Preparing for New Datums and New SPCS

PSLS Wednesday Webinar
March 2023

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Organizational Structure

-Department of Commerce (DoC)

(~47,000 employees)

↓

-National Oceanic and Atmospheric Administration (NOAA)

↓

-National Ocean Service (NOS)

↓

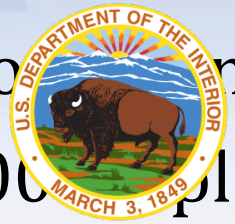
-National Geodetic Survey (NGS)

(~175 employees)

Where's USGS, We're NGS

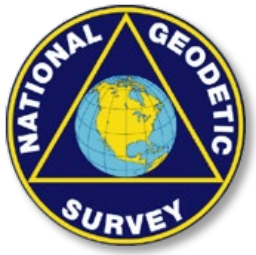
-Department of Commerce (DoC)

(~47,000 employees)



-National Oceanic and Atmospheric Administration (NOAA)

-National Ocean Service (NOS)



-National Geodetic Survey (NGS)

(~175 employees)

≠

NGS Mission

To define, maintain and provide access to the **National Spatial Reference System (NSRS)** to meet our Nation's economic, social, and environmental needs.

"Modernizing" the NSRS means:

- Updating ***all*** NSRS coordinates
  - Replace existing datums with new datums
  - Replacing existing State Plane with new State Plane
  - Accounting for coordinates changing with time
- Improving NGS products and services
- Simplifying customer contributions
- Making the NSRS:
  - ***More*** accurate
  - ***More*** accessible
  - ***More*** efficient

Rollout in 2025

National Spatial Reference System (NSRS)

A consistent coordinate system that defines:

- latitude
- longitude
- height
- scale
- orientation
- gravity

…and their time variants

throughout the United States.

National Spatial Reference System (NSRS)

These items ARE part of the NSRS

Horizontal Datums (aka Geometric Reference Frames)	Vertical Datums	Great Lakes Datums	Geoid Models	Transformations and Conversions
NAD83	NAVD88	IGLD85	GEOID18	NADCON
NAD27	NGVD29	IGLD55	GEOID12B	VERTCON
USSD	VIVD09		GEOID09	
	GUVD04		GEOID06	SPCS83
	NMVD03		GEOID03	SPCS27
	ASVD02		GEOID99	
	PRVD02		GEOID96	
			ALASKA94	
			GEOID93	
			GEOID90	

~~National Spatial Reference System (NSRS)~~

These items are NOT part of the NSRS

Horizontal Datums (aka Geometric Reference Frames)	Vertical Datums	Geoid Models	Transformations and Conversions
WGS84	IHRS (by IAG)	OSU91A	CorpsCon
WGS72		EGM96	Appendix B.6 of DMA TR 8350.2 (WGS 84)
ITRF (Intl. Terrestrial Reference Frame)		EGM2008	Oregon Coordinate Reference System (ORCS)
IGS (Intl. GNSS Service reference frame)			Kansas Regional Coordinate System

Hyperlink to ITRF station map

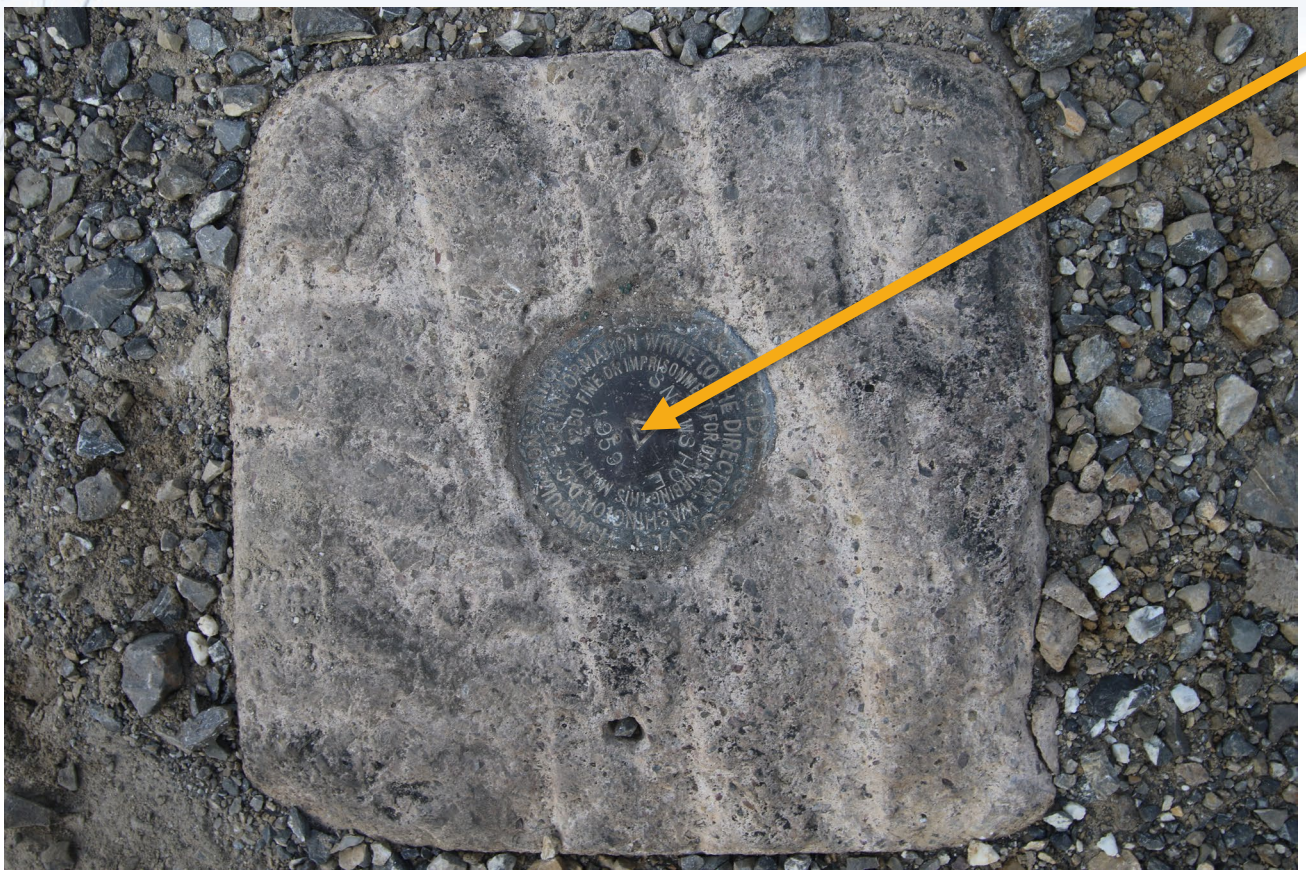
Maintaining the NSRS

- NSRS ***does*** get updated over the years.
  - NAD27→NAD83 … NGVD29→NAVD88
- **Federal Register** (federalregister.gov)
  - official indication of changes and updates
  - via a **Federal Register Notice (FRN)**
  - FRN affirmed NAD 83 in 1989 (54 FR 25318)
    - Federal Register Vol 58, No. 120
  - FRN affirmed NAVD 88 in 1993 (58 FR 34245)
    - Federal Register Vol 54, No. 113
  - ***Same for forthcoming new datums***

Geodetic Control – Terminology

Passive Control

- *All marks* are **passive**—they sit there and hold a **point**

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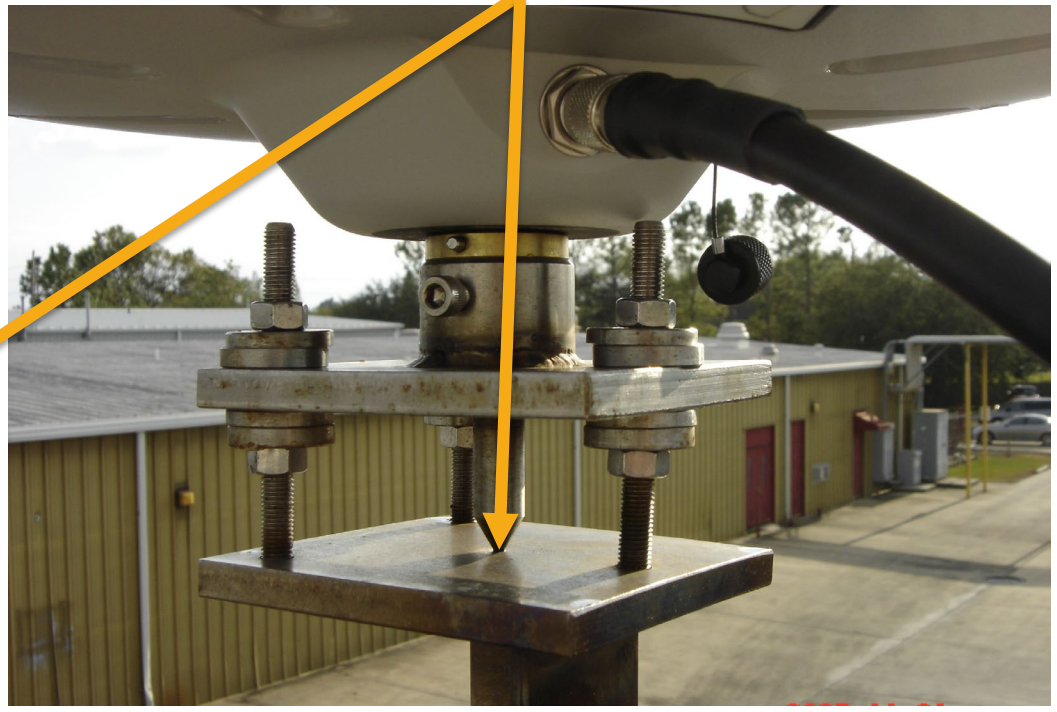
TURBINE
MEANS

Geodetic Control – Terminology

Active Control

- *Some marks* have permanently installed equipment that enables nearly continuous observations

(they still sit there and hold a **point**)



Active Control

Geodetic Control – Terminology

Active vs. Passive Control

Passive – setting up your RTK Base on existing geodetic control (e.g. Datasheet) while collecting with RTK Rover

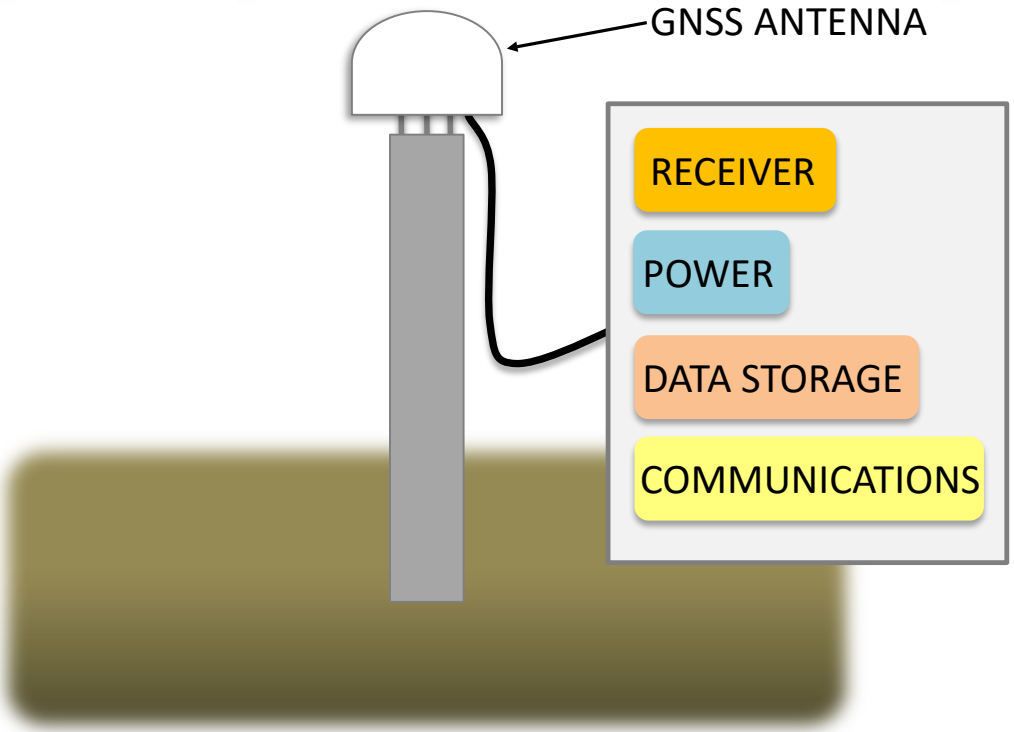
Active – setting up your RTK Base to log data while collecting with RTK Rover then processing Base data via OPUS; or collecting with RTN Rover

