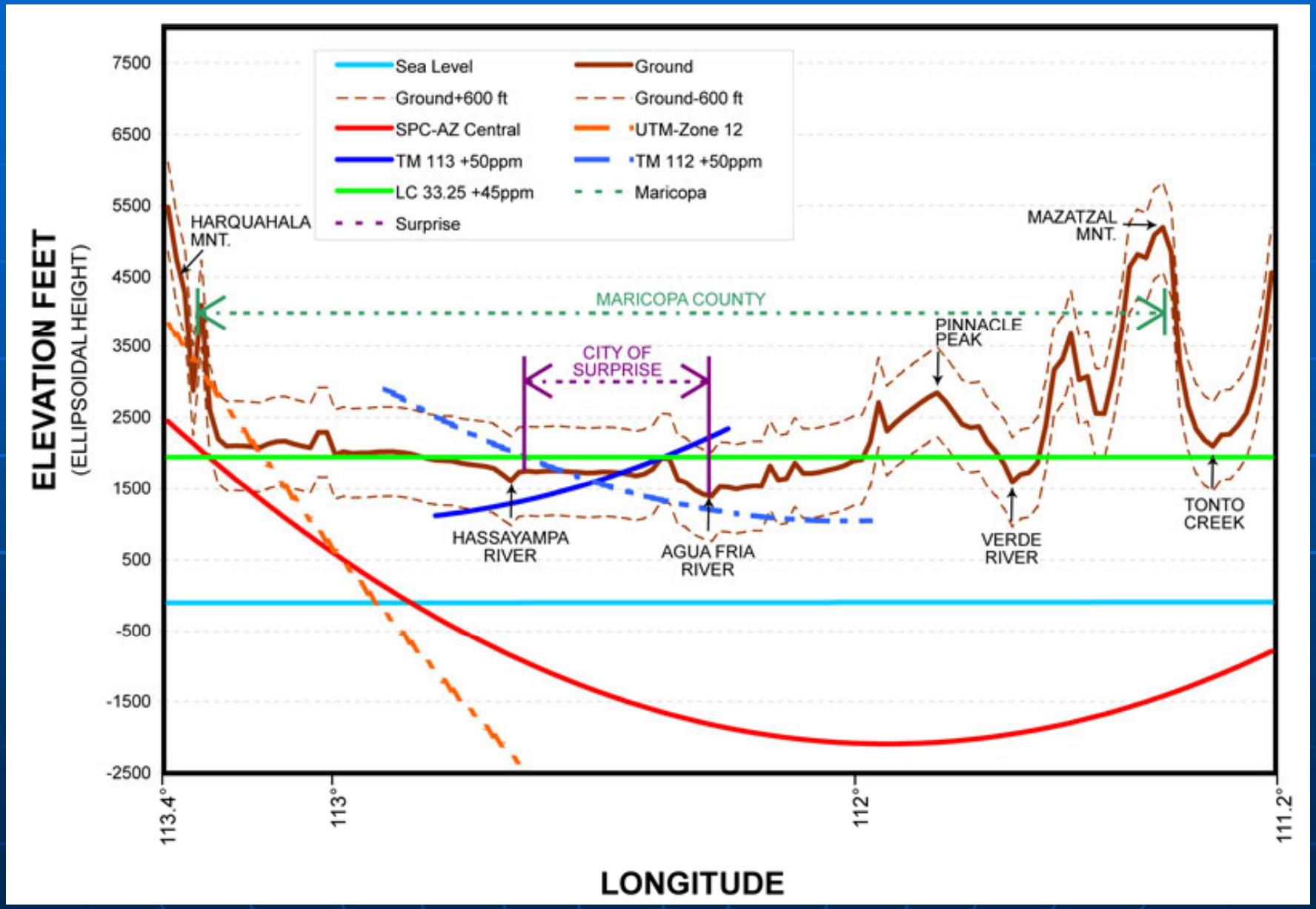
Scale from ellipsoid 34 degrees latitude AZ



