Modernization of the National Spatial Reference System **2022 Datum**

Society of American Military Engineers

Jacksonville Chapter
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Randy Tompkins, PSM, PLS

Geomatics Project Manager

Surveyor, Hydrographer, & Geodesist

DRMP, Inc.
Jacksonville, FL
(904) 641-0123
rtompkins@drmp.com

Credit where credit is due:
Most of the slides and data shown were created by
Dr. Dru Smith, Michael Dennis, and the Staff
National Geodetic Survey (NGS)

Answers …

What is changing?

- All horizontal datums and vertical datums in the NSRS
  - NAD 83 , NAVD 88 , etc

Why?

- Predominantly to keep up with technology
  - The current datums have systematic errors exceeding 1 meter.
  - New GPS Block III satellites stated Autonomous Positioning @ .63 m (95%)
  - Global proliferation of real time cm-accuracy positioning (in the hands of people who have no understanding of geodesy, datums, plate tectonics, error sources or other subtleties) is *rapidly* approaching.
    - Many surveying, mapping and navigation professionals already enjoy this accuracy.

When is it changing?

- No later than December 31, 2022

Will it be an immediate or gradual change?

- Immediate

Answers…

Possible impacts?

- Every historic position (on a map, chart, survey, etc) with an assumed accuracy of better than 1 meter will become obsolete
  - Transformations will exist before 2022 to help
- Every piece of navigating, mapping and surveying software will become obsolete
  - NGS is working with industry to get ahead of this

Will there be conversion tables from the old datum?

- Not in the sense of “a book with pages and pages of numbers”. But there will be digital products available to transform from old to new.

Answers…

Is WGS 84 updated too?

- Not necessarily
- WGS-84 is a military system. The military is not beholden to the civilian spatial reference system.
  - But NGS is in contact with NGA about co-defining the new system with the latest update to WGS-84

Reminder…

WGS-84 is not part of the NSRS

- It is a military-controlled system
- Raw data from GPS satellites are in WGS84
- That does not matter if your handheld device is only accurate to +/-10m.

All civilian federal agencies are required to work in the NSRS (as per OMB A-16)

- NAD 83 is part of the NSRS
  - The UTM is not necessarily WGS-84, any data processed in North America, using NGS CORS or OPUS is in NAD 83 and the coordinates would be in the projection of the user's control. i.e. UTM (NAD83(2011)), (NAD83(2011)), UTM (NAD83(2007)), UTM (NAD83(1990))…..
  - Right now, it is possible that the uninformed user would say that the data is in UTM (WGS84) when it is really in UTM (NAD83(2011))
    - Replacing NAD 83 will impact the DOD if you have received survey quality data for any project in North America. I do not know about the rest of the world.

Replacing the NAD 83's

OLD	NEW
NAD 83(2011)	The North American Terrestrial Reference Frame of 2022 (NATRF2022) The Caribbean Terrestrial Reference Frame of 2022 (CATRF2022)
NAD 83(PA11)	The Pacific Terrestrial Reference Frame of 2022 (PATRF2022)
NAD 83(MA11)	The Mariana Terrestrial Reference Frame of 2022 (MATRF2022)

Replacing NAVD 88

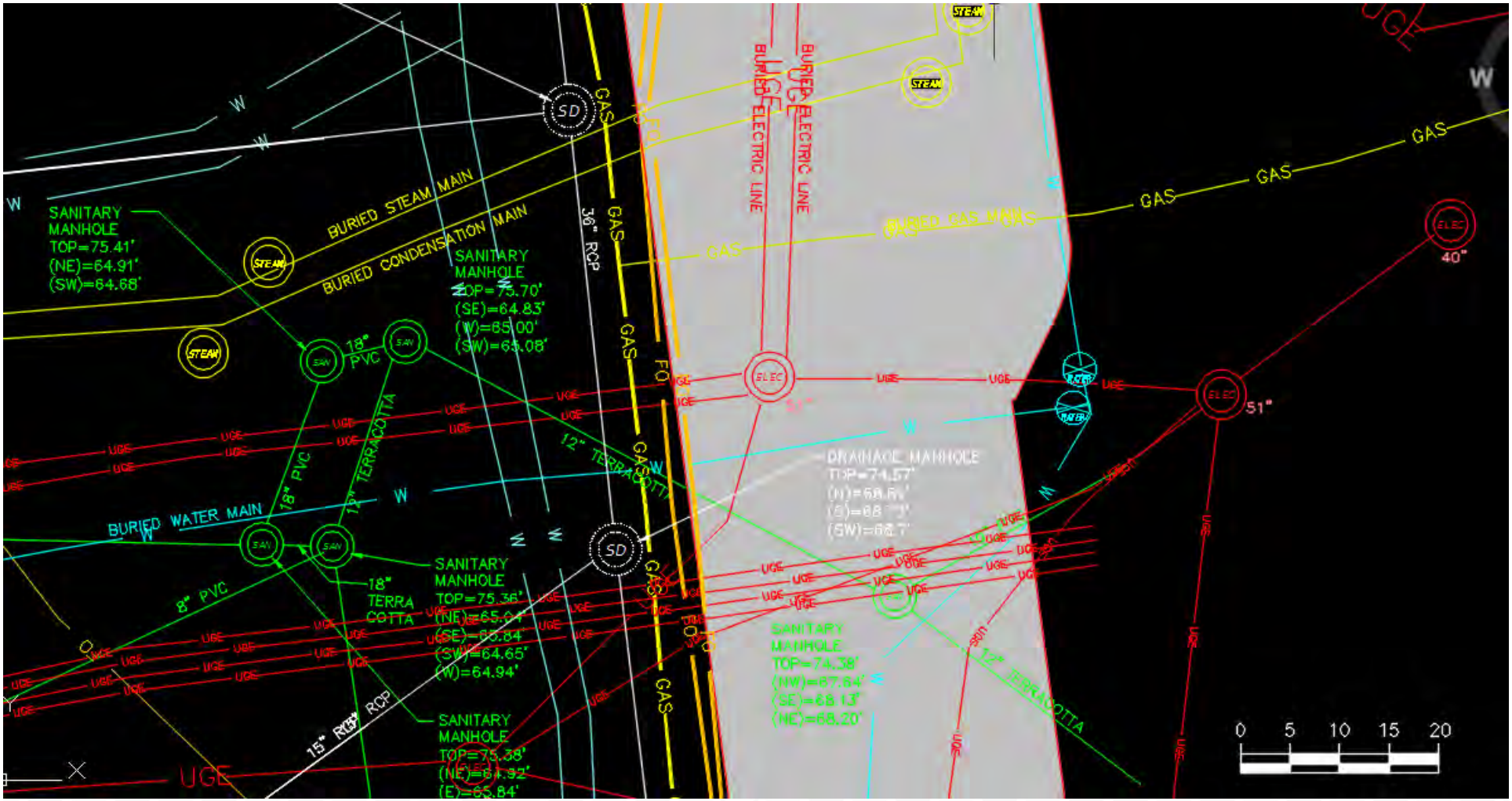
	OLD	NEW
Orthometric Heights	NAVD 88	The North American-Pacific Geopotential Datum of 2022 (NAPGD2022)
Normal Orthometric Heights	PRVD 02 VIVD09 ASVD02 NMVD03 GUVD04	
Dynamic Heights	IGLD 85	
Gravity	IGSN71	Will include GEOID2022
Geoi Undulations	GEOID12B	
Deflections of the Vertical	DEFLEC12B	

Q: When should I care?

A: When your accuracy needs are smaller than about 4 meters

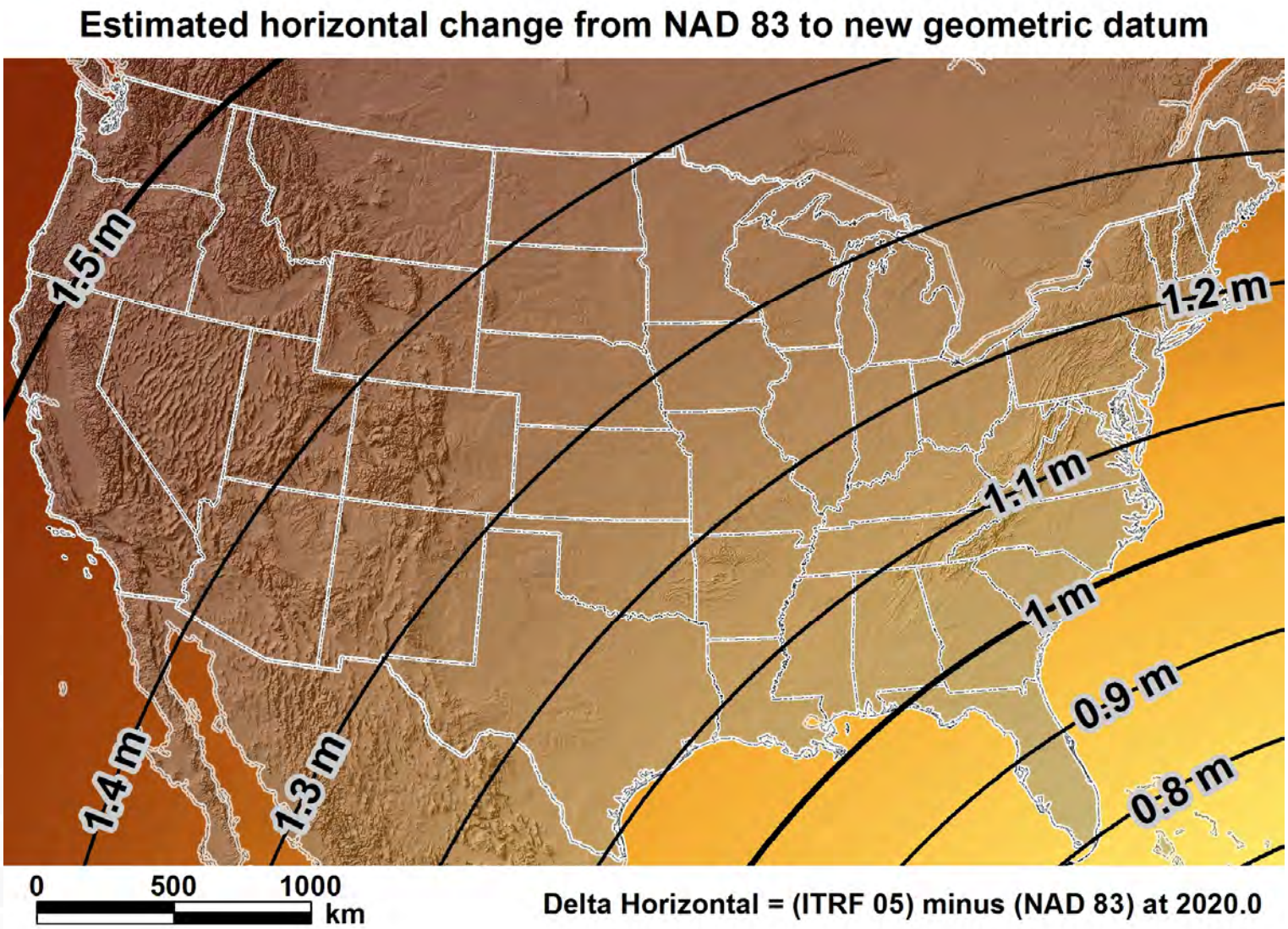
- Expected latitude/longitude changes:
  - 0-2 meters CONUS
  - 2+ meters Alaska
  - 4+ meters Hawaii
- Expected ("MSL") height changes:
  - 0-2 meters CONUS
  - 2+ meters Alaska
  - Unclear Hawaii
- Plus, time-dependent changes to all of these at ~few cm/year

Q: When should I care?

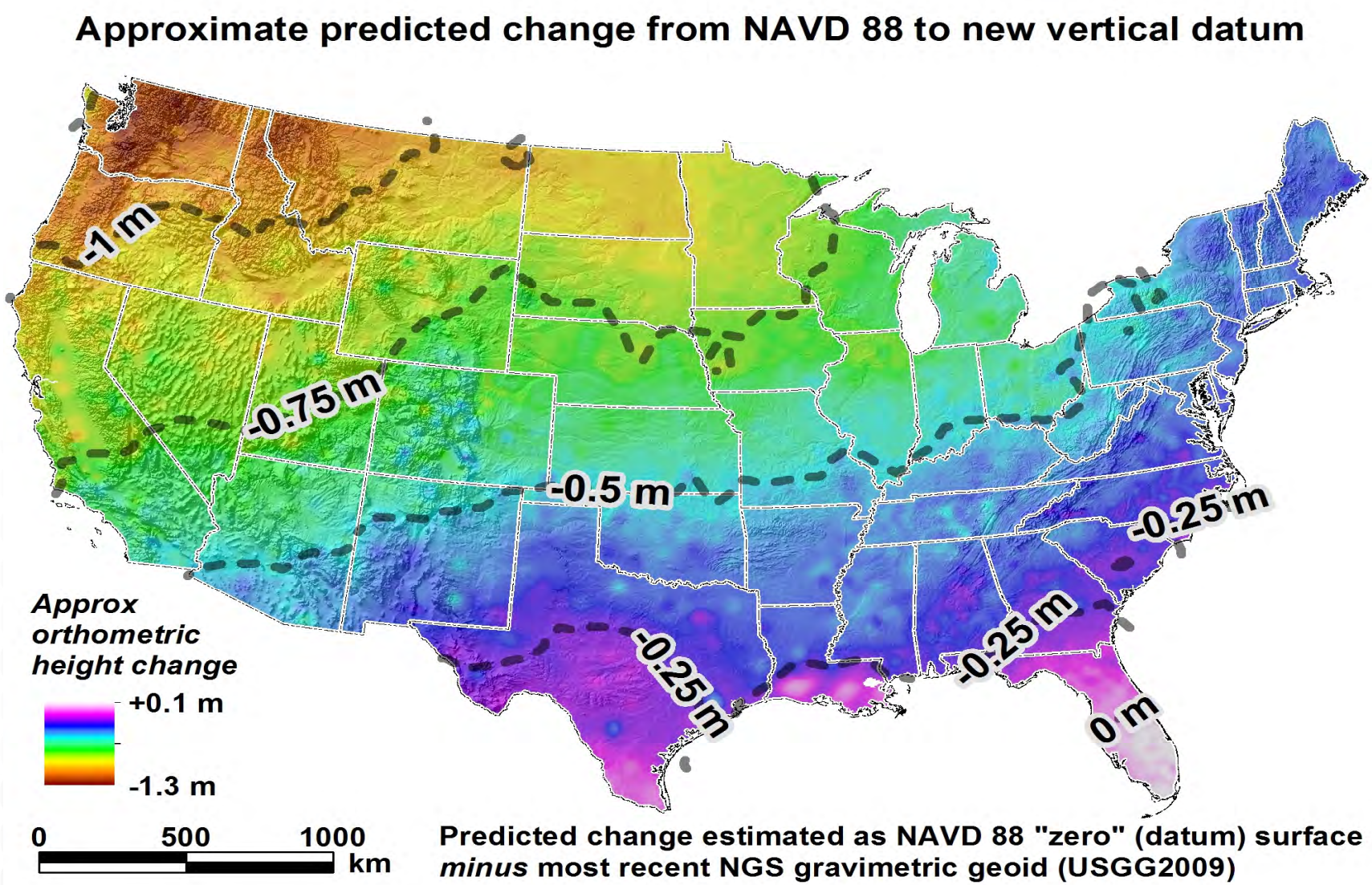


Q: When should I care?