My point: *surveying is still surveying*

Active Control

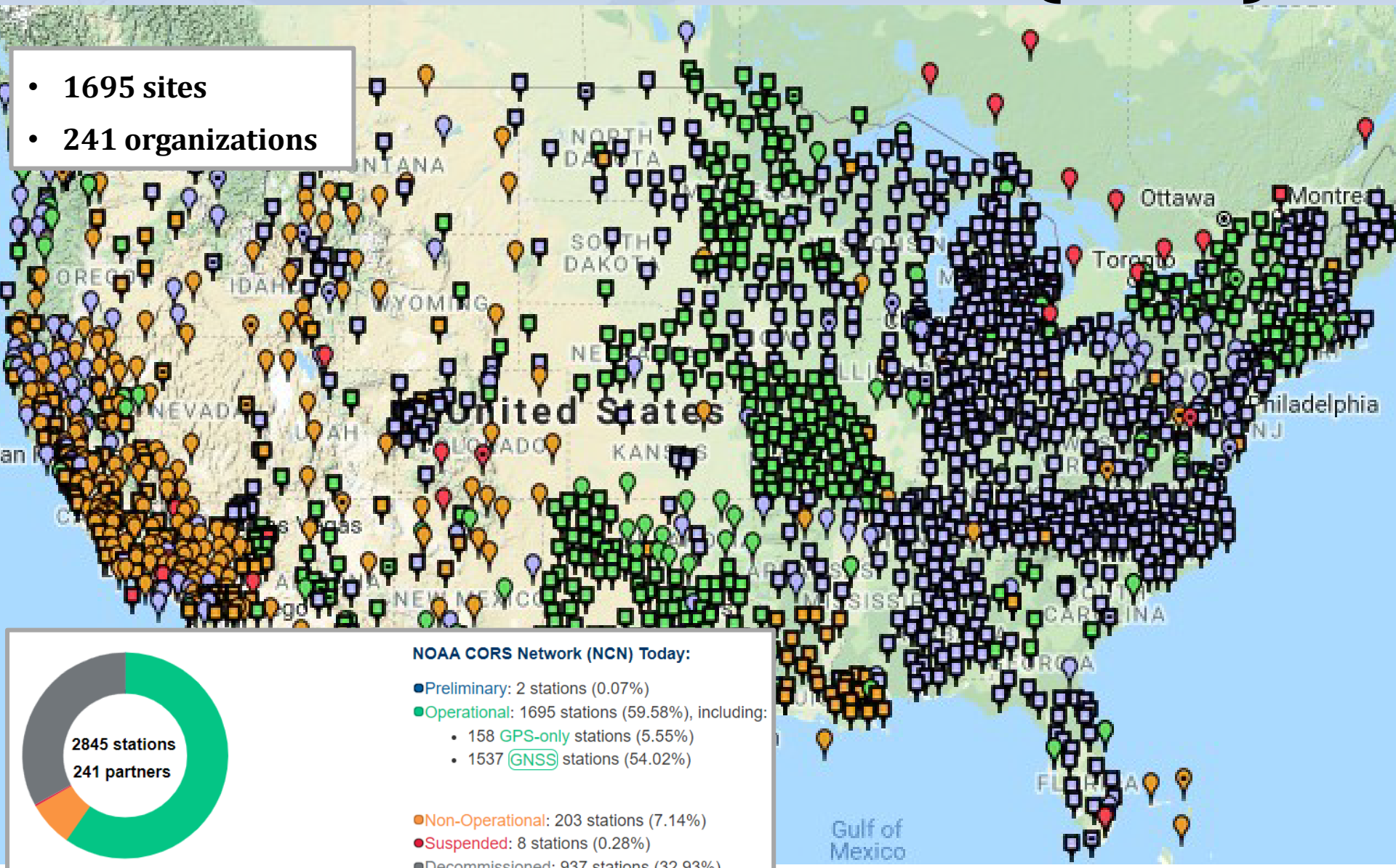
CORS

Continuously Operating Reference Station



NOAA CORS Network (NCN)

- 1695 sites
- 241 organizations



NOAA CORS Network (NCN) Today:

- Preliminary: 2 stations (0.07%)
- Operational: 1695 stations (59.58%), including:
  - 158 GPS-only stations (5.55%)
  - 1537 GNSS stations (54.02%)
- Non-Operational: 203 stations (7.14%)
- Suspended: 8 stations (0.28%)
- Decommissioned: 937 stations (32.93%)

CORS Networks

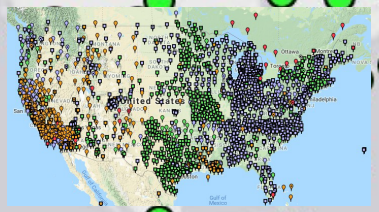
- **Global**: International GNSS Service (IGS) Network

- **NSRS**: NOAA CORS Network (NCN)

- **Regional**: State or Private CORS Networks

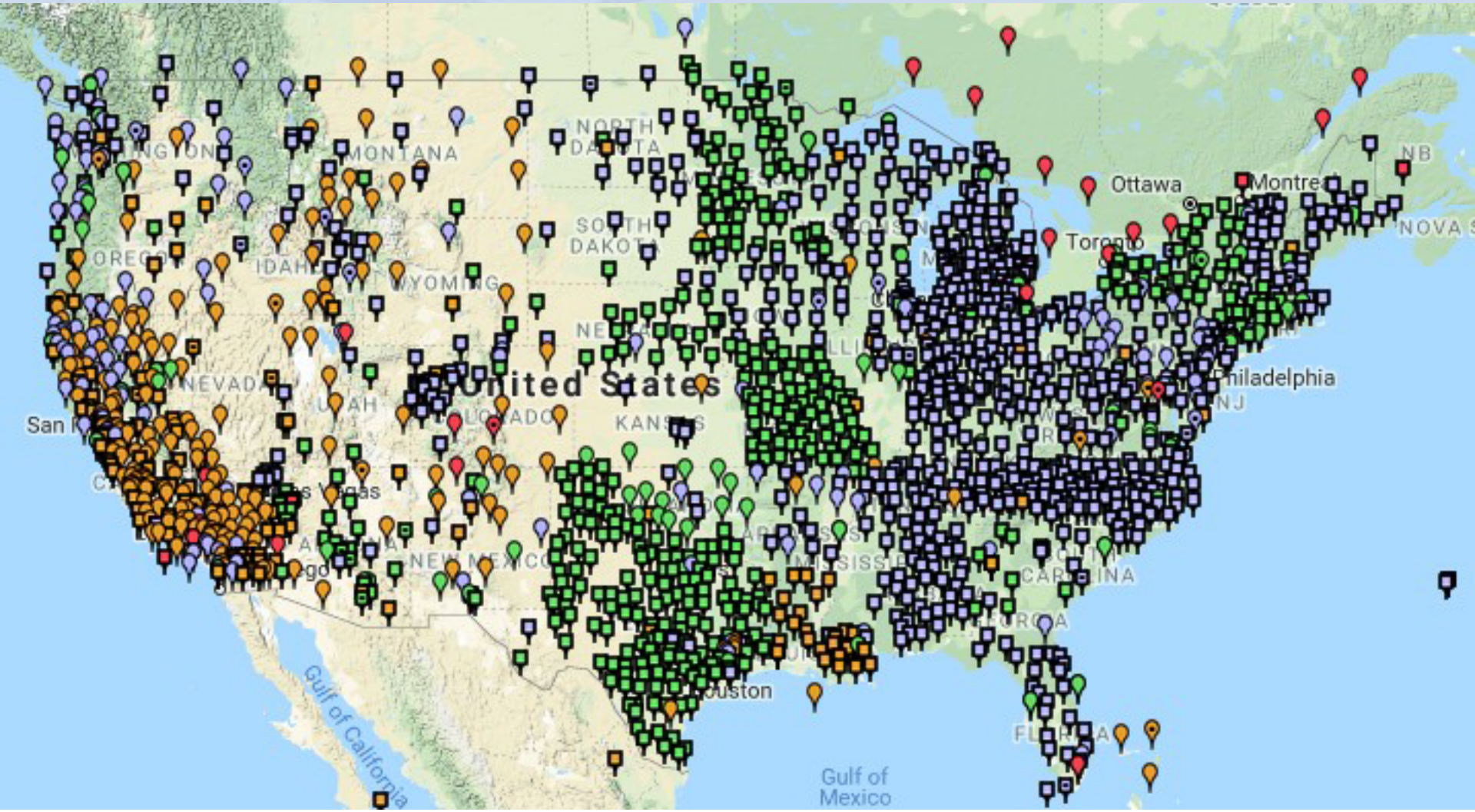
They're all *semi*-coupled, not 100% overlap.