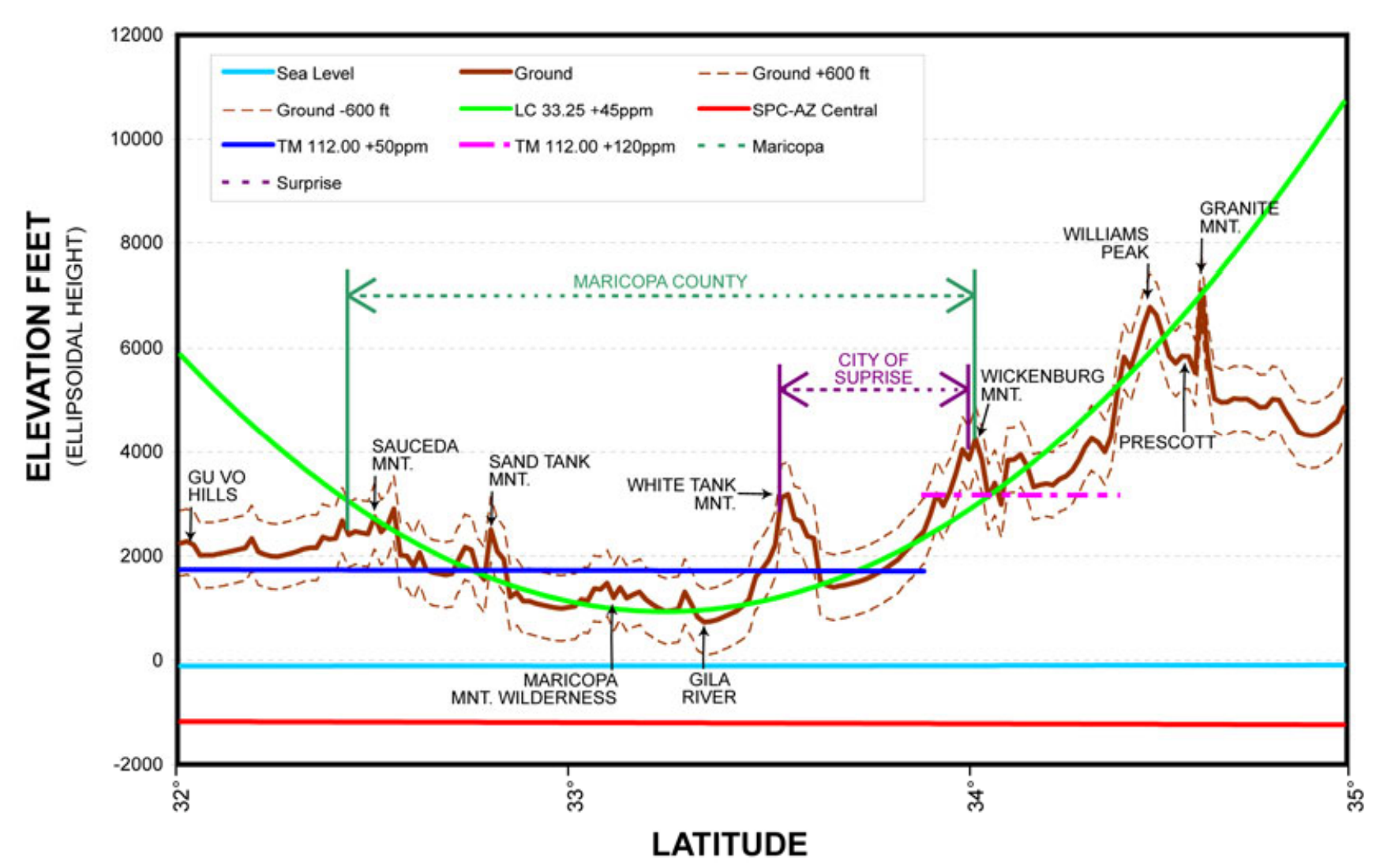
Scale from ellipsoid 34 degrees latitude AZ



33d 45’ 10” degrees latitude AZ
Looking North



112d 33’ 00” degrees longitude AZ
Looking West



Questions?