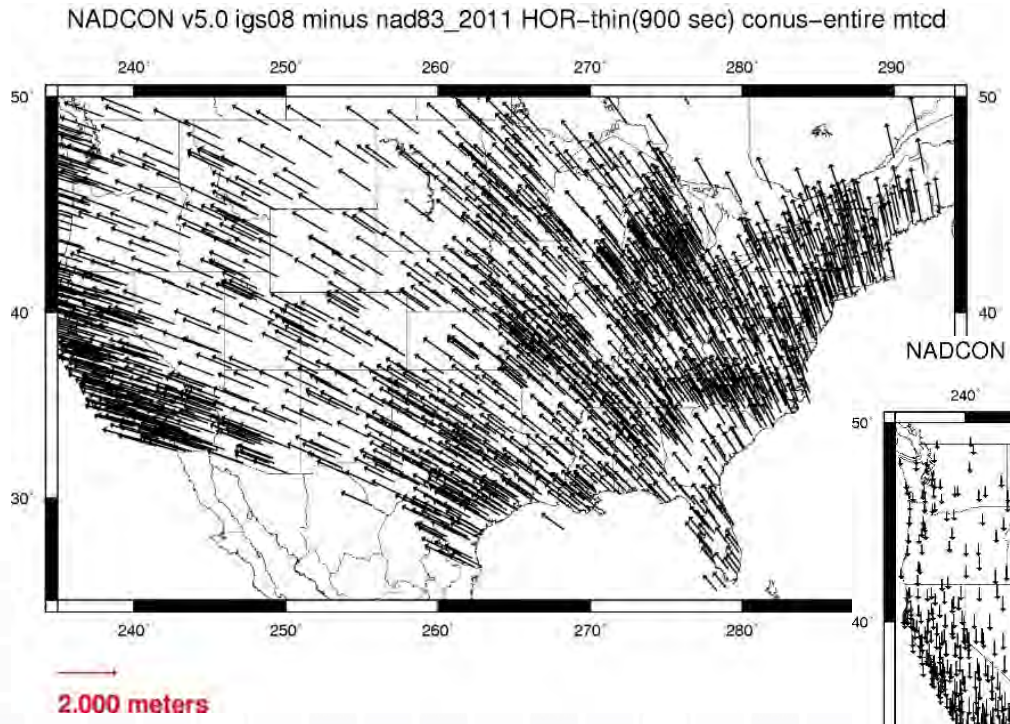
Expected changes to horizontal positions

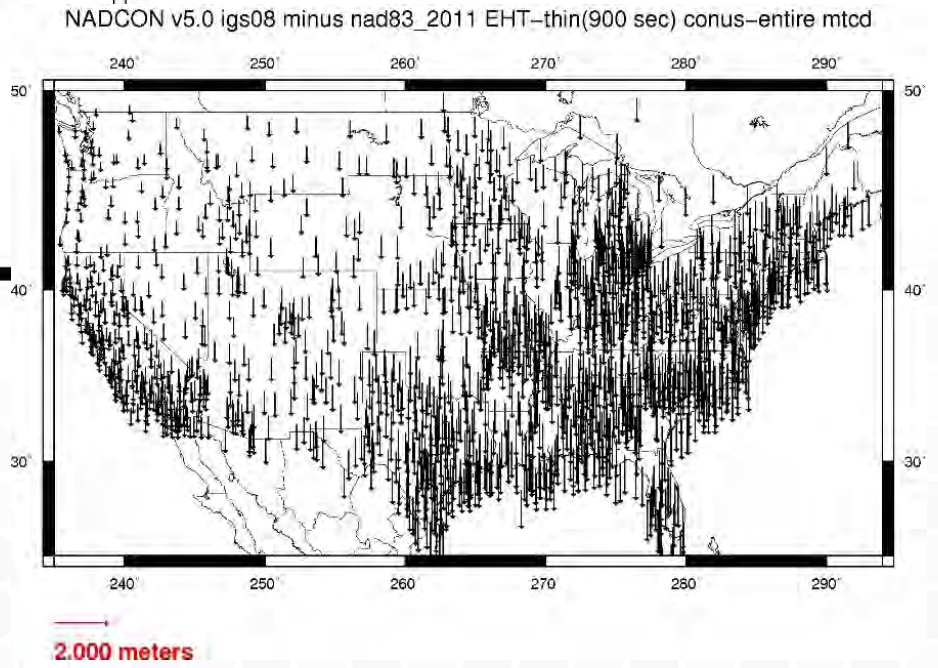


Expected changes to orthometric heights

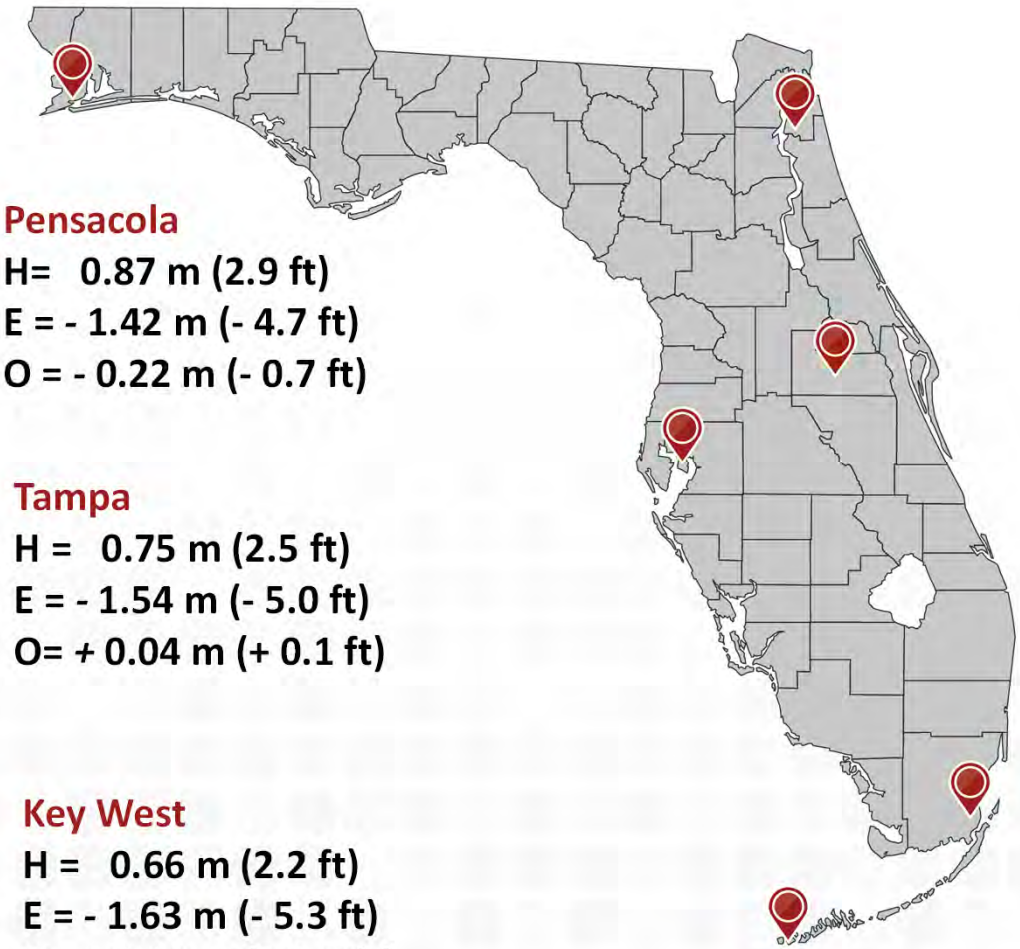


Fixed-Epoch Transformation NAD 83 to “2022”





Predicted Positional Changes in 2022 Computed with xGEOID16B



Pensacola
H= 0.87 m (2.9 ft)
E = - 1.42 m (- 4.7 ft)
O = - 0.22 m (- 0.7 ft)

Tampa
H = 0.75 m (2.5 ft)
E = - 1.54 m (- 5.0 ft)
O= + 0.04 m (+ 0.1 ft)

Key West
H = 0.66 m (2.2 ft)
E = - 1.63 m (- 5.3 ft)
O= + 0.20 m (+ 0.7 ft)

Jacksonville
H= 0.80 m (2.6 ft)
E = - 1.49 m (- 4.9 ft)
O = - 0.12 m (- 0.4 ft)

Orlando
H = 0.75 m (2.2 ft)
E = - 1.54 m (- 5.1 ft)
O = + 0.01 m (0.03 ft)

Miami
H = 0.67 m (2.2 ft)
E = - 1.62 m (- 5.3 ft)
O = + 0.06 m (+ 0.2 ft)

H=Horizontal Shift
E=Ellipsoid Height Shift
O=Orthometric Height Shift

What to do with historic charts/maps?

Is the accuracy expected to be better than a few meters?

Yes

No

Stop. You won't likely gain much by transforming

Do you have trusted metadata which puts the chart in the NSRS? (Note, WGS 84 is not part of the NSRS)

Yes

No

Use NADCON and VERTCON to update the datums in 2022

Stop. Transformation tools only work in the NSRS and only if you trust the metadata

Transformation tools

NADCON

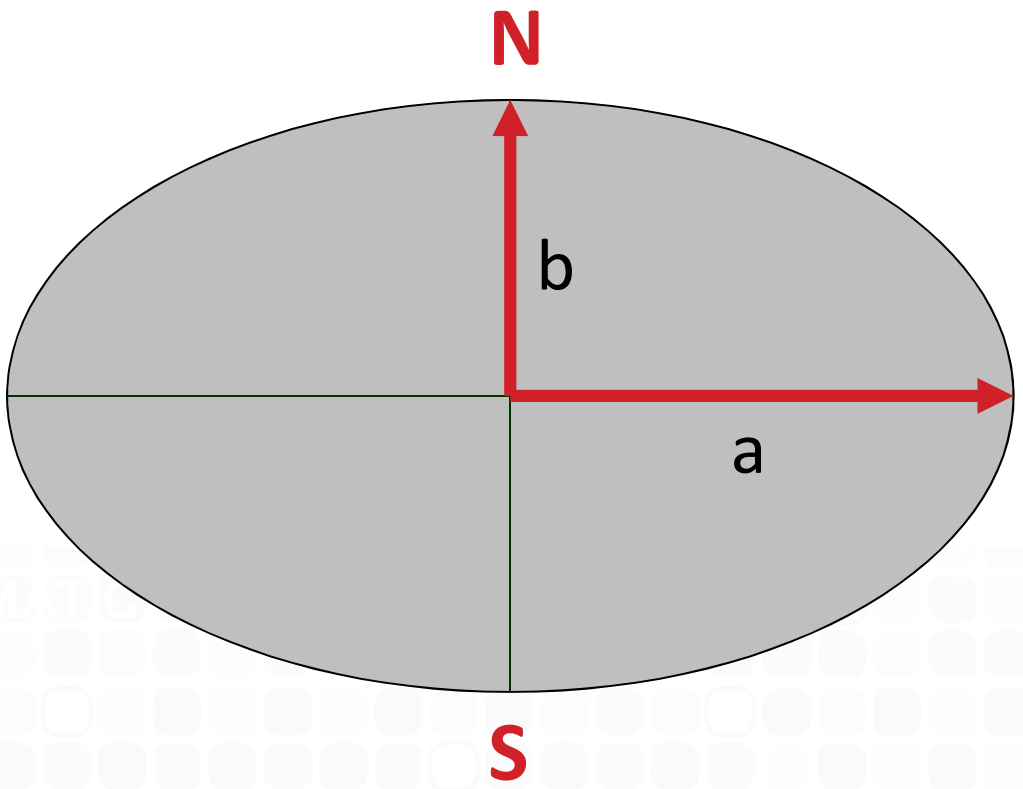
- Latitudes, longitudes, ellipsoid heights
- NAD 83 to the 2022 NSRS (IGS, NATRF2022, PATRF2022, MATRF2022, CATRF2022)

VERTCON

- Orthometric (“MSL”) heights
- NAVD 88 to the 2022 NSRS (NAPGD2022)

Why Do We Need This?