IGS Network

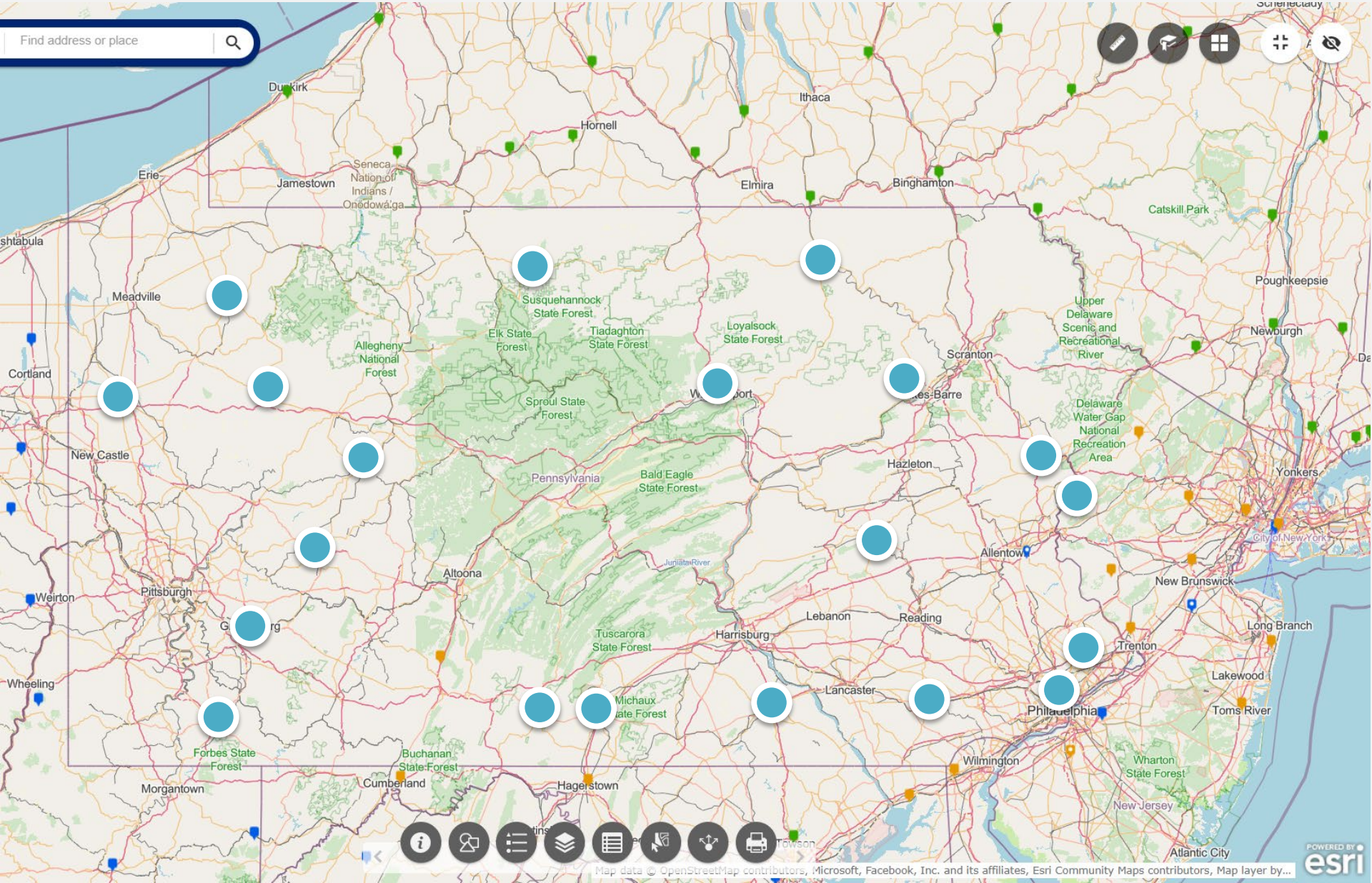


Source: https://www.igs.org/maps/#station-map

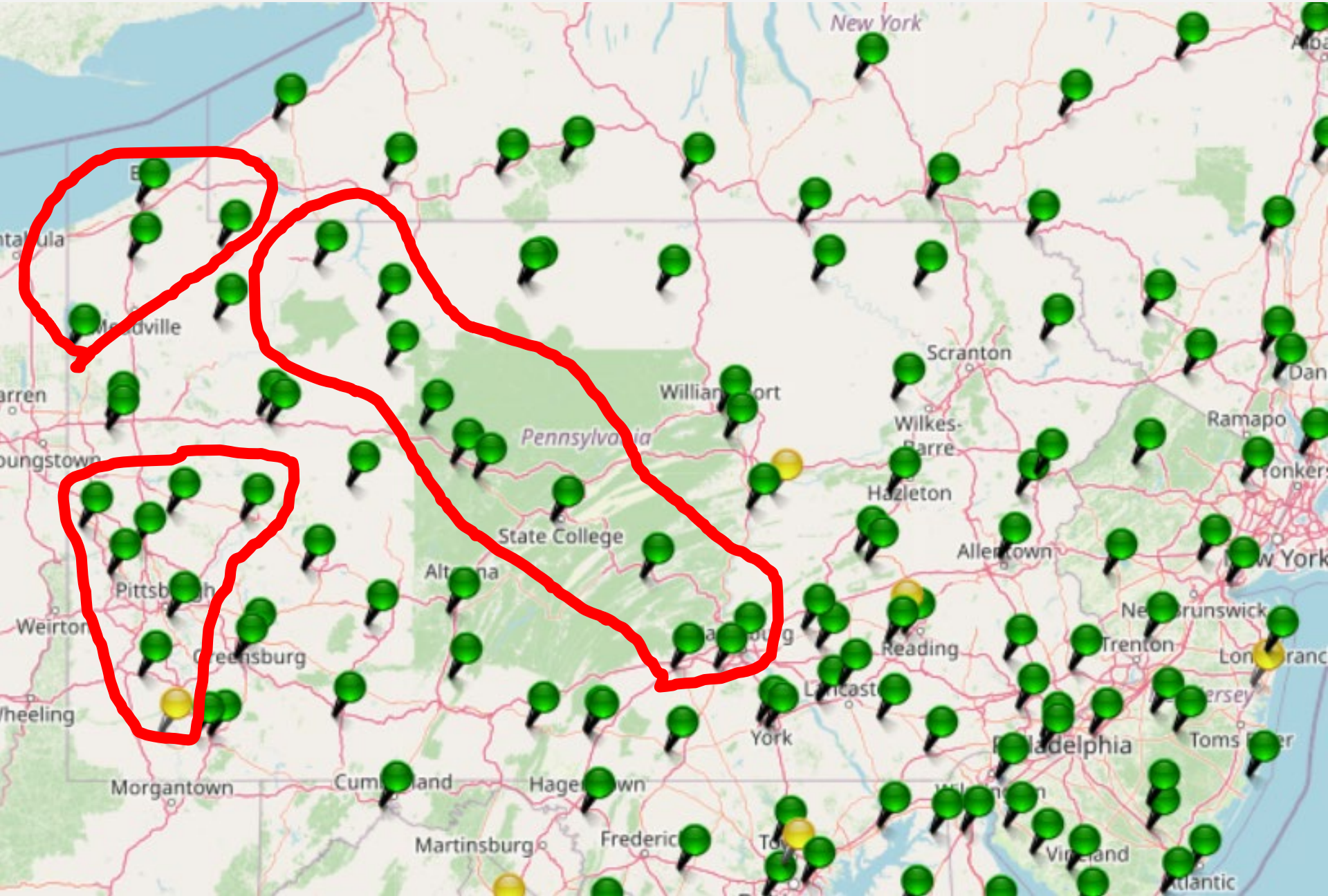
NOAA CORS Network (NCN)



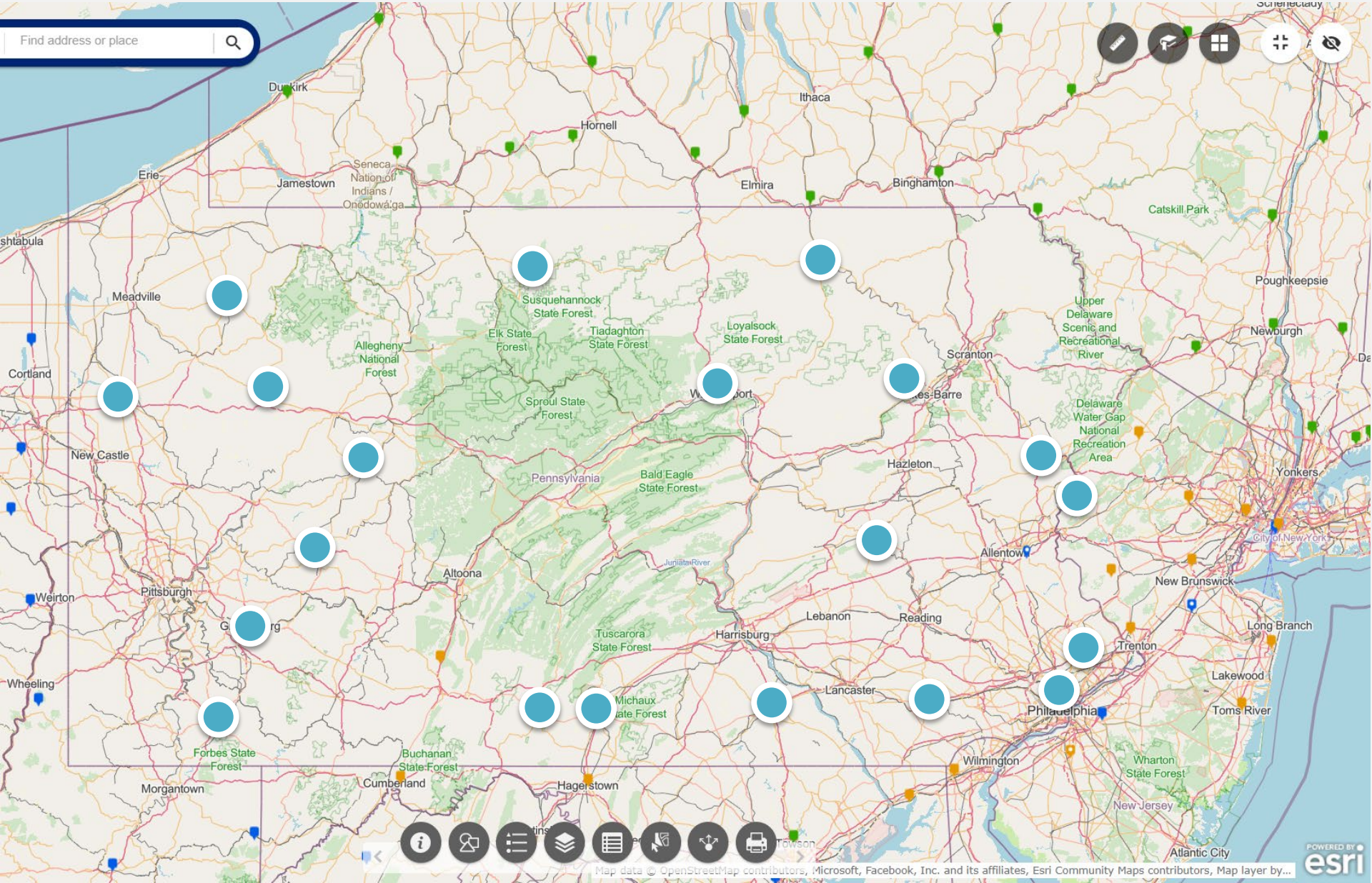
NOAA CORS Network (NCN) in PA



KeyNetGPS CORS Network



NOAA CORS Network (NCN) in PA



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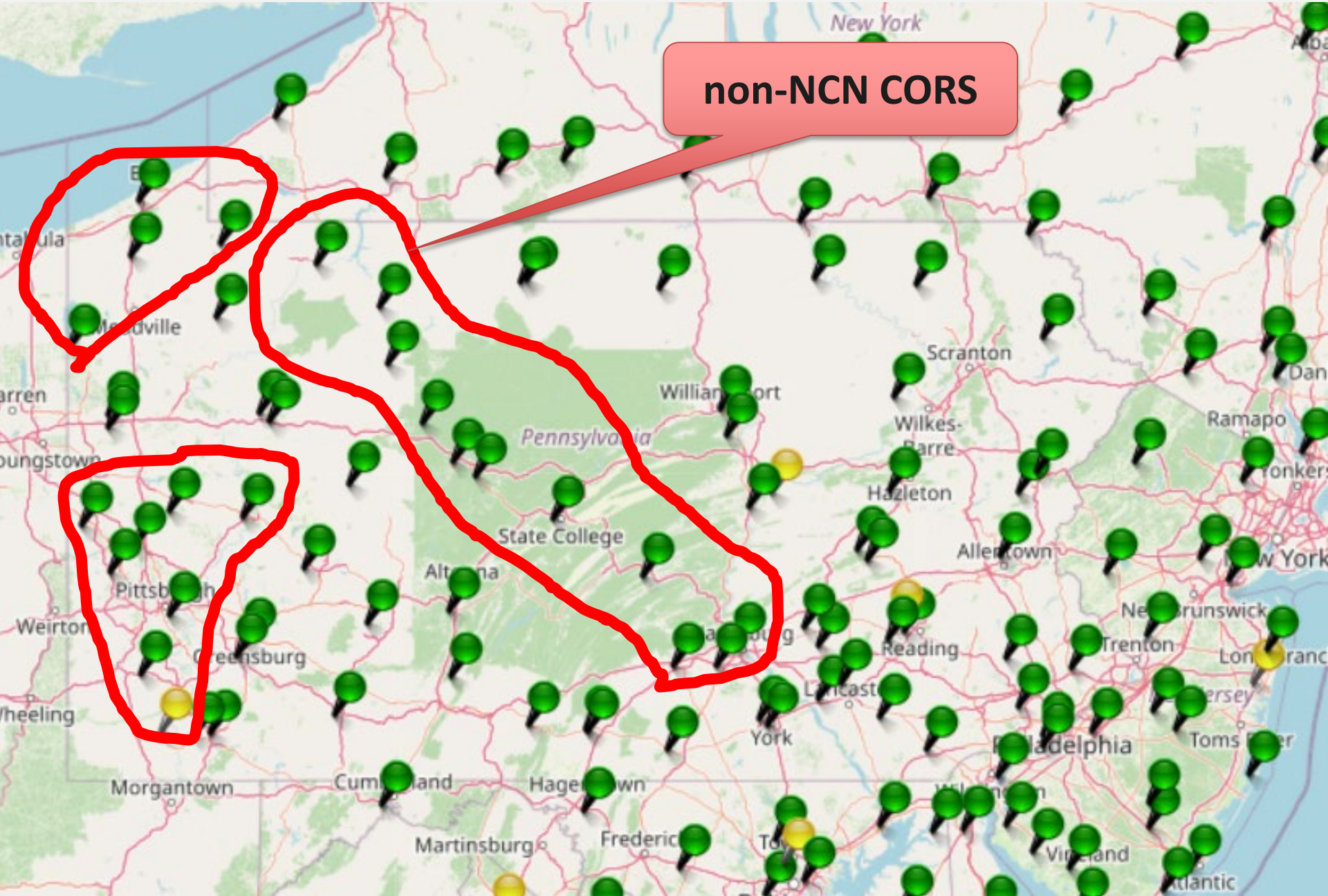