The Ellipsoid Mathematical Model of The Earth



a = Semi major axis
b = Semi minor axis
f = $\frac{a-b}{a}$ = Flattening

Current United States Ellipsoid Definitions

BESSEL 1841

a = 6,377,397.155 m 1/f = 299.1528128

CLARKE 1866 (NAD 27)

a = 6,378,206.4 m 1/f = 294.97869821

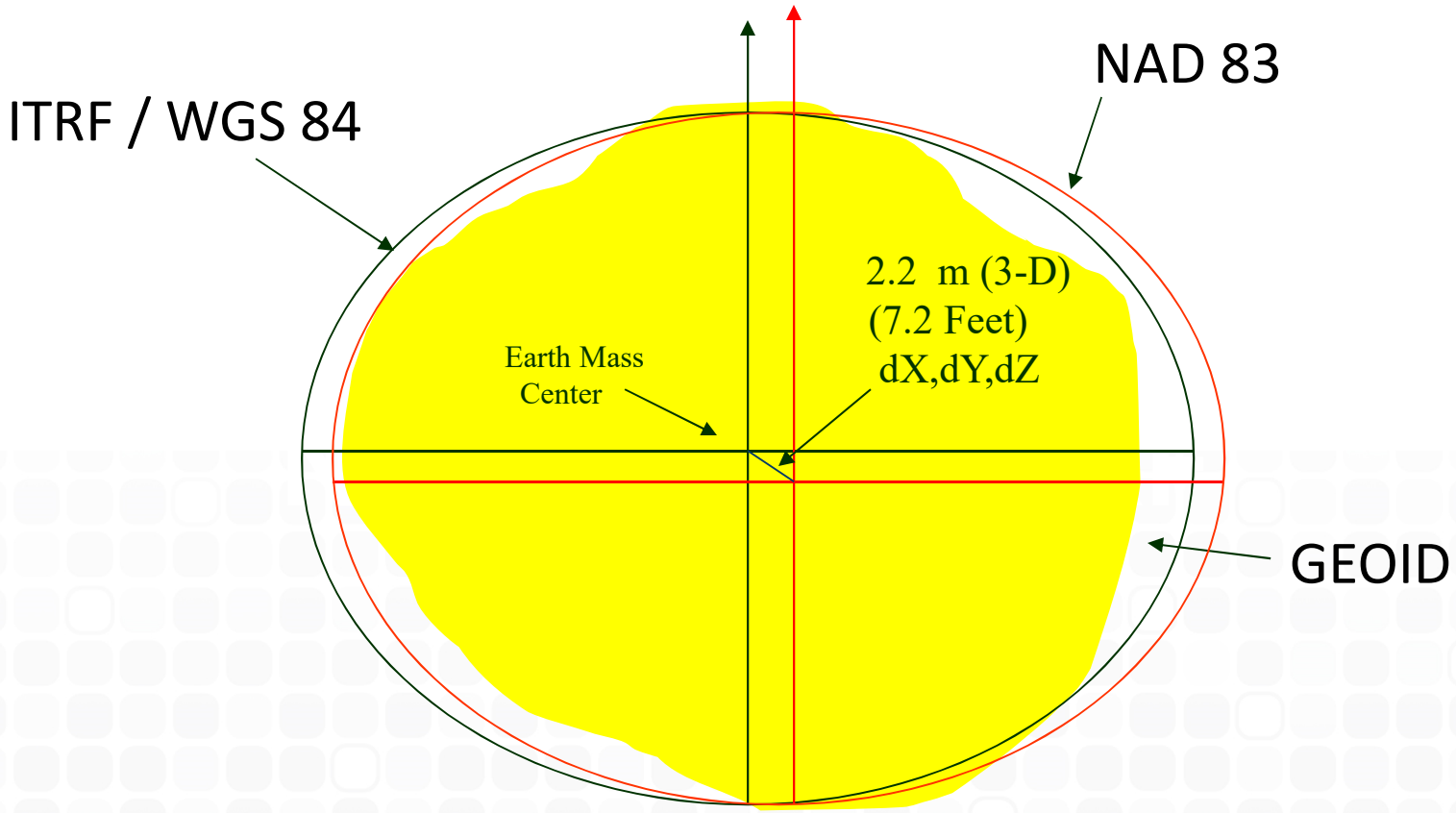
GEODETIC REFERENCE SYSTEM 1980 - (GRS 80)

a = 6,378,137 m 1/f = 298.257222101

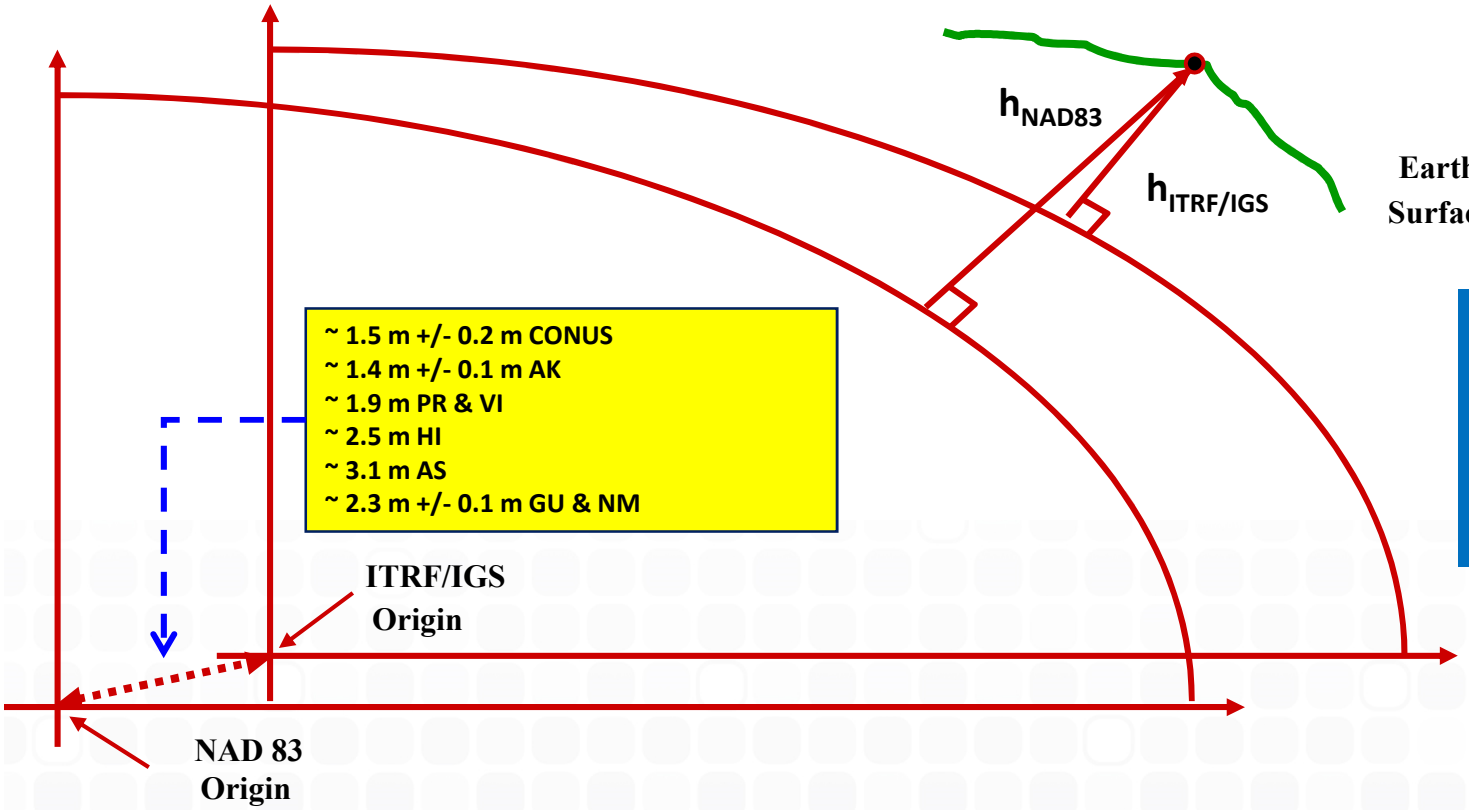
WORLD GEODETIC SYSTEM 1984 - (WGS 84)

a = 6,378,137 m 1/f = 298.257223563

NAD 83 and ITRF / WGS84



Simplified Concept of NAD 83 vs. ITRF/IGS



Columbus - COLB
dX = 0.678 m
dY = 1.410 m
dZ = 0.086 m
3D = 1.567 m

Identically shaped ellipsoids (GRS-80)
a = 6,378,137.000 meters (semi-major axis)
1/f = 298.25722210088 (flattening)

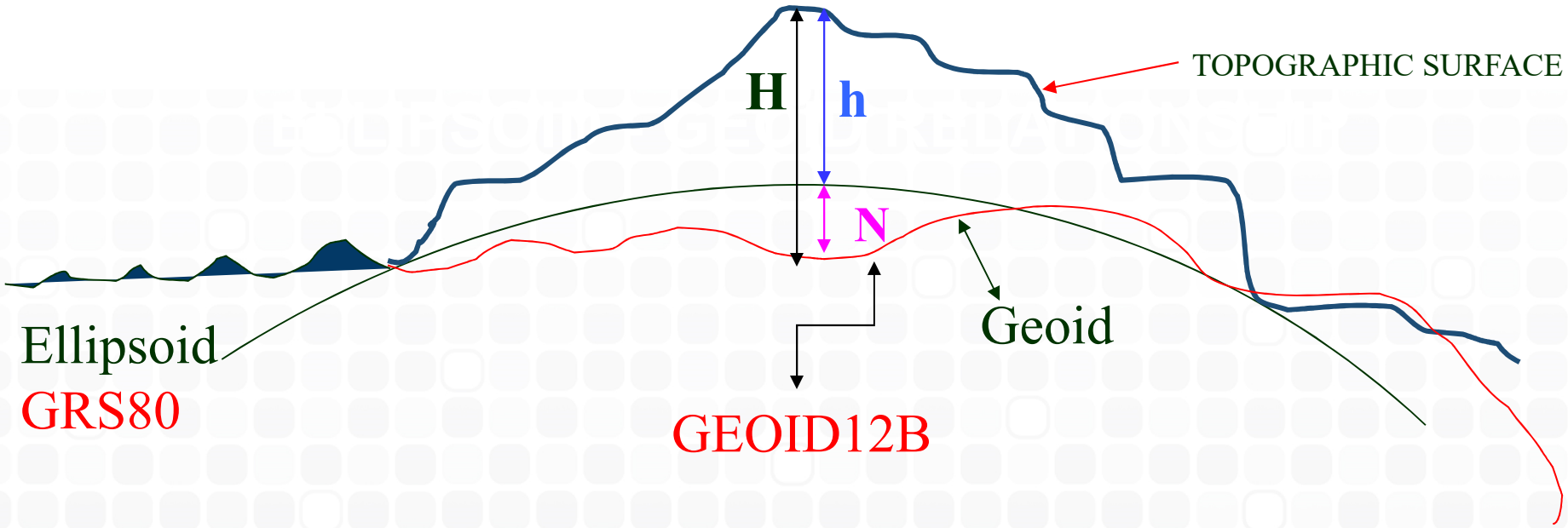
Ellipsoid - Geoid Relationship

H = Orthometric Height (NAVD88)

h = Ellipsoidal Height (from GPS)

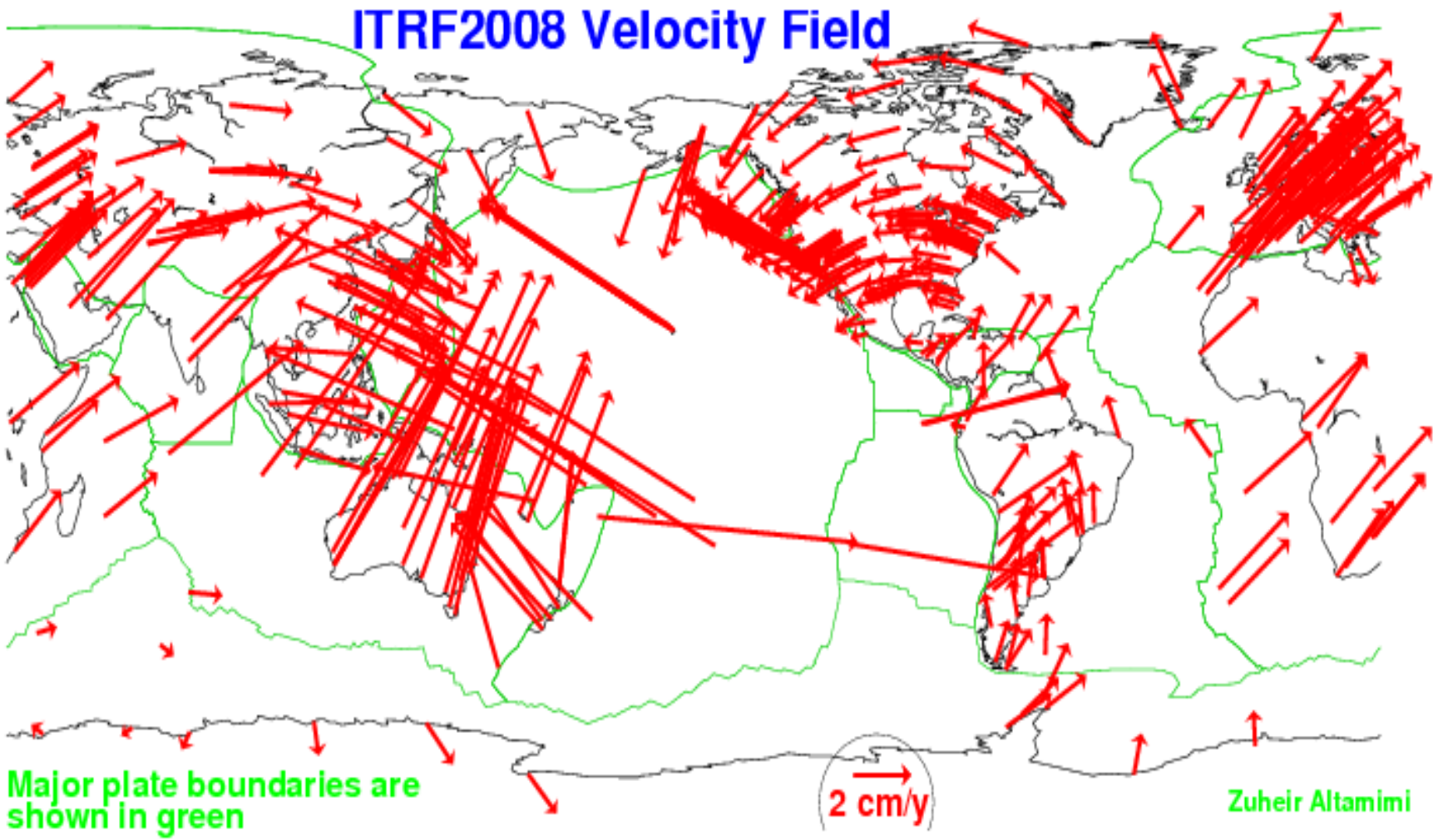
N = Geoid Height (from geoid model)

$$H = h - N$$



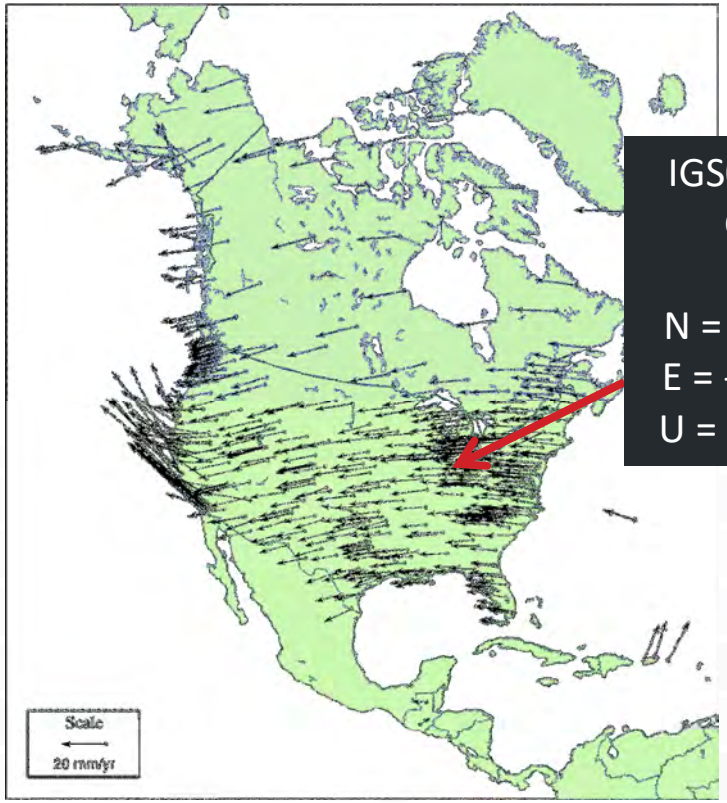
Lateral Tectonic Plate Velocities

Lateral Tectonic Plate Velocities

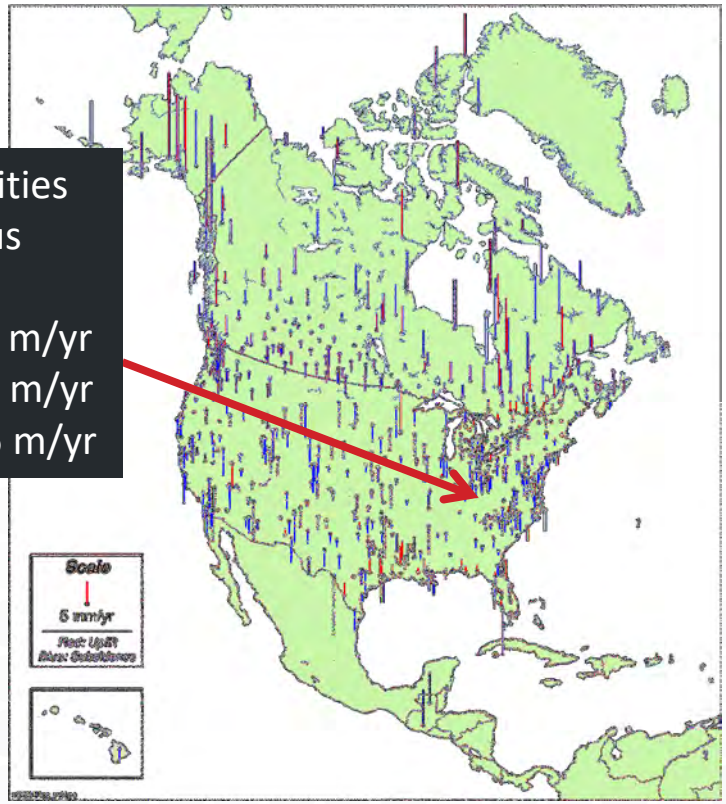


Tectonic Plate Velocities

Horizontal



Vertical

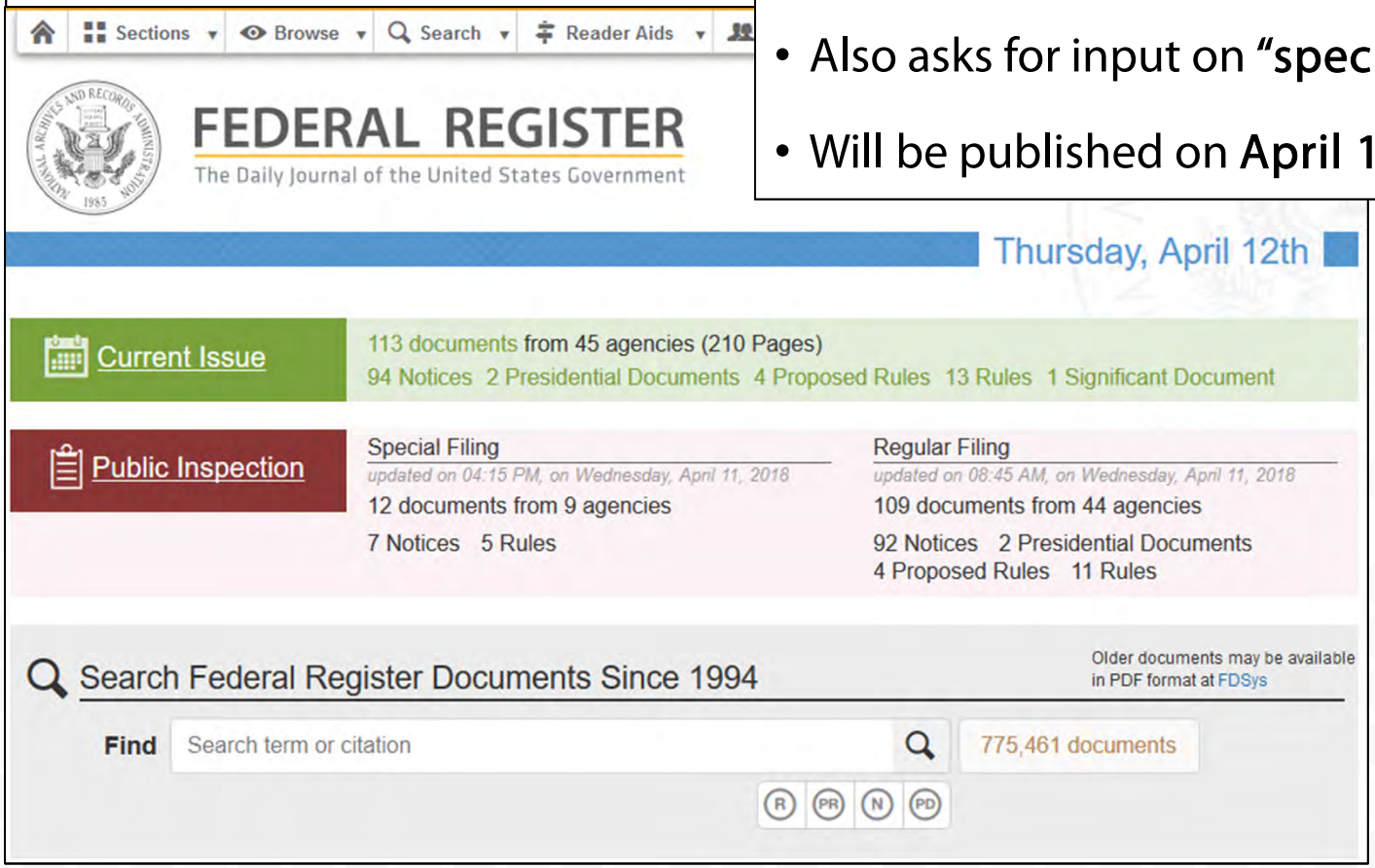


IGS08 Velocities
Columbus
COLB
N = - 0.0018 m/yr
E = - 0.0152 m/yr
U = - 0.0026 m/yr

Federal Register Notice

- Announces **SPCS2022 Policy and Procedures**
- Public comment period through **Aug 31, 2018** at NGS.Feedback@noaa.gov
- Also asks for input on **"special purpose"** zones
- Will be published on **April 18, 2018**

https://www.federalregister.gov/



geodesy.noaa.gov/SPCS/

Look here for link

2022 SPCS Policy Changes

National Geodetic Survey

Positioning America for the Future

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State Plane Coordinate System
- Home
- Maps
- Convert Coordinates
- Current Policy

Have State Plane Questions?
- Contact Us

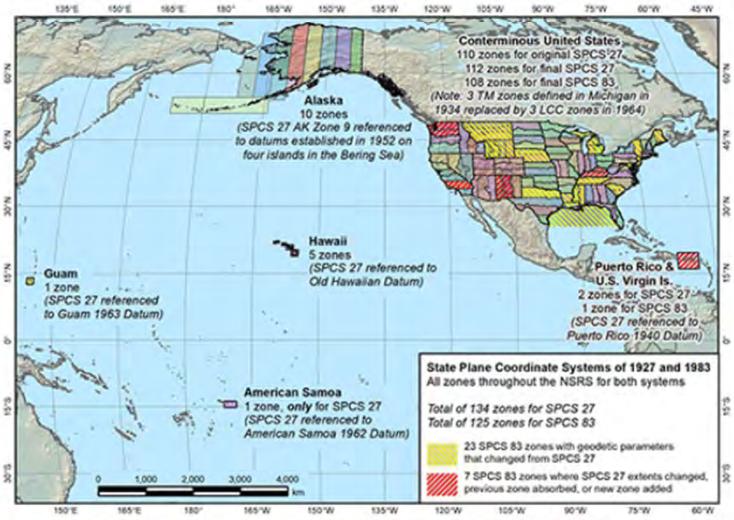
State Plane Coordinate System (SPCS)

SPCS is a system of large-scale conformal map projections originally created in the 1930s to support surveying, engineering, and mapping activities throughout the U.S. and its territories. As a reminder, a map projection is a systematic transformation of the latitudes and longitudes of locations on the surface of a sphere or ellipsoid representing the Earth to grid coordinates (x, y or easting, northing values) on a plane.

Since its inception, SPCS has served as a practical means for NGS customers to access to the National Spatial Reference System (NSRS). These web pages will help you convert coordinates, find related NGS policies and other documents, read about the history and status of current SPCS, and learn about how SPCS will change in 2022.

The map below shows the full extents and all zones of the 1927 and 1983 versions of SPCS (select the map for a higher resolution version). View **more detailed maps** or a **map depicting SPCS 83 legislation**.

State Plane Coordinate Systems of 1927 and 1983



Full extents and all zones of the 1927 and 1983 versions of SPCS. **Map High Res Version**

Website Owner: National Geodetic Survey / Last modified by **NGS Infocenter** Mar 05 2018

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Definitions in Policy & Procedures

- Stakeholders. State organizations that can give input on SPCS2022: DOTs, GIS offices, surveying & engineering societies, professional geospatial organizations, and universities that perform geospatial education or research.

- Contributing partners. Organizations or individuals that design SPCS2022 zones for stakeholders and in cooperation with NGS.

- Zone. The region where a projected coordinate system is used.

- Linear distortion. Amount a map projection distance differs from "true" horizontal distance at the ground surface.

- Conformal map projection. Linear distortion is unique (same in every direction) at a point.