NGS Mission

To define, maintain and provide *access to* the

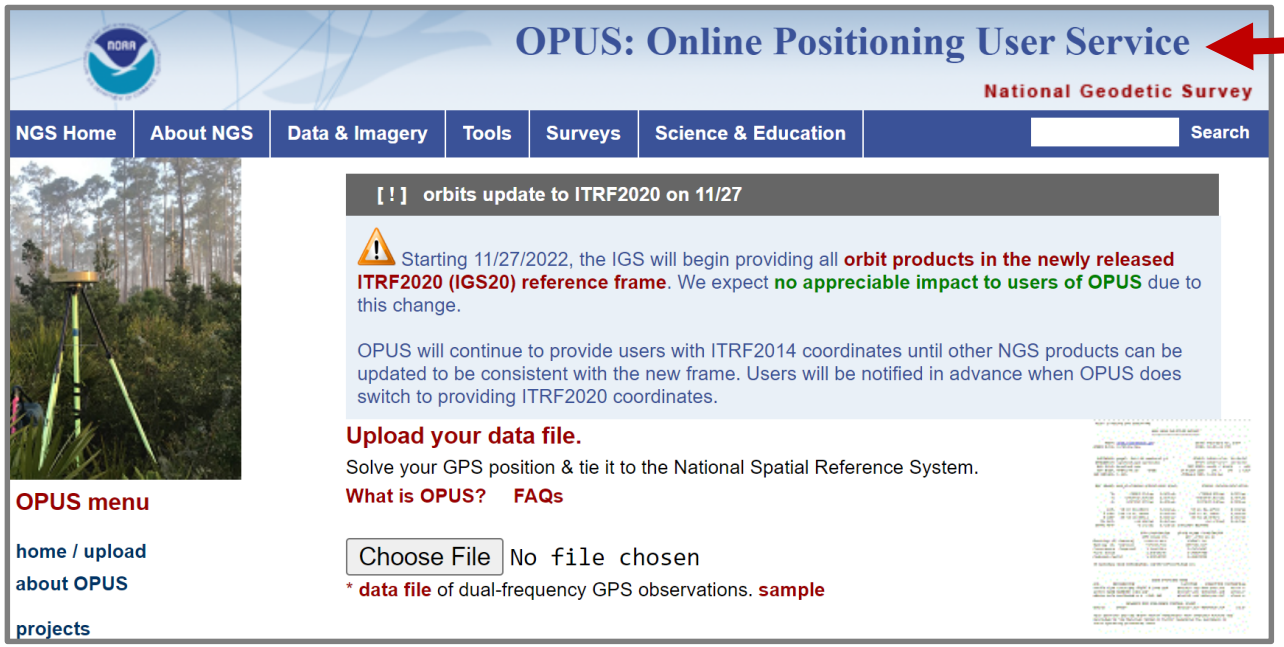
National Spatial Reference System (NSRS)

to meet our Nation's economic, social, and environmental needs.

access... ? = traditionally → passive control (marks/disks/objects)

= modern and future → active control (NCN CORS)

via OPUS



North American Vertical Datum of 1988

NAVD88

will be replaced by

North American-Pacific Geopotential Datum of 2022

NAPGD2022

(pronounced: nap-jee-dee)

NAVD88 geoids versus NAPGD2022 geoids

Two types of geoid models

- **Gravimetric**
- **Hybrid**

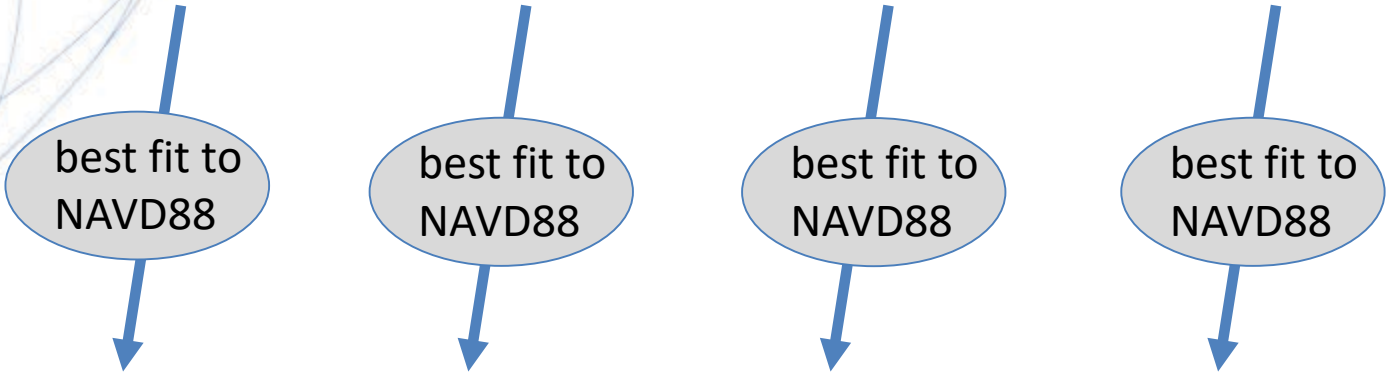
Gravimetric → Hybrid

- **Gravimetric** geoid is created from "scratch" with various types of gravity data
  - USGG2003, USGG2009, USGG2012, xGEOID19

- **Hybrid** geoid is simply a gravimetric geoid then best fit some vertical datum… like NAVD88
  - GEOID03, GEOID09, GEOID12B, GEOID18