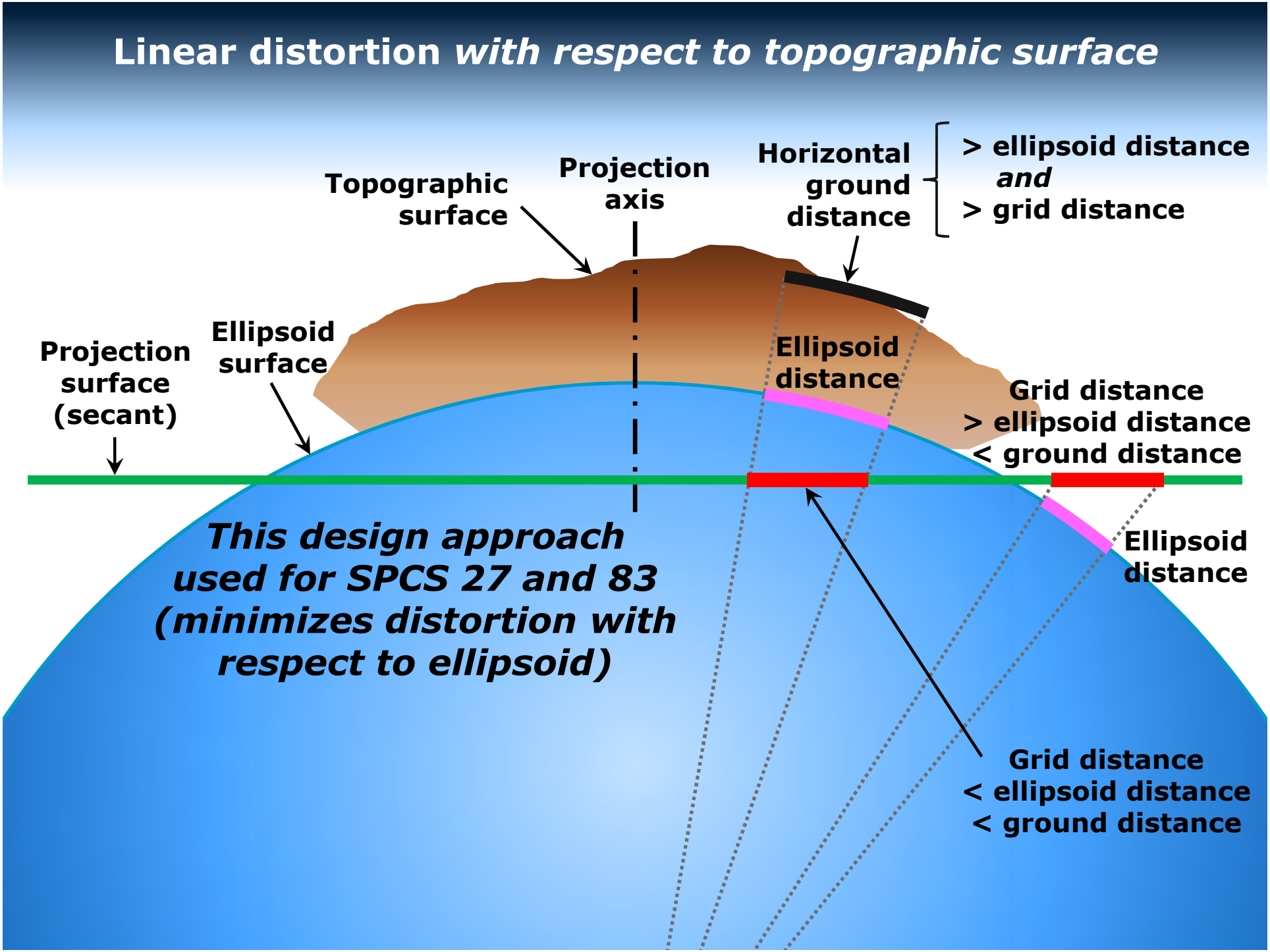
- Projection axis. The line along which linear distortion is minimum and constant with respect to the reference ellipsoid.

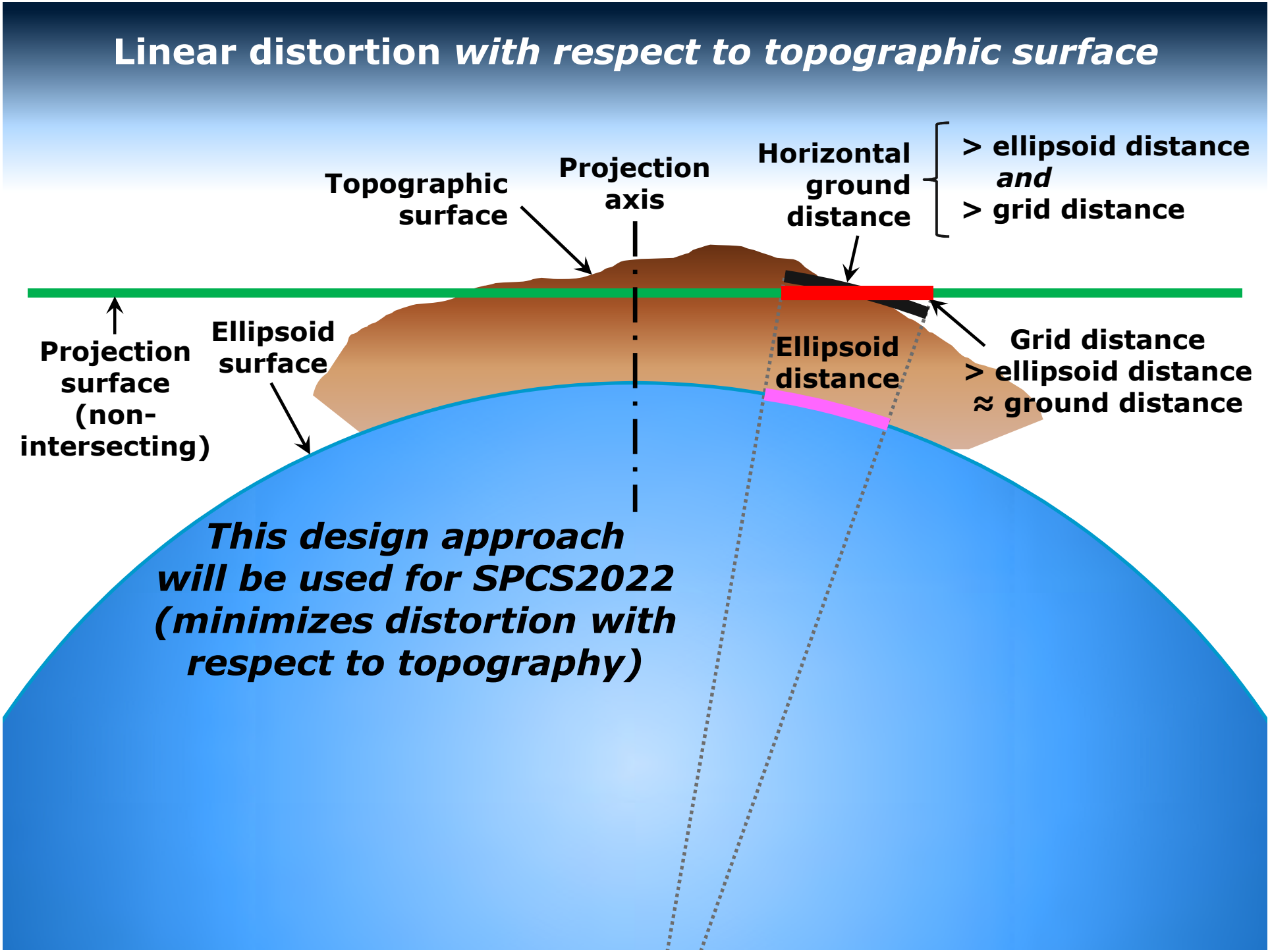
Linear distortion magnitudes

ppm = parts per million (mm/km)

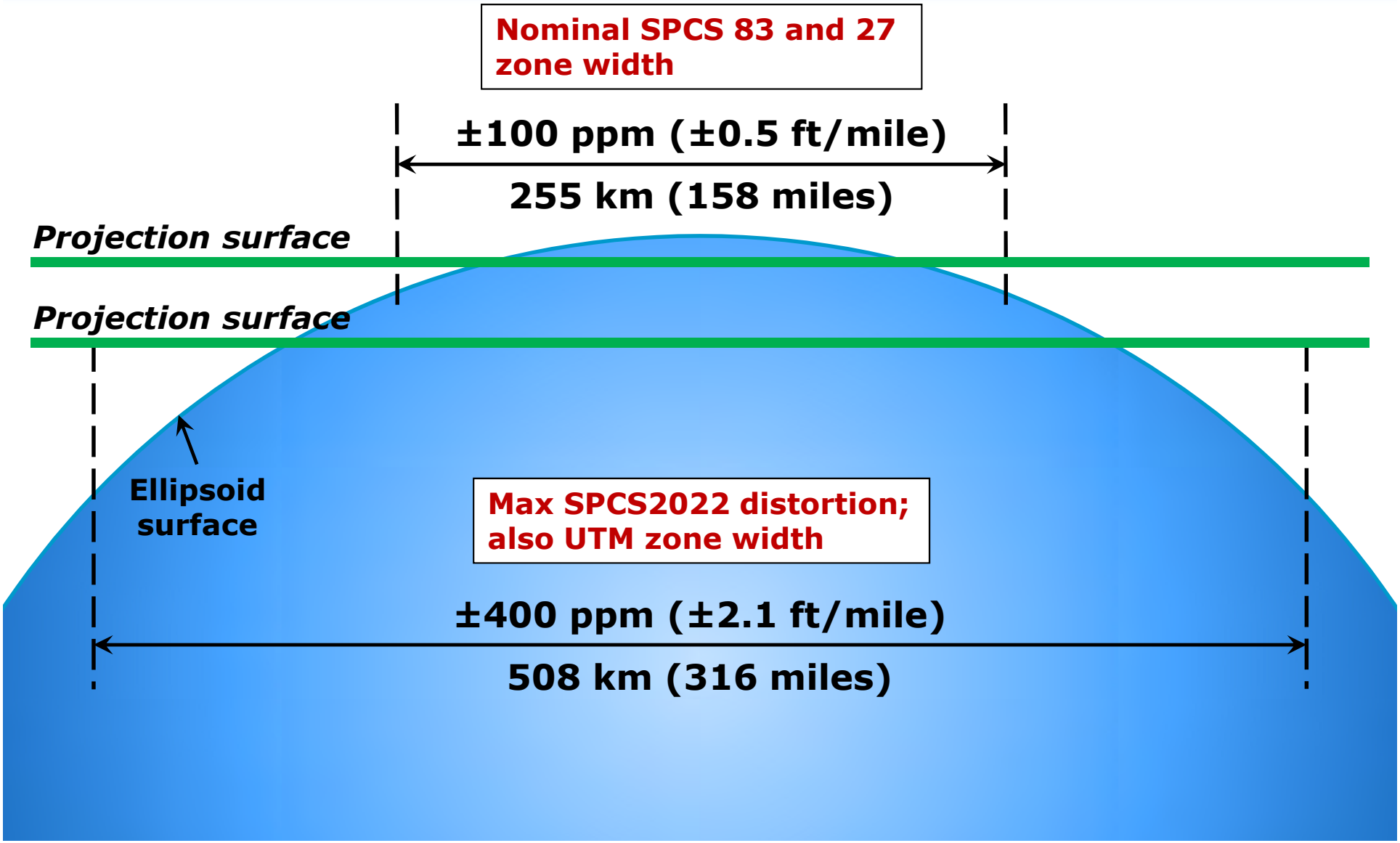
- **±20 ppm** = 2 cm/km = 0.1 ft/mile = 1 : 50,000
  Often used as "low distortion" design criterion (***at ground***)
- **±50 ppm** = 5 cm/km = 0.3 ft/mile = 1 : 20,000
  Minimum design criterion for SPCS2022 designs by NGS (***at ground***)
- **±100 ppm** = 10 cm/km = 0.5 ft/mile = 1 : 10,000
  "Nominal" maximum State Plane value (***on ellipsoid***)
  Can be much greater at topo surface
- **±400 ppm** = 40 cm/km = 2.1 ft/mile = 1 : 2,500
  Maximum design criterion for SPCS2022 zones (***at ground***)
  Maximum UTM value (***on ellipsoid***)

Nominal distortion criterion (on ellipsoid) for SPCS 27 and 83 zones (although greatly exceeded for some zones in SPCS 83).

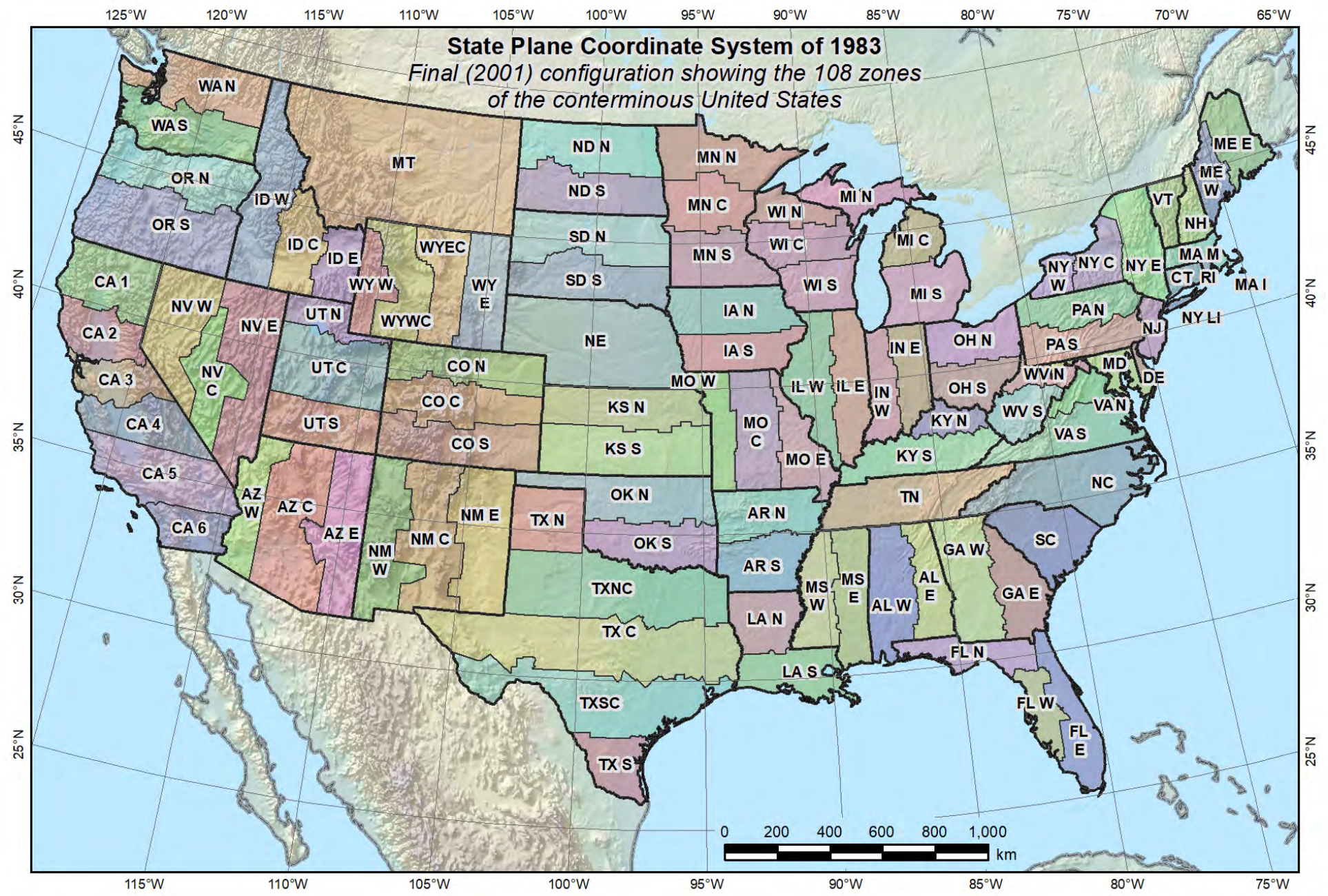

Linear distortion *with respect to topographic surface*
Topographic surface
Projection axis
Horizontal ground distance
> ellipsoid distance
and
> grid distance
Projection surface (secant)
Ellipsoid surface
Ellipsoid distance
Grid distance
> ellipsoid distance
< ground distance
This design approach used for SPCS 27 and 83 (minimizes distortion with respect to ellipsoid)
Ellipsoid distance
Grid distance
< ellipsoid distance
< ground distance

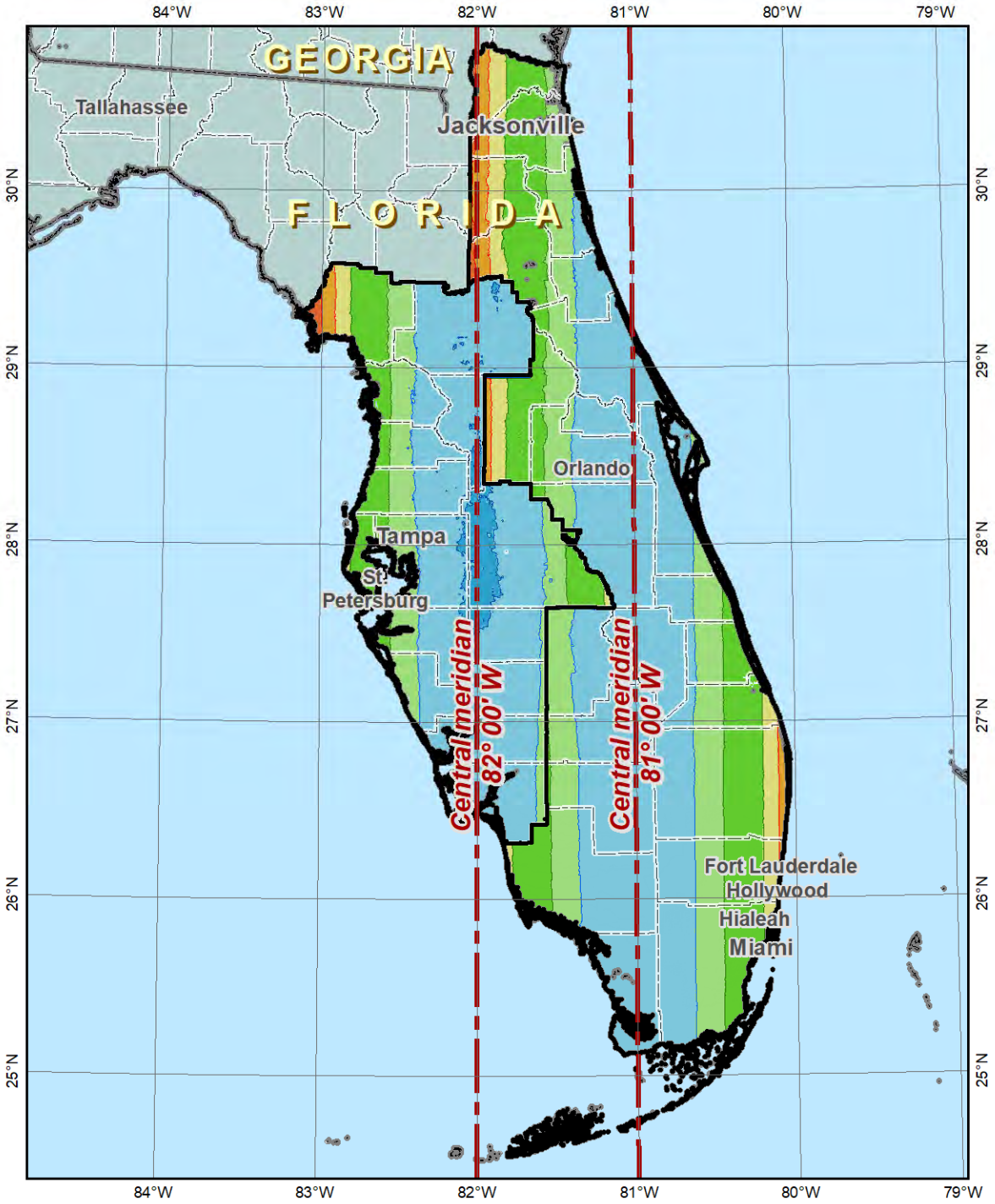

Linear distortion *with respect to topographic surface*
Topographic surface
Projection axis
Horizontal ground distance
> ellipsoid distance
and
> grid distance
Projection surface (non-intersecting)
Ellipsoid surface
Ellipsoid distance
Grid distance
> ellipsoid distance
≈ ground distance
This design approach will be used for SPCS2022 (minimizes distortion with respect to topography)

Zone widths for distortion due to curvature



Default SPCS2022 would look a lot like SPCS 83…





Existing SPCS 83 design:

Florida East and West zones combined

Transverse Mercator projections

Topographic ellipsoid height

Min	-29 m
Max	77 m
Mean	-14 m

Statistics are for area within zone boundary

SPCS 83 E&W zones

Axis scale **0.999 941…**

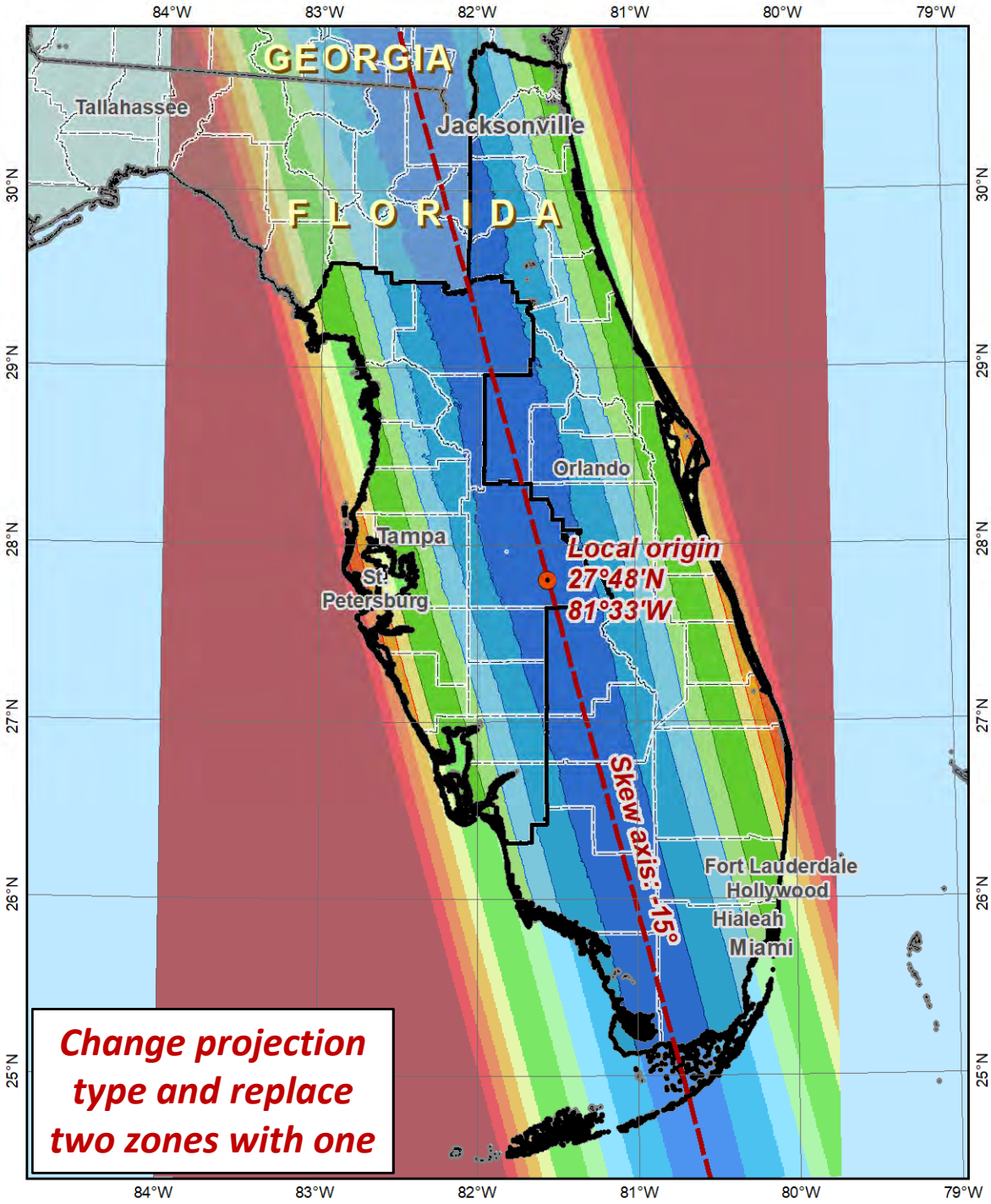
Linear distortion (ppm)

Min	-68
Max	+100
Range	168
Mean	-32

Linear distortion (parts per million)

<-120	to -60	to +60
to -120	to -40	to +80
to -100	±20 ppm	to +100
to -80	to +40	>+100

0 50 100 150 200 250 300 km



Preliminary SPCS2022 default design (alternative 1):
Florida East and West zones combined
Oblique Mercator projection

Topographic ellipsoid height

Min	-29 m
Max	77 m
Mean	-14 m

Statistics are for area within zone boundary

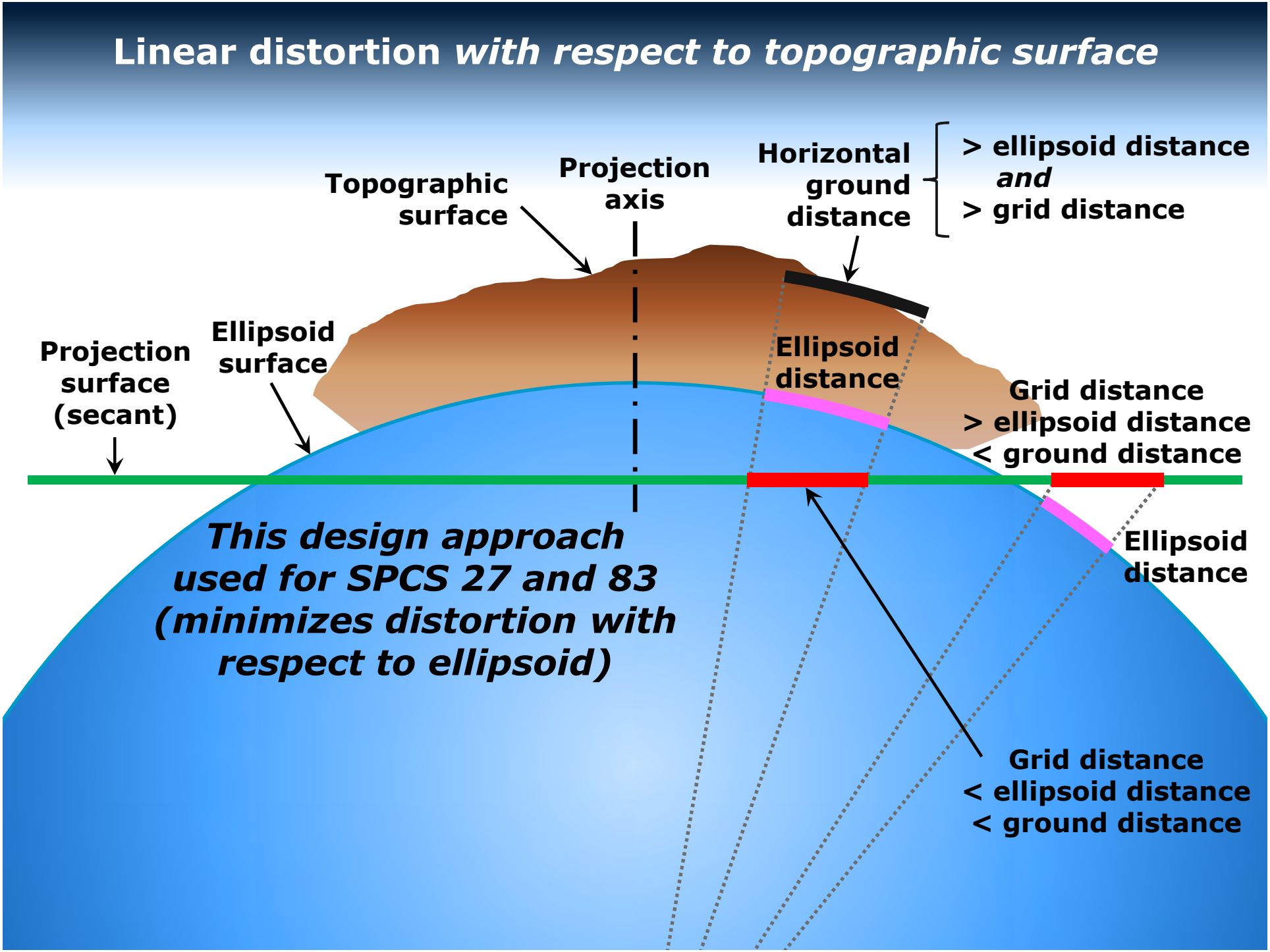
	SPCS 83 E&W zones	SPCS2022 one zone
Axis scale	0.999 941…	0.999 91
Linear distortion (ppm)		
Min	-68	-99
Max	+100	+97
Range	168	196
Mean	-32	-50