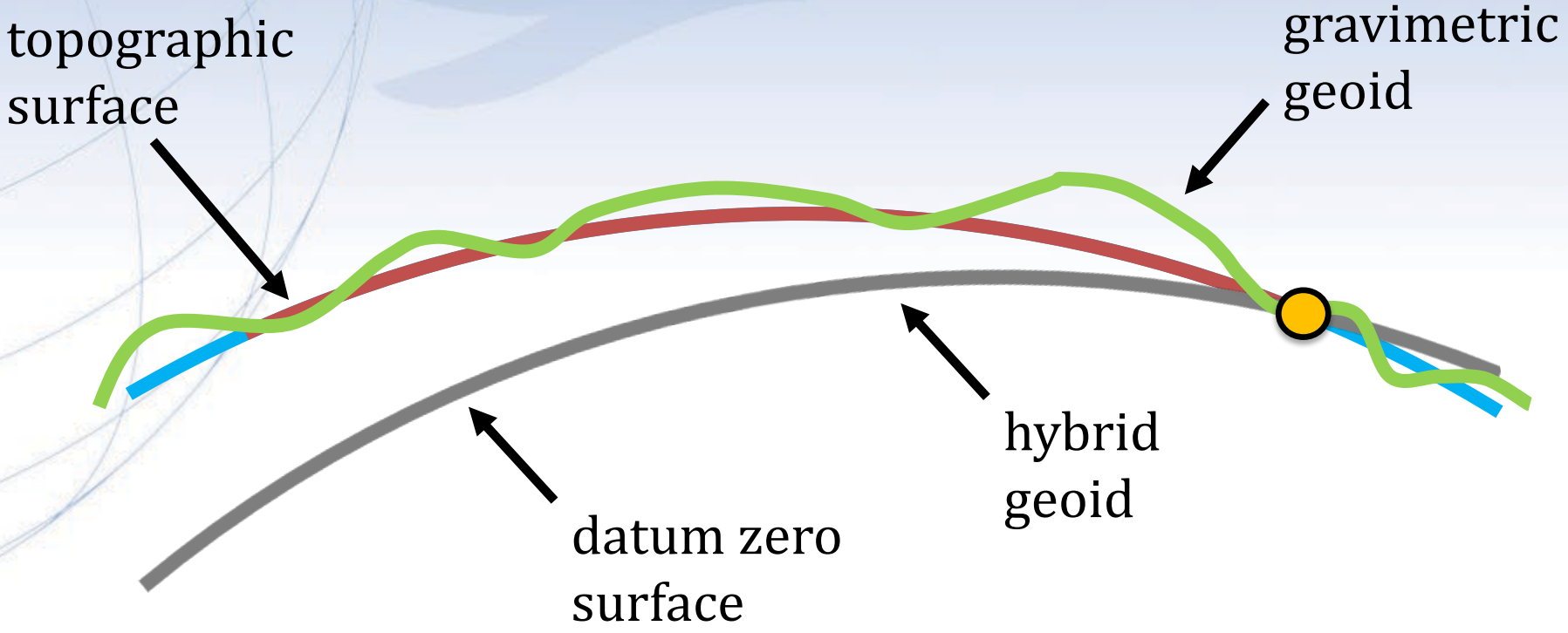
Gravimetric → Hybrid

- USGG2003, USGG2009, USGG2012, xGEOID19



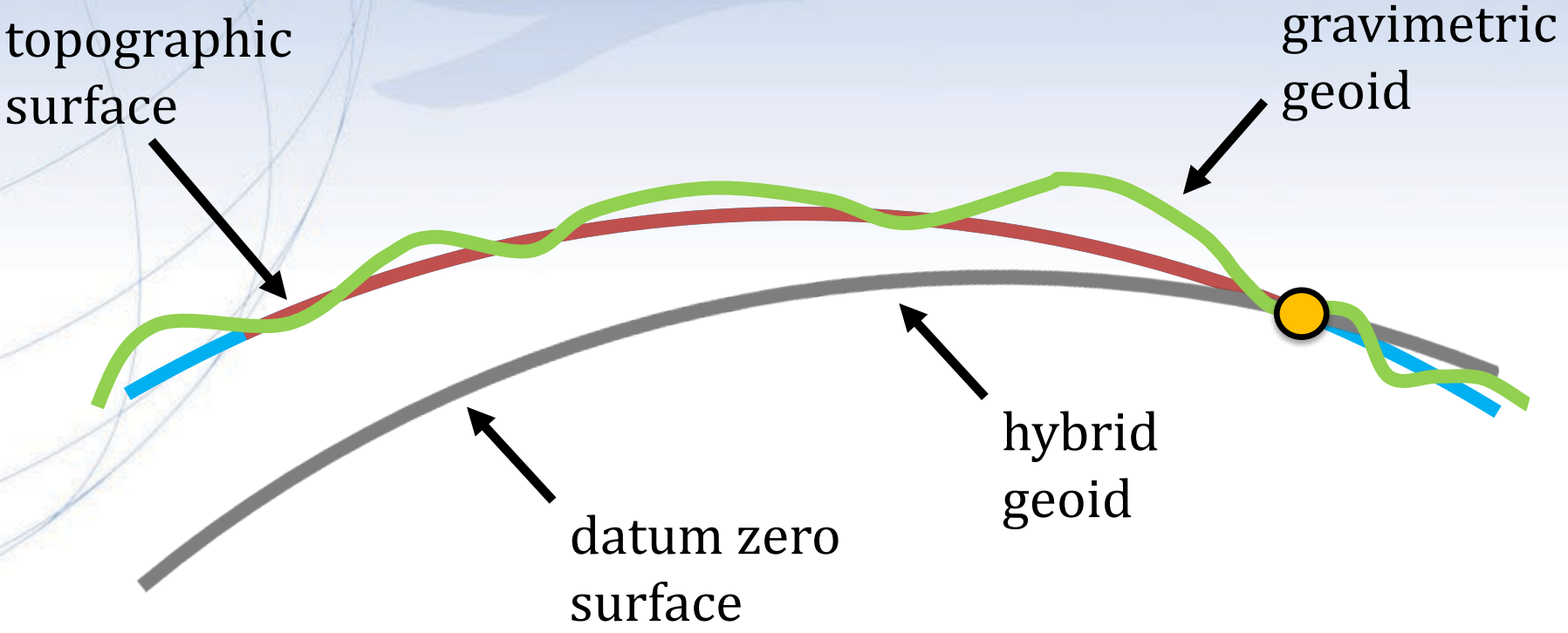
- GEOID03, GEOID09, GEOID12B, GEOID18

Gravimetric vs. Hybrid Geoid



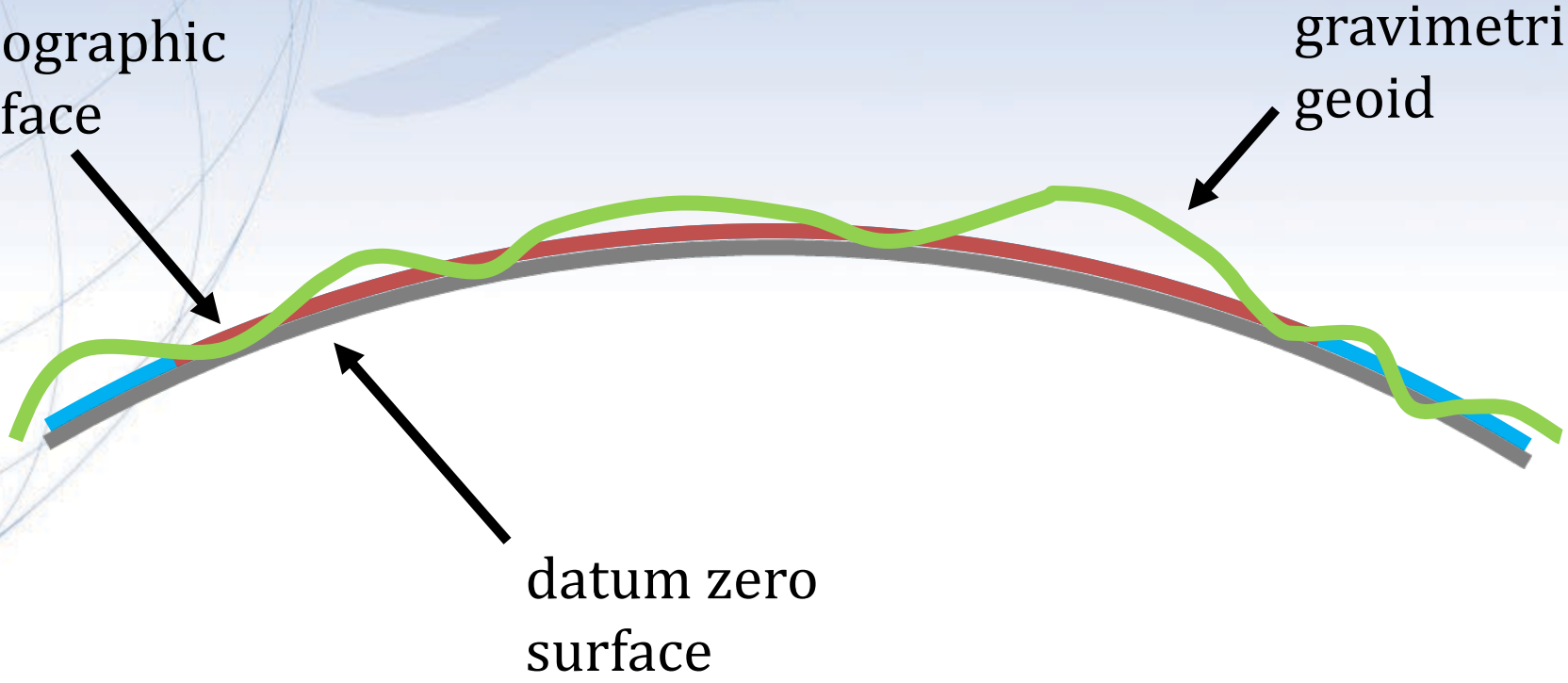
Concept

NAVD88 uses a Hybrid Geoid



Concept

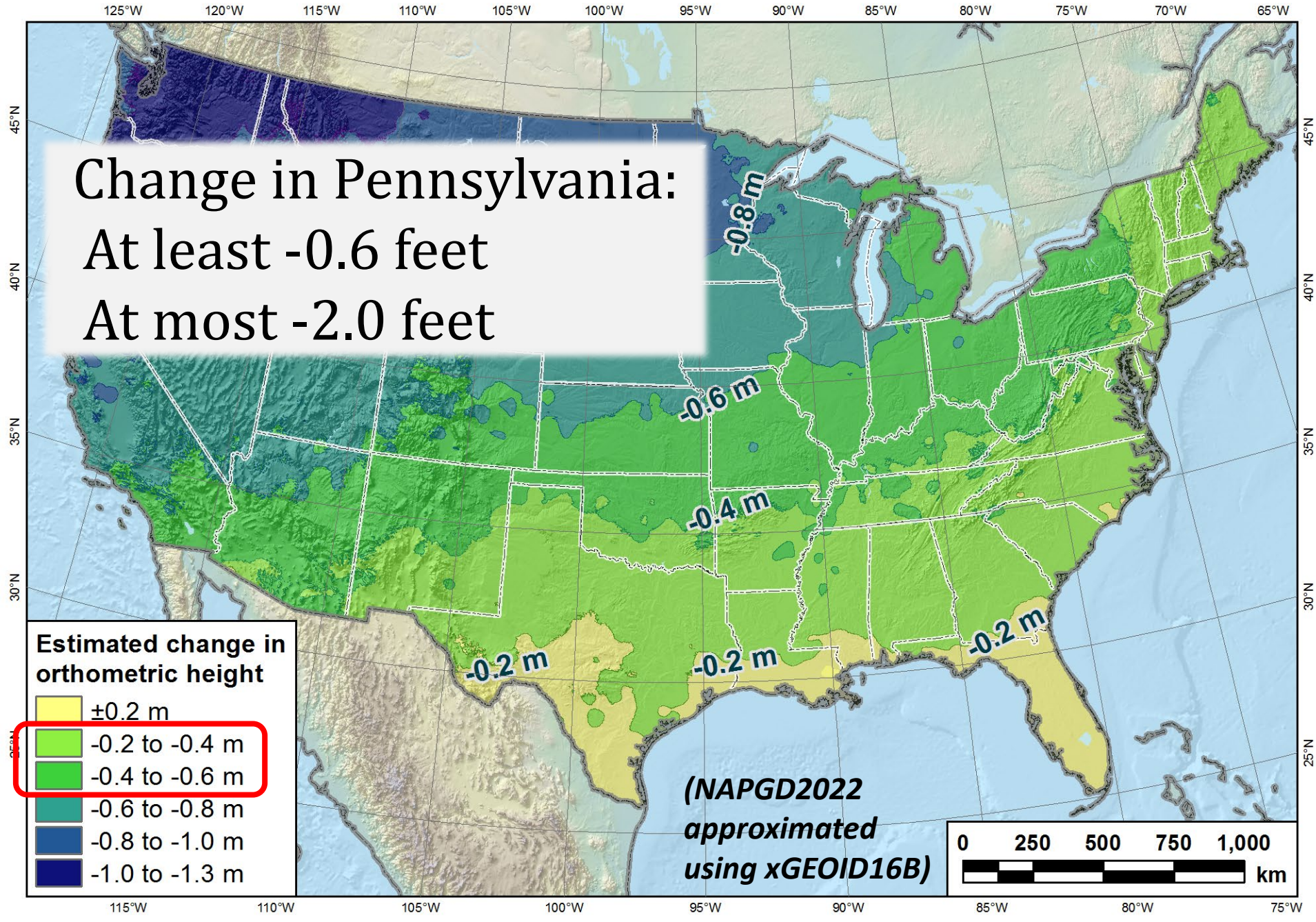
NAPGD2022 uses a Gravimetric Geoid



Concept

- Datum zero surface aligned to Global Mean Sea Level (GMSL)

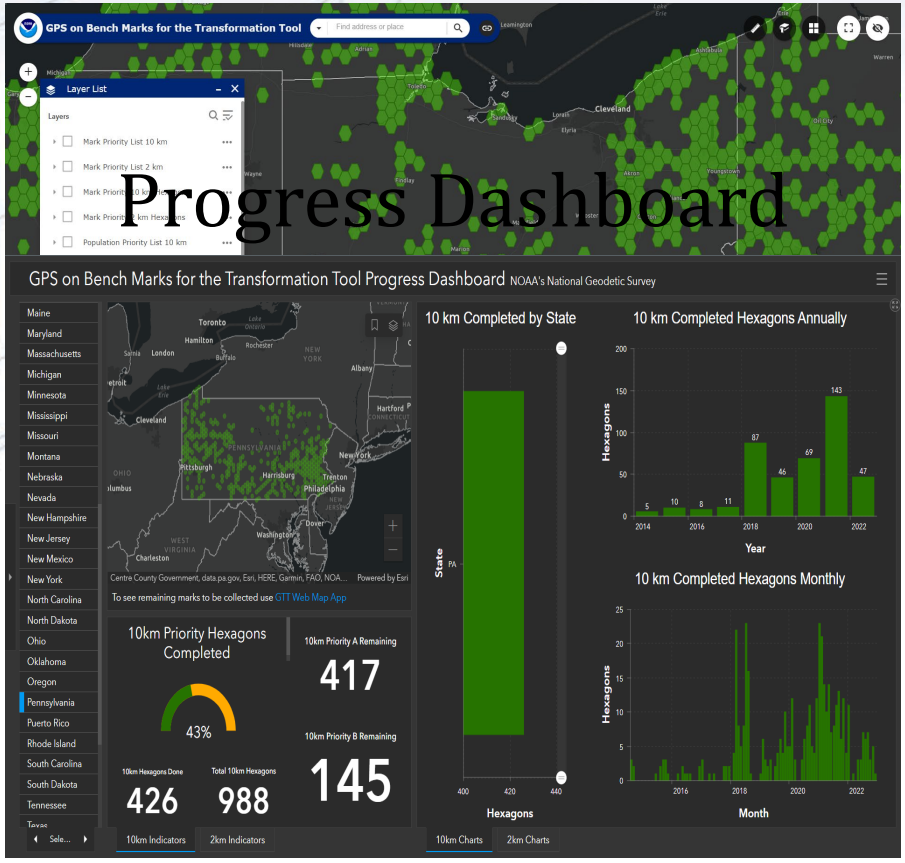
Estimated change in orthometric heights from NAVD88 to **NAPGD2022**



Quality of vertical datum transformation?

GPS on Bench Marks (GPSonBM)

Web Map Application

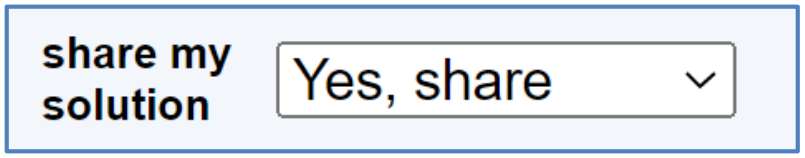


Anyone can collect and provide:

- 2 OPUS-Static solutions
  - ≥4 hours each
- 2 photos of each setup
- Brief Description w/Ties

Deadline = 30 September 2023

Results increase accuracy of NAVD88<->NAPGD2022 transformation.



North American Datum of 1983

NAD83

will be replaced by

North American Terrestrial Reference Frame of 2022

NATRF2022

(pronounced: nat-ref)

Datum Defined

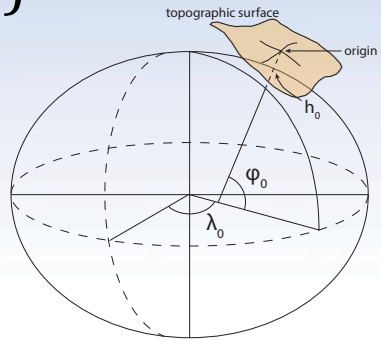
"The adopted standard latitude and longitude of a given station, together with the adopted standard azimuth of a line from that station."

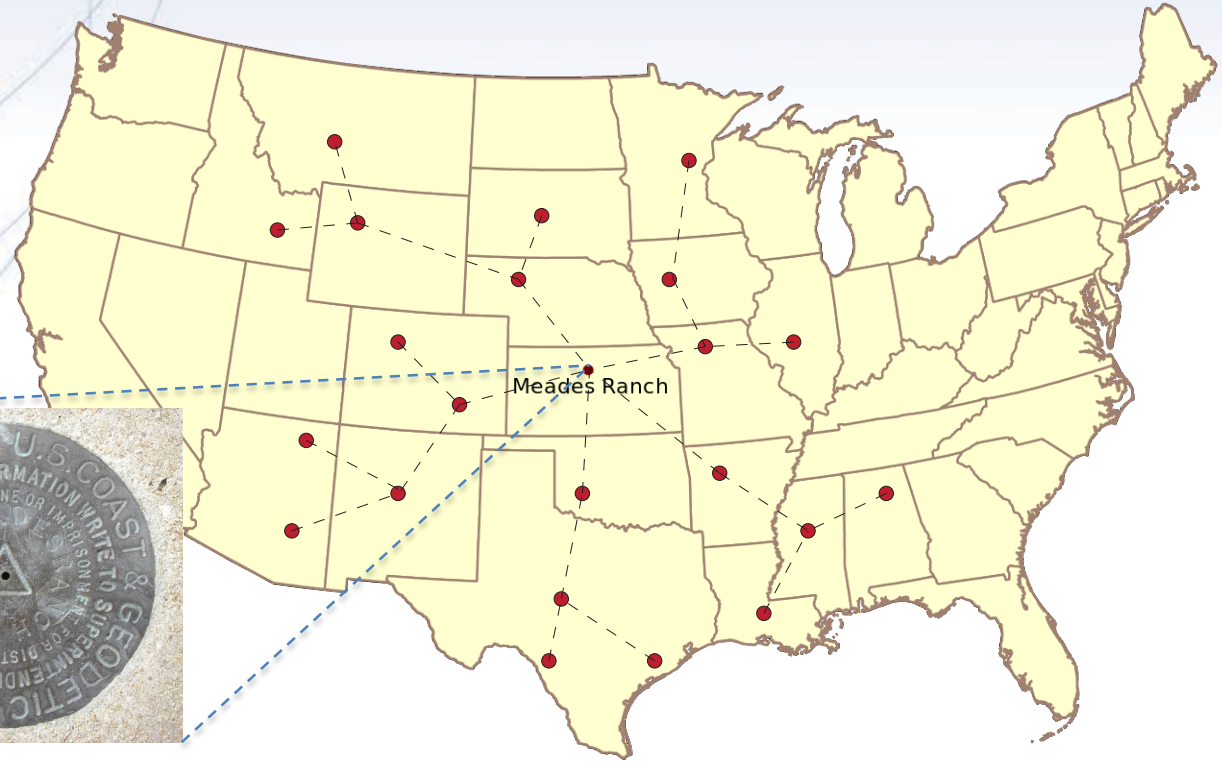
- e.g. NAD27
  - –station Meade's Ranch and it's azimuth mark Waldo