Linear distortion (parts per million)

<-120	to -60	to +60
to -120	to -40	to +80
to -100	±20 ppm	to +100
to -80	to +40	>+100

0 50 100 150 200 250 300 km

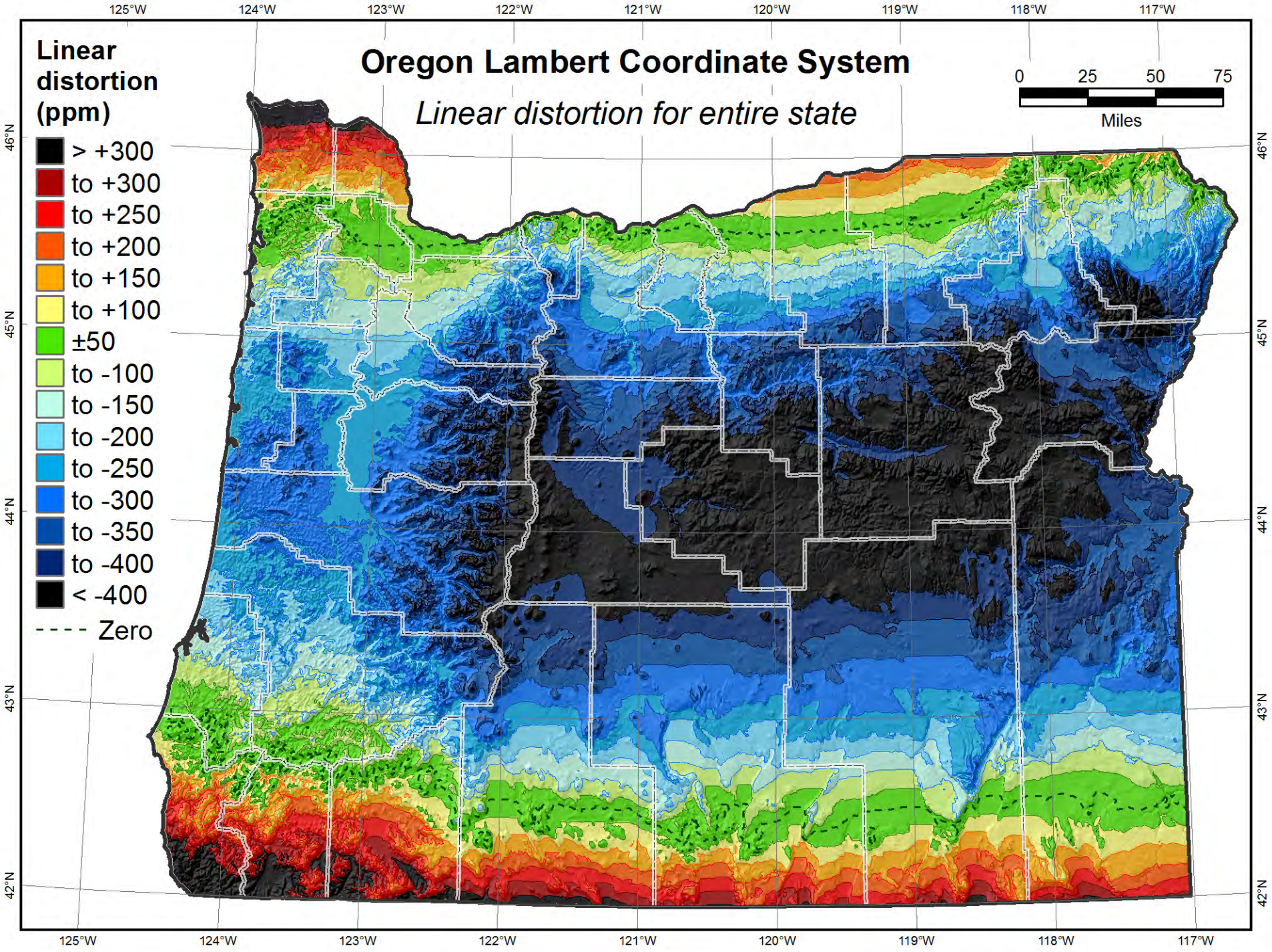
5	ppm	0.5	cm/km	0.026	ft/mile	1:200,000
10	ppm	1	cm/km	0.05	ft/mile	1:100,000
20	ppm	2	cm/km	0.1	ft/mile	1:50,000
50	ppm	5	cm/km	0.3	ft/mile	1:20,000
100	ppm	10	cm/km	0.5	ft/mile	1:10,000
200	ppm	20	cm/km	1.1	ft/mile	1:5,000
400	ppm	40	cm/km	2.1	ft/mile	1:2,500

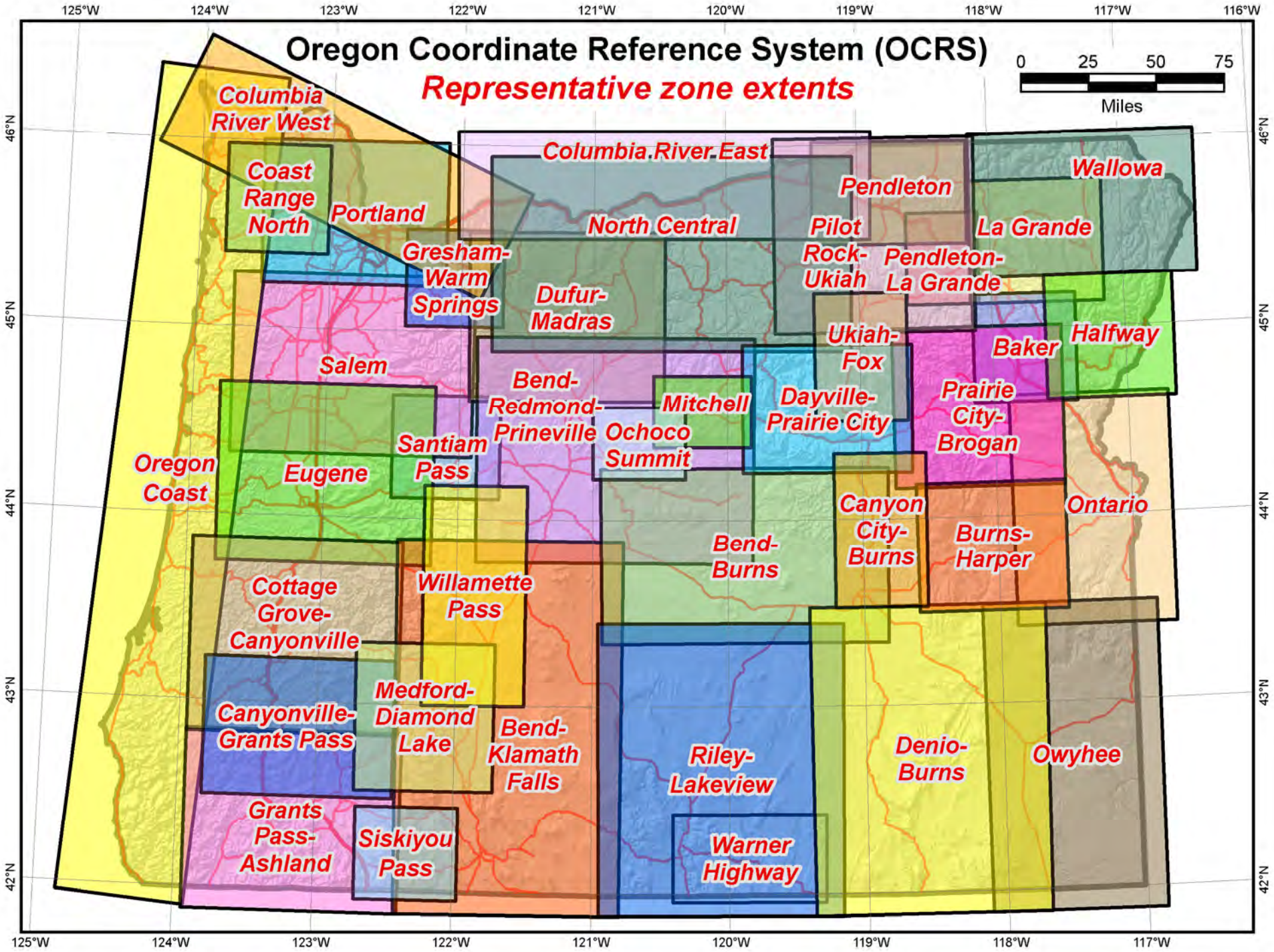

Linear distortion *with respect to topographic surface*
Topographic surface
Projection axis
Horizontal ground distance
> ellipsoid distance
and
> grid distance
Projection surface (secant)
Ellipsoid surface
Ellipsoid distance
Grid distance
> ellipsoid distance
< ground distance
This design approach used for SPCS 27 and 83 (minimizes distortion with respect to ellipsoid)
Ellipsoid distance
Grid distance
< ellipsoid distance
< ground distance