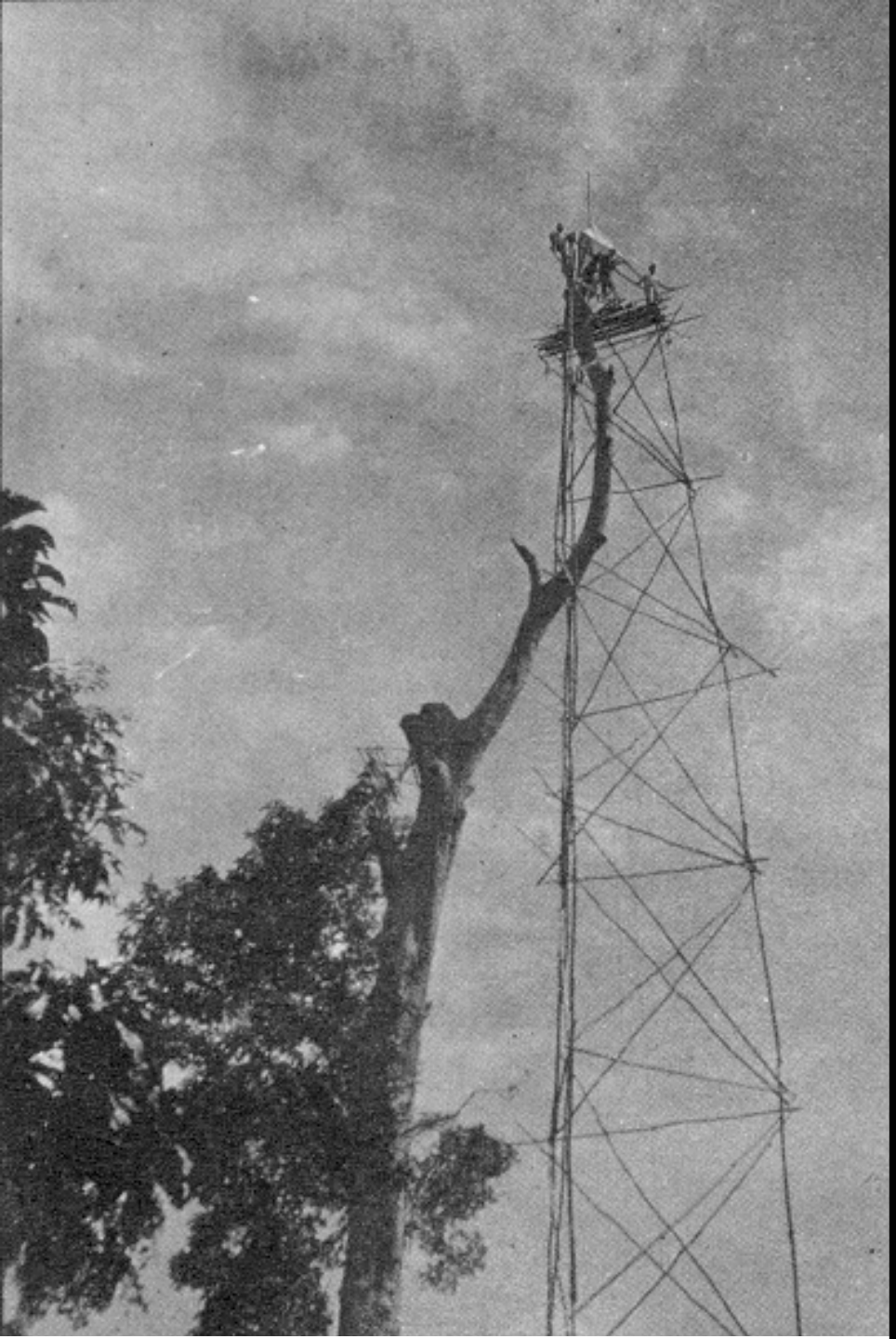
Source: Proceedings of the 14th General Conference of the International Geodetic Association (IAG) - "Report on Geodetic Operations in the United States", O.H. Tittmann, Superintendent of the USC&GS

Datum – Traditional Horizontal

North American Datum of 1927 (NAD27)







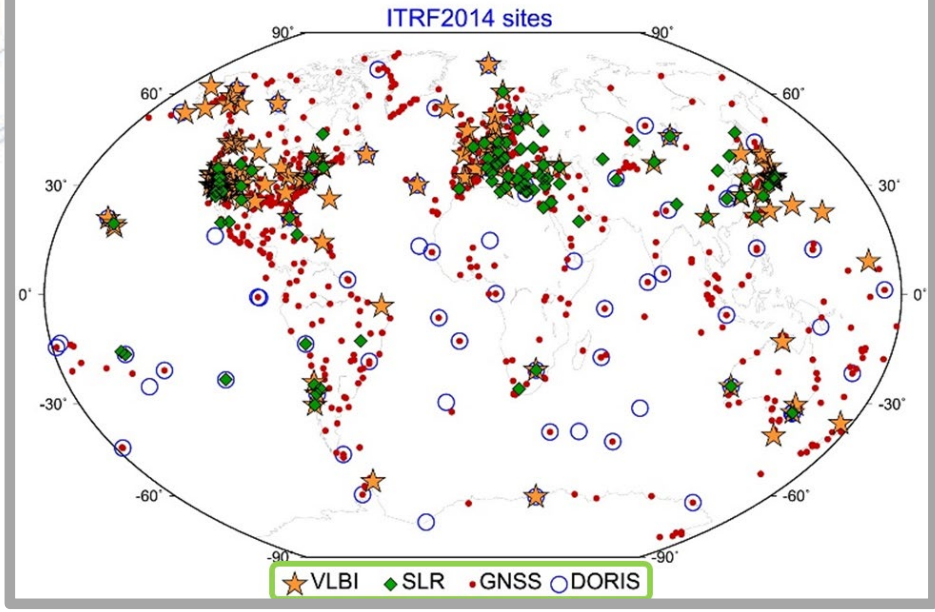
Reference Frame Defined

"A system of graduated lines symbolically attached to a body that serve to **describe the position of points relative to the body.**"

Source: Encyclopaedia Brittanica – Reference Frame (Physics), The Editors of the Encyclopaedia Brittanica, April 08, 2016.

International Terrestrial Reference Frame (ITRF)

International Network of SGTs



International Network of SGTs

International Earth Rotation and Reference Systems Service (IERS)