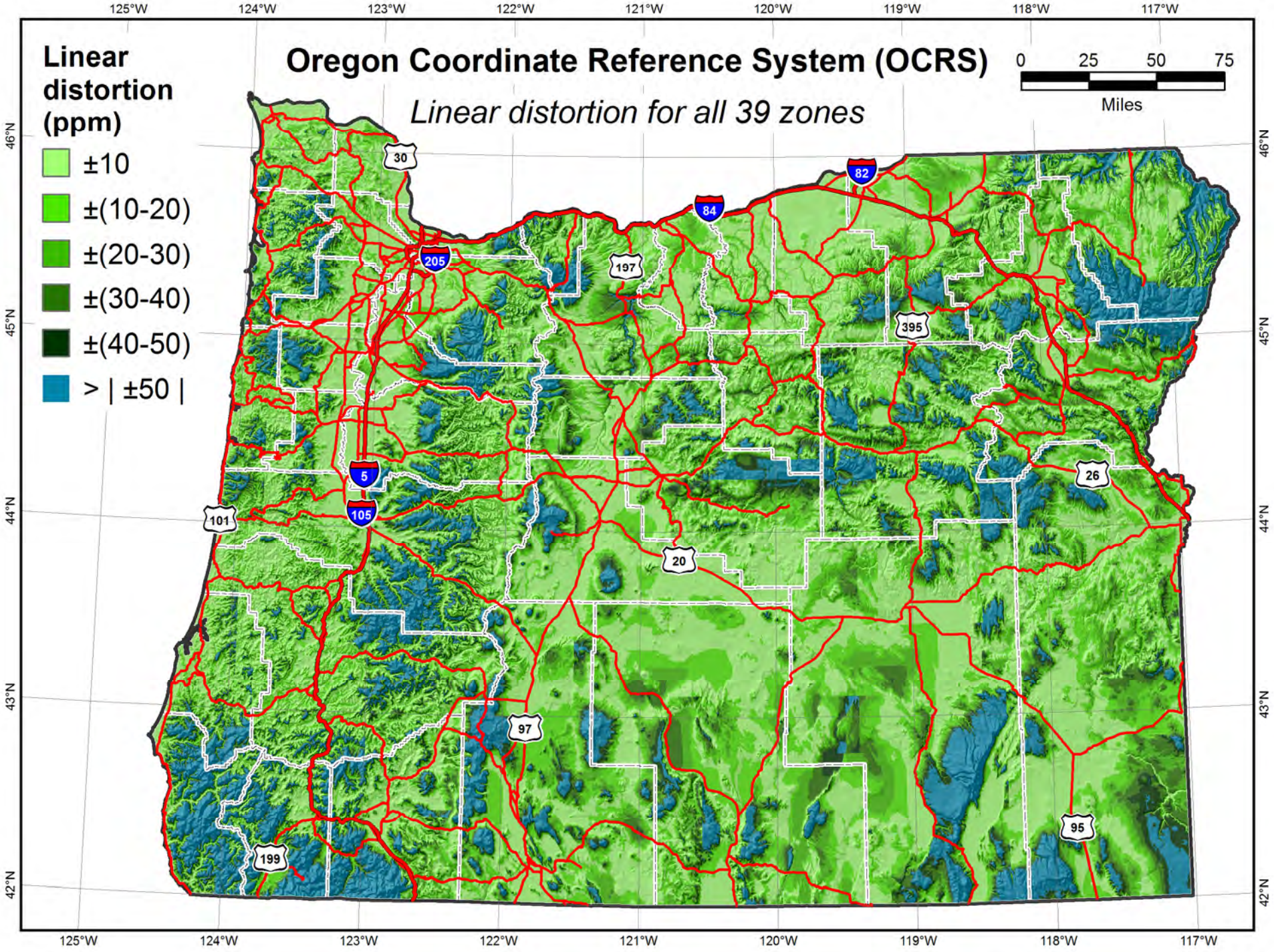
Statewide and "layered" zones

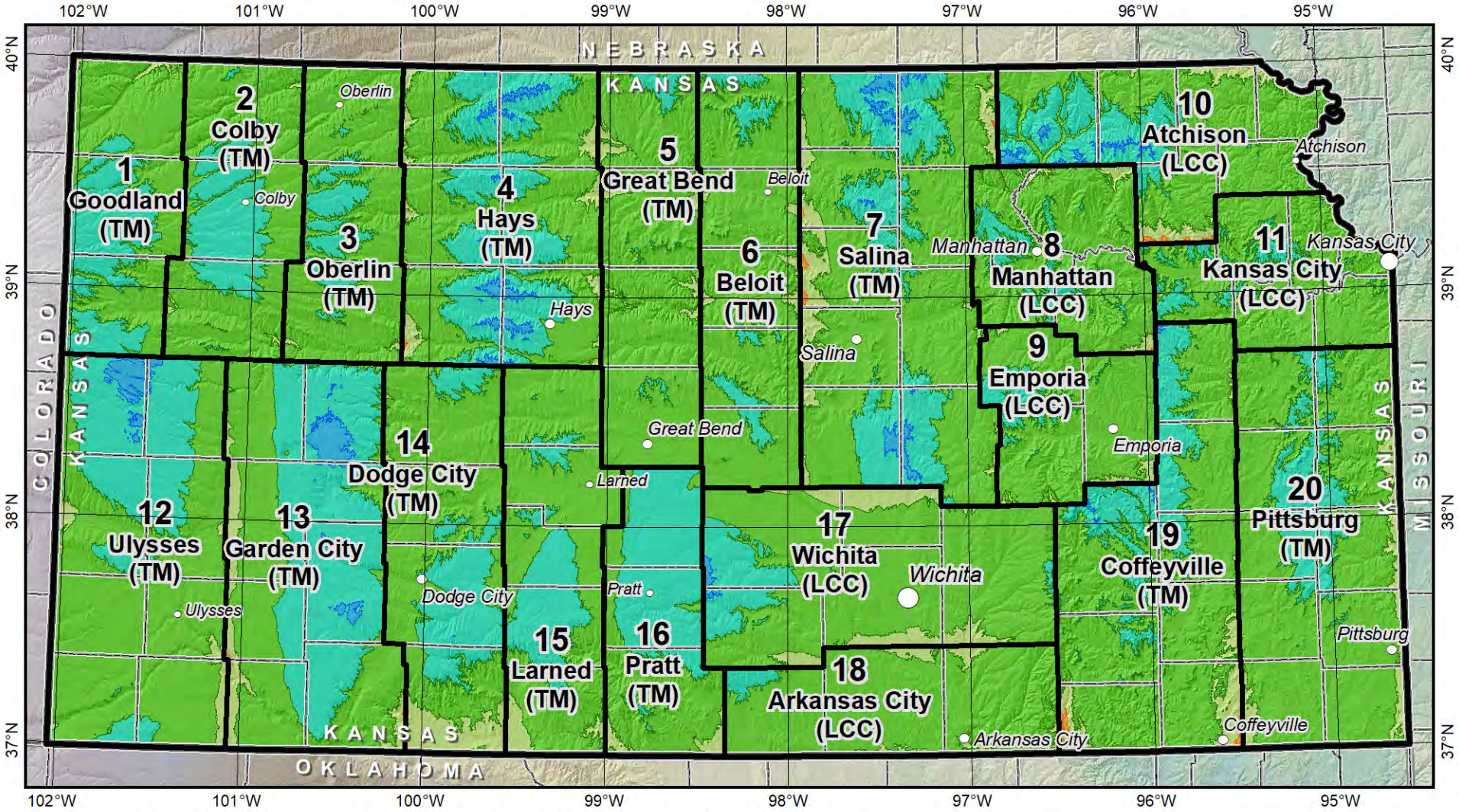
Policy § III.A.2.

- Limitations
  - Max of ***TWO*** layers: Statewide and sub-zones
  - If two layers, one ***MUST*** be statewide
  - Minimum subzone dimension > 50 km
- States often want statewide ***and*** small zones
  - *Statewide:* Single geometry required for state GIS
  - *Sub-zones:* Lower distortion for surveying/engineering
- Accommodates state needs, but with restrictions
  - Prevent poor design choices for statewide zones


Oregon Lambert Coordinate System
Linear distortion for entire state
Linear distortion (ppm)
> +300
to +300
to +250
to +200
to +150
to +100
±50
to -100
to -150
to -200
to -250
to -300
to -350
to -400
< -400
Zero
0 25 50 75
Miles
125°W
124°W
123°W
122°W
121°W
120°W
119°W
118°W
117°W
46°N
45°N
44°N
43°N
42°N


Oregon Coordinate Reference System (OCRS)
Representative zone extents
0 25 50 75
Miles
125°W
124°W
123°W
122°W
121°W
120°W
119°W
118°W
117°W
116°W
46°N
45°N
44°N
43°N
42°N
Columbia River West
Columbia River East
Coast Range North
Portland
North Central
Pendleton
Wallowa
La Grande
Pilot Rock-Ukiah
Pendleton-La Grande
Gresham-Warm Springs
Dufur-Madras
Ukiah-Fox
Baker
Halfway
Salem
Bend-Redmond-Prineville
Mitchell
Dayville-Prairie City
Prairie City-Brogan
Santiam Pass
Ochoco Summit
Oregon Coast
Eugene
Canyon City-Burns
Ontario
Bend-Burns
Burns-Harper
Cottage Grove-Canyonville
Willamette Pass
Medford-Diamond Lake
Canyonville-Grants Pass
Bend-Klamath Falls
Riley-Lakeview
Denio-Burns
Owyhee
Grants Pass-Ashland
Siskiyou Pass
Warner Highway


Oregon Coordinate Reference System (OCRS)
Linear distortion for all 39 zones
Linear distortion (ppm)
±10
±(10-20)
±(20-30)
±(30-40)
±(40-50)
> | ±50 |
0 25 50 75
Miles
125°W
124°W
123°W
122°W
121°W
120°W
119°W
118°W
117°W
46°N
45°N
44°N
43°N
42°N
30
82
84
205
197
395
5
105
101
26
20
97
199
95



Kansas Regional Coordinate System (KRCS)

All zones referenced to the North American Datum of 1983

Statewide Distortion Statistics

		Area of the state that is:
Minimum:	-26.9 ppm	within ±10 ppm = 68.330%
Maximum:	+26.0 ppm	within ±20 ppm = 98.802%
Mean:	-4.0 ppm	within ±25 ppm = 99.998%
Std dev:	±8.2 ppm	

Linear Distortion (parts per million)

- <-25 ppm (0.16 ft/mile)
- -20 to -25 ppm
- -10 to -20 ppm
- ±10 ppm (0.05 ft/mile)
- +10 to +20 ppm
- +20 to +25 ppm
- >+25 ppm (0.13 ft/mile)

Projection Types

TM = Transverse Mercator
LCC = Lambert Conformal Conic

0 25 50 75 100 Miles

What Can You Do to Get Ready for 2022?

Understand the magnitude of changing positions and heights for your clients and community

Watch for upcoming NGS status reports/webinars
www.geodesy.noaa.gov/corbin/calendar.shtml

Watch for upcoming NGS status reports/webinars
https://www.ngs.noaa.gov/datums/newdatums/TrackOurProgress.shtml

NGS plans on new State Plane Coordinates using the same geometric parameters as NAD83 (mostly)

What Can You Do to Get Ready for 2022?

NGS Webinar Series

Building a State Plane Coordinate System for the Future

Presented by Michael Dennis, National Geodetic Survey

April 12, 2018 at 2:00 pm EDT

Register For This Webinar

Webinar Description:
NGS has begun defining the State Plane Coordinate System of 2022 (SPCS2022). This webinar builds on the March 8 SPCS2022 webinar by going into more detail about how SPCS2022 will be created, including the role of NGS customers in the process, and changes from how the SPCS was defined in the past.

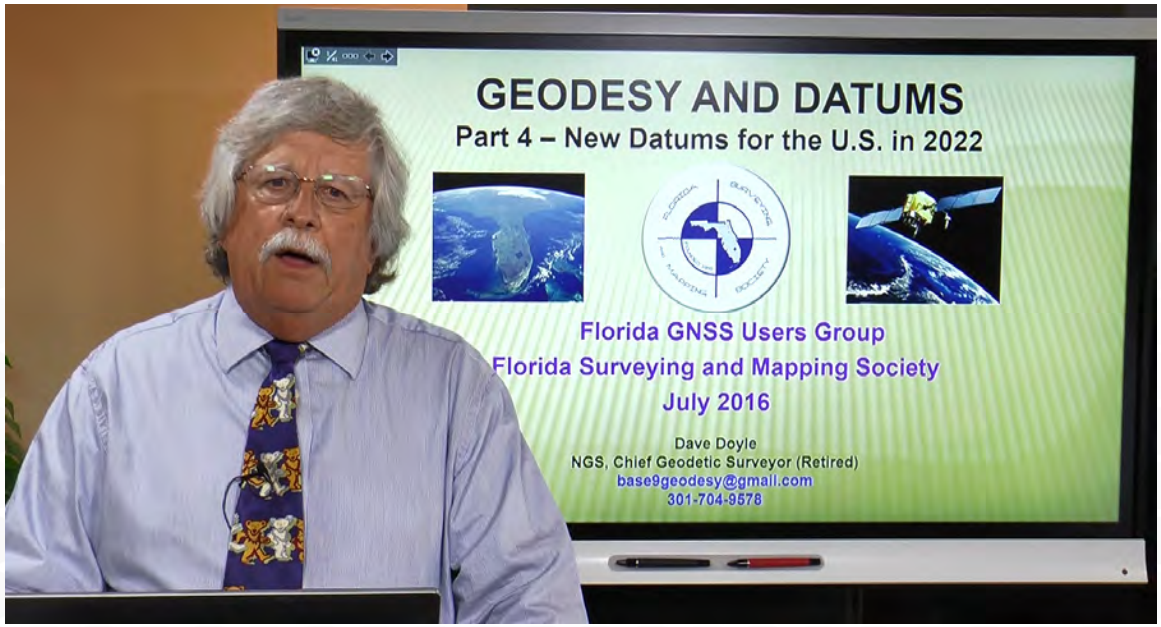
Technical Content Rating:
Intermediate - Some prior knowledge of the topic is helpful.

What Can You Do to Get Ready for 2022?

Videos – several very good 1 hour videos on Datums, Surfaces, and the new 2022 Datum change presented by Dr. David Doyle, retired chief of the National Geodetic Survey (NGS).

Geospatial Users Group – www.youtube.com

search for “Geospatial Users Group”

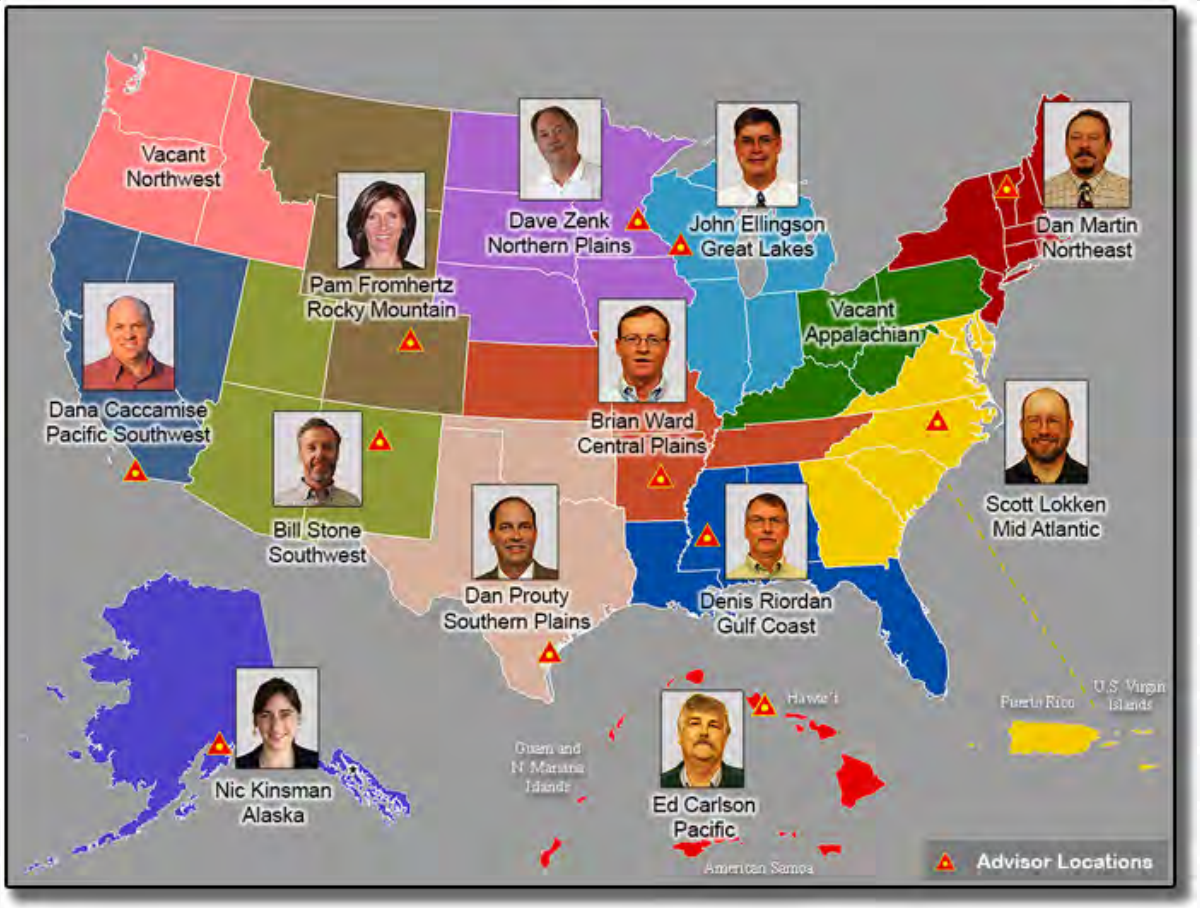


What Can You Do to Get Ready for 2022?

Communicate your issues directly to NGS

NGS Local Regional Advisor -

https://www.ngs.noaa.gov/ADVISORS/index.shtml



Randy Tompkins, PSM, PLS

Geomatics Project Manager

Surveyor, Hydrographer, & Geodesist

DRMP, Inc.
Jacksonville, FL
(904) 641-0123
rtompkins@drmp.com

Education

Bachelor of Science in Geomatics, University of Florida, (1999).

Licensure

FL Professional Surveyor and Mapper #6503
North Carolina Professional Land Surveyor #5042

Memberships

Society of American Military Engineers
Geospatial Working Group (SAME)
Florida Surveying and Mapping Society (FSMS)
Board of Directors – 2016 to Present
Geospatial Users Group (FSMS)
The American Association of Geodetic Surveying (AAGS)
The Hydrographic Society of America (THSOA)
National Society of Professional Surveyors (NSPS)