IGS INTERNATIONAL GNSS SERVICE

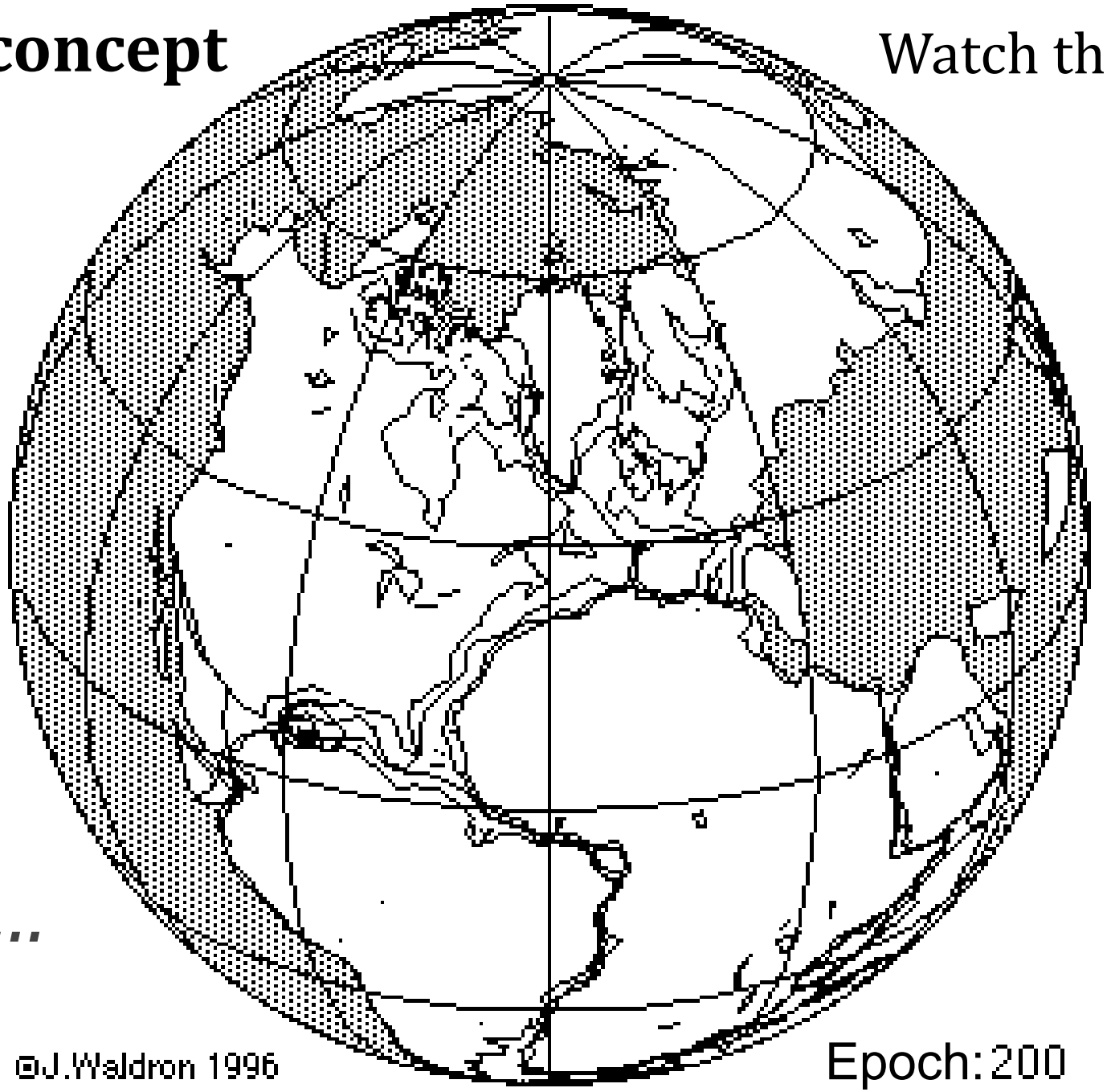
ILRS

IVS

IDS

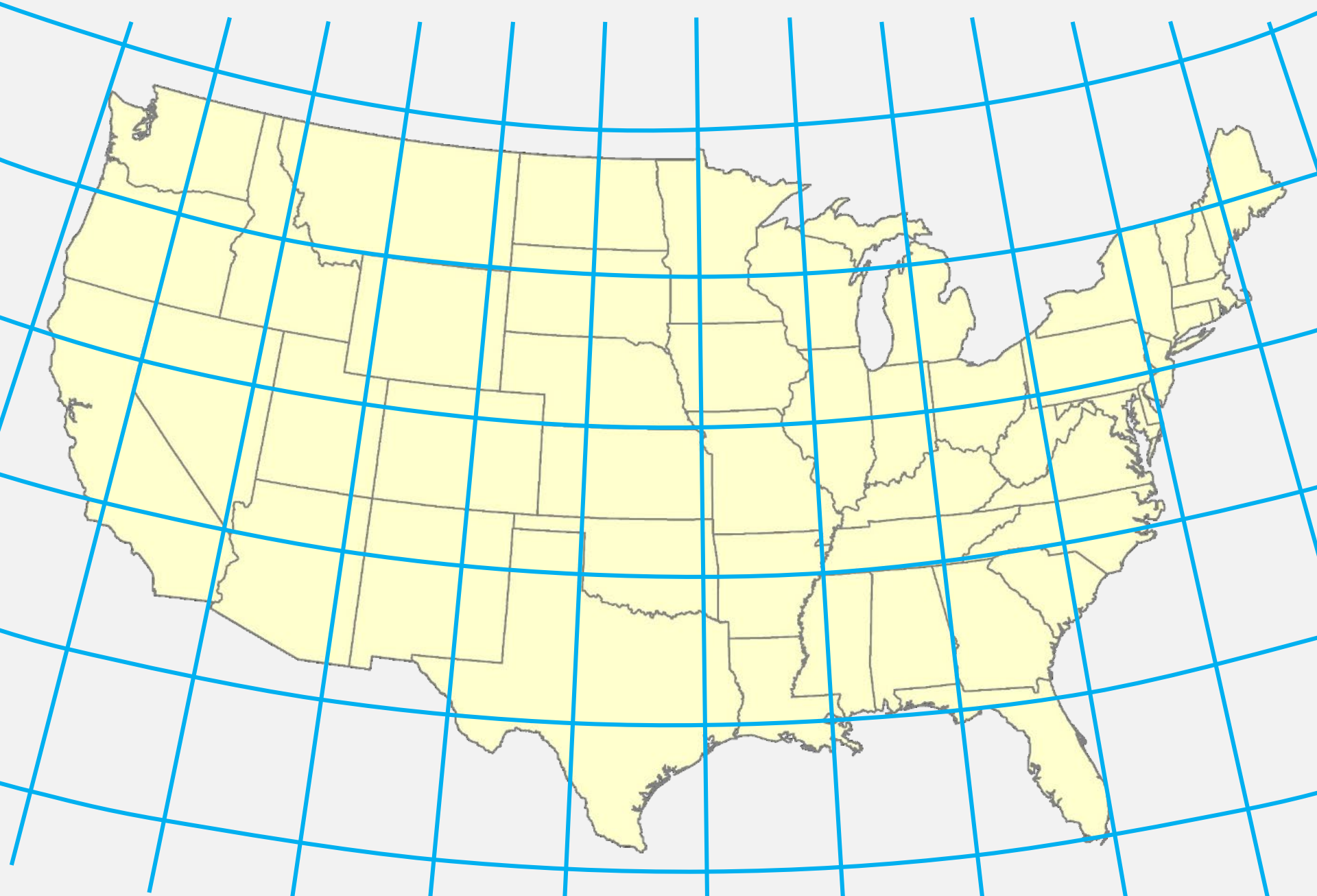
ITRF concept

Watch the grid!



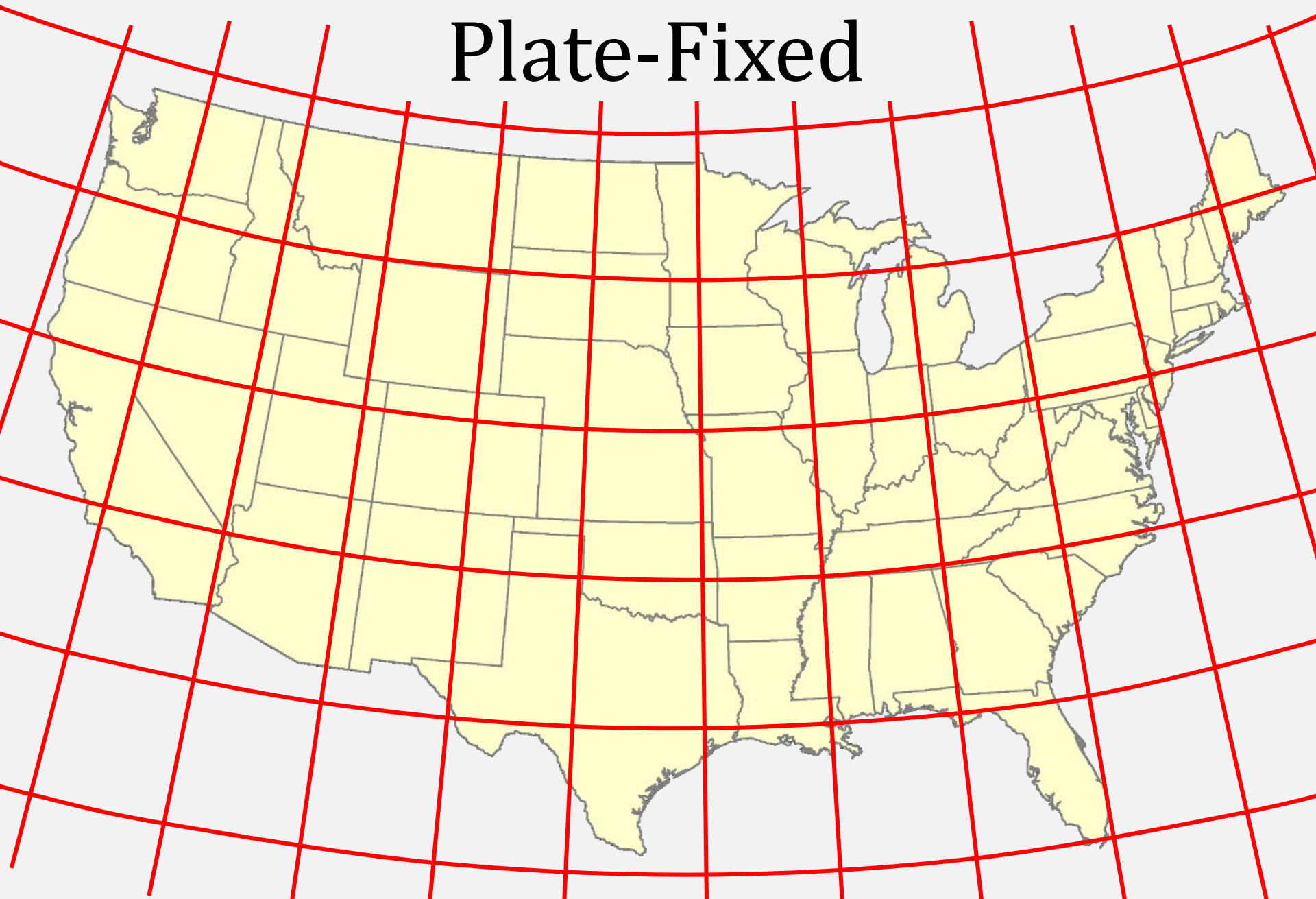
Drift…

ITRF – constant frame, rotating plate

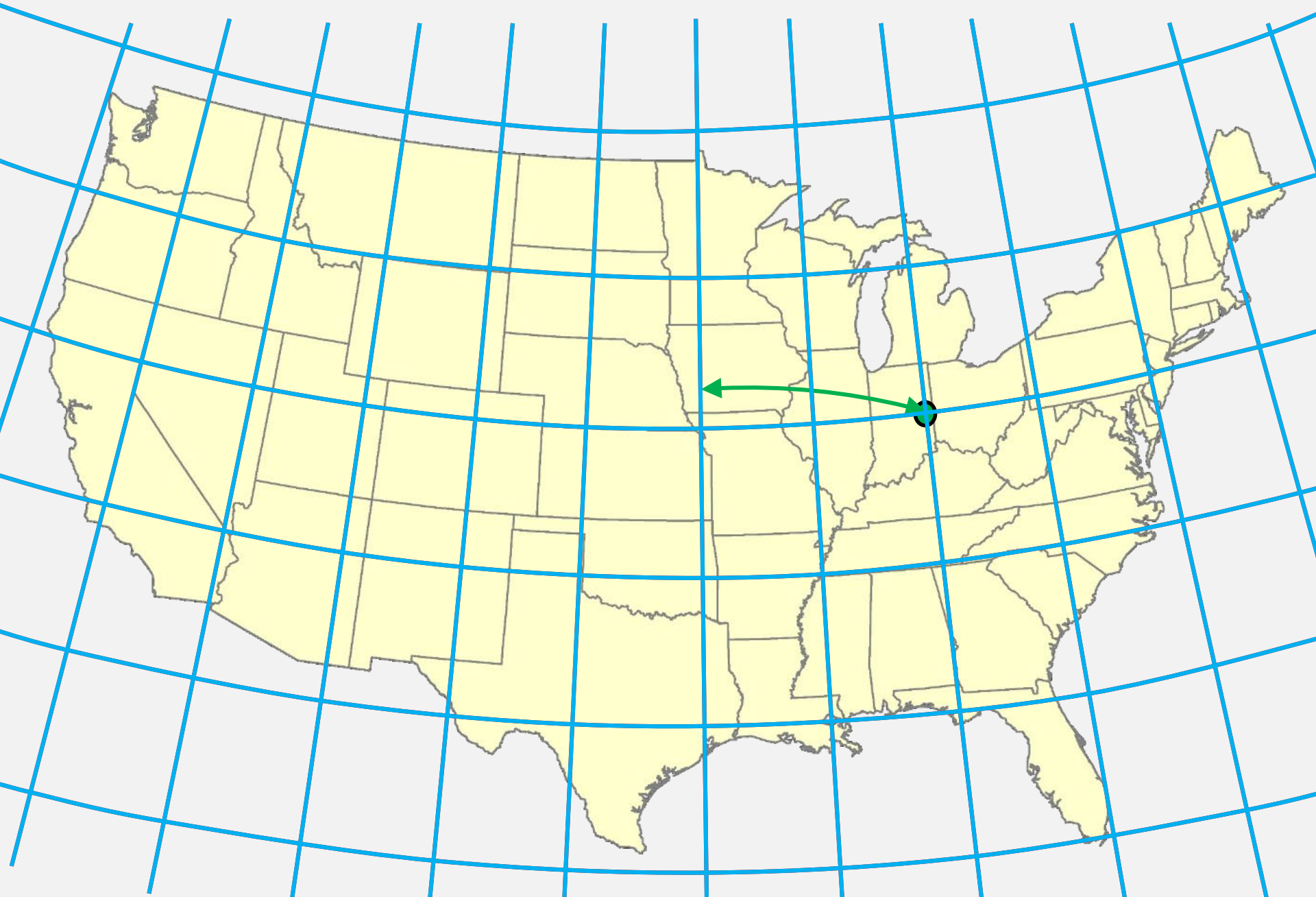


NATRF – rotating frame, constant with plate

Plate-Fixed



ITRF or NATRF – your choice if you know epoch



Terminology - Changing Coordinates

Conversion

- change the ***type*** of coordinate
- NAD83(2011) ***latitude & longitude*** → NAD83(2011) ***SPCS***

Transformation

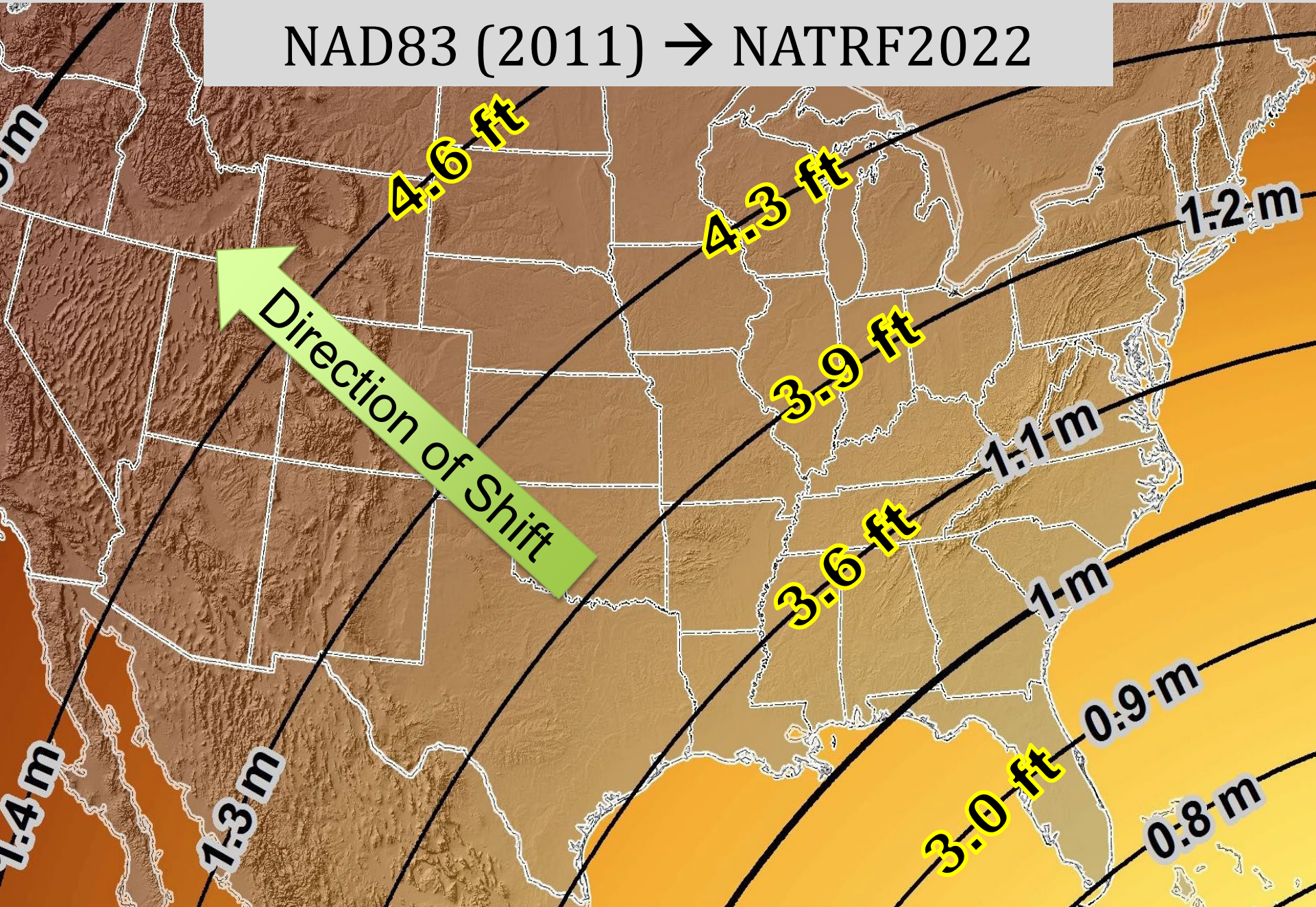
- change the ***datum*** of coordinate
- ***NGVD29*** height → ***NAVD88*** height
- ***NAD 27*** latitude & longitude → ***NAD 83(2011)*** latitude & longitude

Propagation

- change the ***epoch*** of coordinate
- NATRF2022 ***epoch 2020.00*** to NATRF2022 ***epoch 2023.243***

Estimated Geometric Change - Horizontal

NAD83 (2011) → NATRF2022



I'll be selling these bumper stickers
on LinkedIn…

SPCS2022

MAKING EARTH FLAT AGAIN

…ONE ZONE AT A TIME

Really?

No… not really!

State Plane Coordinate System of 1983

SPCS83

Pennsylvania Coordinate System Law

Act of Dec. 16, 1992, P.L. 1224, No. 161

Problems

- Designates specific zones
- Parameters of projections included
- Restricts datum usage to 1983 or 1927
- Unit of measure designated as Survey Foot

PSLS Geospatial Committee and Pennsylvania GeoBoard have been working on this for ~3 years now.

In agreement how to proceed, it's all about timing at this point.

State Plane Coordinate System of 2022

SPCS2022

Stakeholders Involved in PA SPCS2022

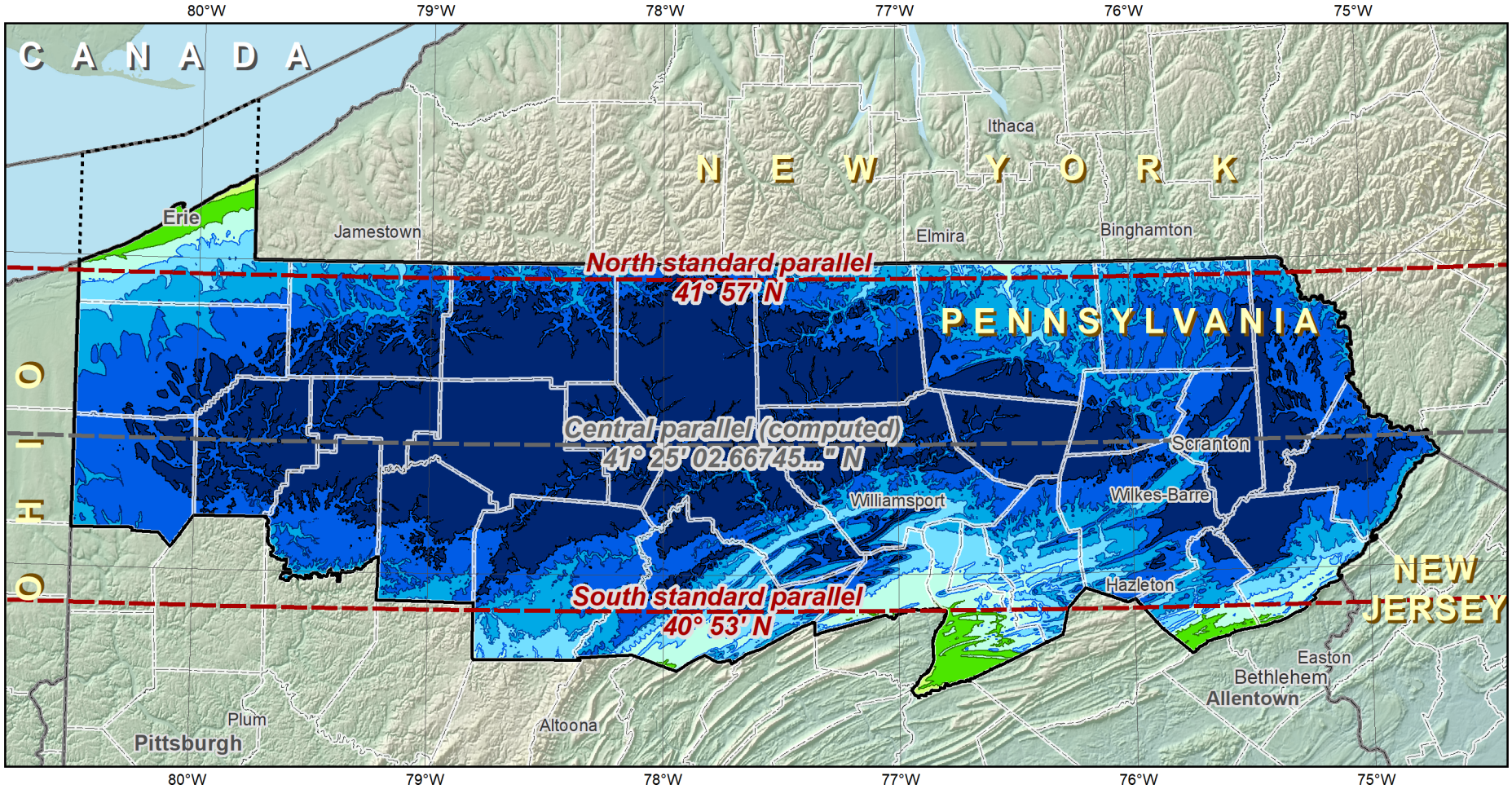
- PennDOT
- PTC
- PSLS
- PSPE
- PA Geospatial Coordinating Board (GeoBoard)
  - Geodetic Working Group
- County GIS Professionals Association of PA
- PA-MAGIC (*now Keystone GIS*)
- PA-MAPPS

State Plane Coordinate System of 1983

SPCS83

North and South Zones as they exist now

Existing SPCS83 design: Pennsylvania North Zone



Lambert Conformal Conic projection

North American Datum of 1983

Central parallel: 41° 25' 02.66745..." N

Central parallel scale: 0.999 956 840...

NOAA's National Geodetic Survey

Areas within ±50 ppm distortion (1:20,000 = ±0.26 ft per mile):

28% of population

22% of all cities and towns

10% of entire zone area

Distortion values (ppm)

Entire zone:

Min= -155 Range = 200

Max = +45 Mean = -89

Weighted mean = -66

(weighted by population)

Cities and towns:

Min = -136 Range = 167

Max = +31 Mean = -69

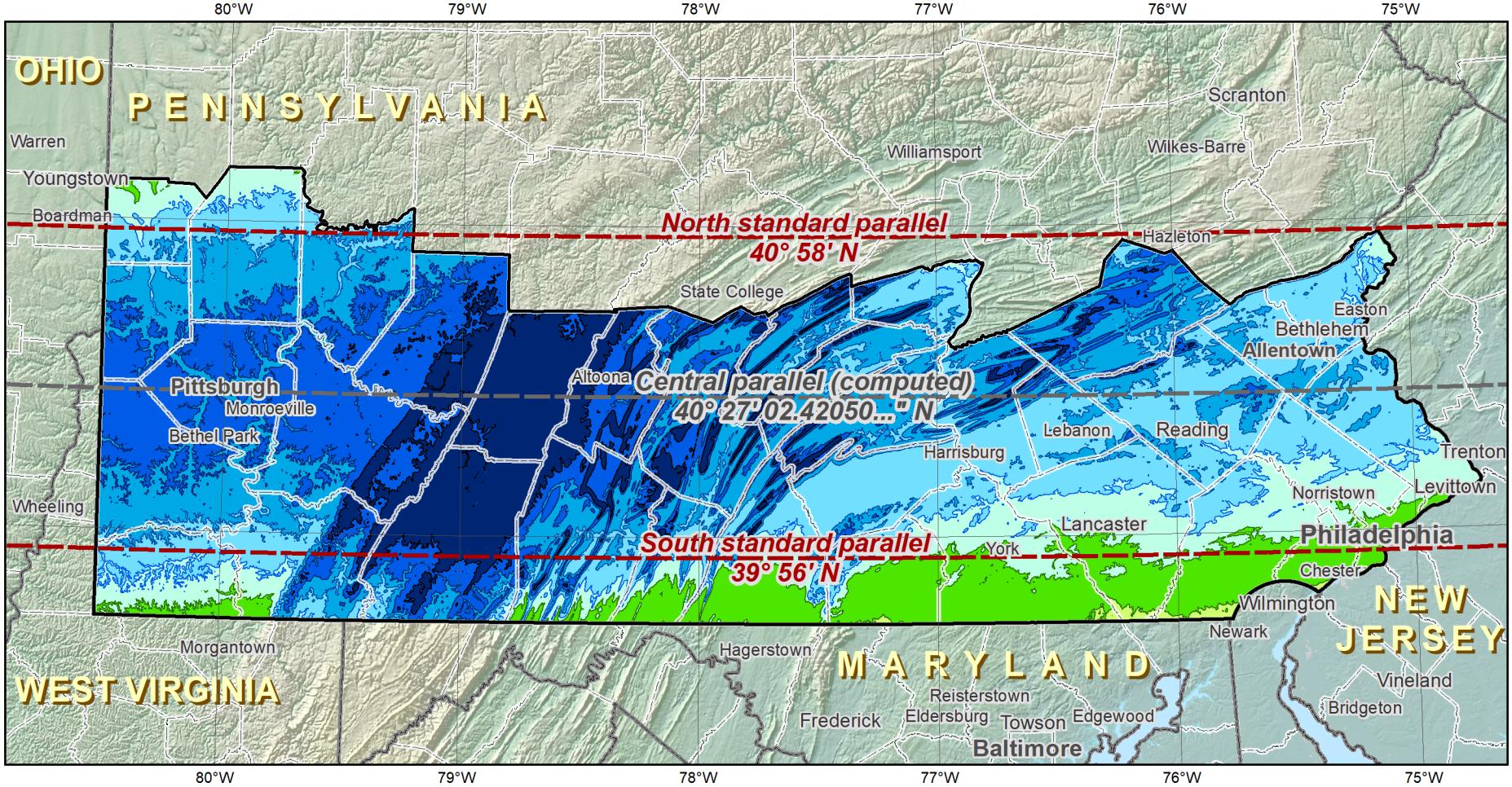
Linear distortion at topographic surface (parts per million)

<-100	±20	to +120
to -100	to +40	to +140
to -80	to +60	to +160
to -60	to +80	to +180
to -40	to +100	>+180

0 30 60 90 120 km

Created 2/11/2021 (Nagendra Paudel)

Existing SPCS83 design: Pensylvania South Zone



Lambert Conformal Conic projection

North American Datum of 1983

Central parallel: 40° 27' 02.4..." N

Central parallel scale: 0.999 959 500...

NOAA's National Geodetic Survey

Areas within ±50 ppm distortion (1:20,000 = ±0.26 ft per mile):

60% of population

36% of all cities and towns

32% of entire zone area

Distortion values (ppm)

Entire zone:

Min= -178 Range = 218

Max = +40 Mean = -63

Weighted mean = -44

(weighted by population)

Cities and towns:

Min = -146 Range = 171

Max = +24 Mean = -57

Linear distortion at topographic surface (parts per million)

<-100	±20	to +120
to -100	to +40	to +140
to -80	to +60	to +160
to -60	to +80	to +180
to -40	to +100	>+180

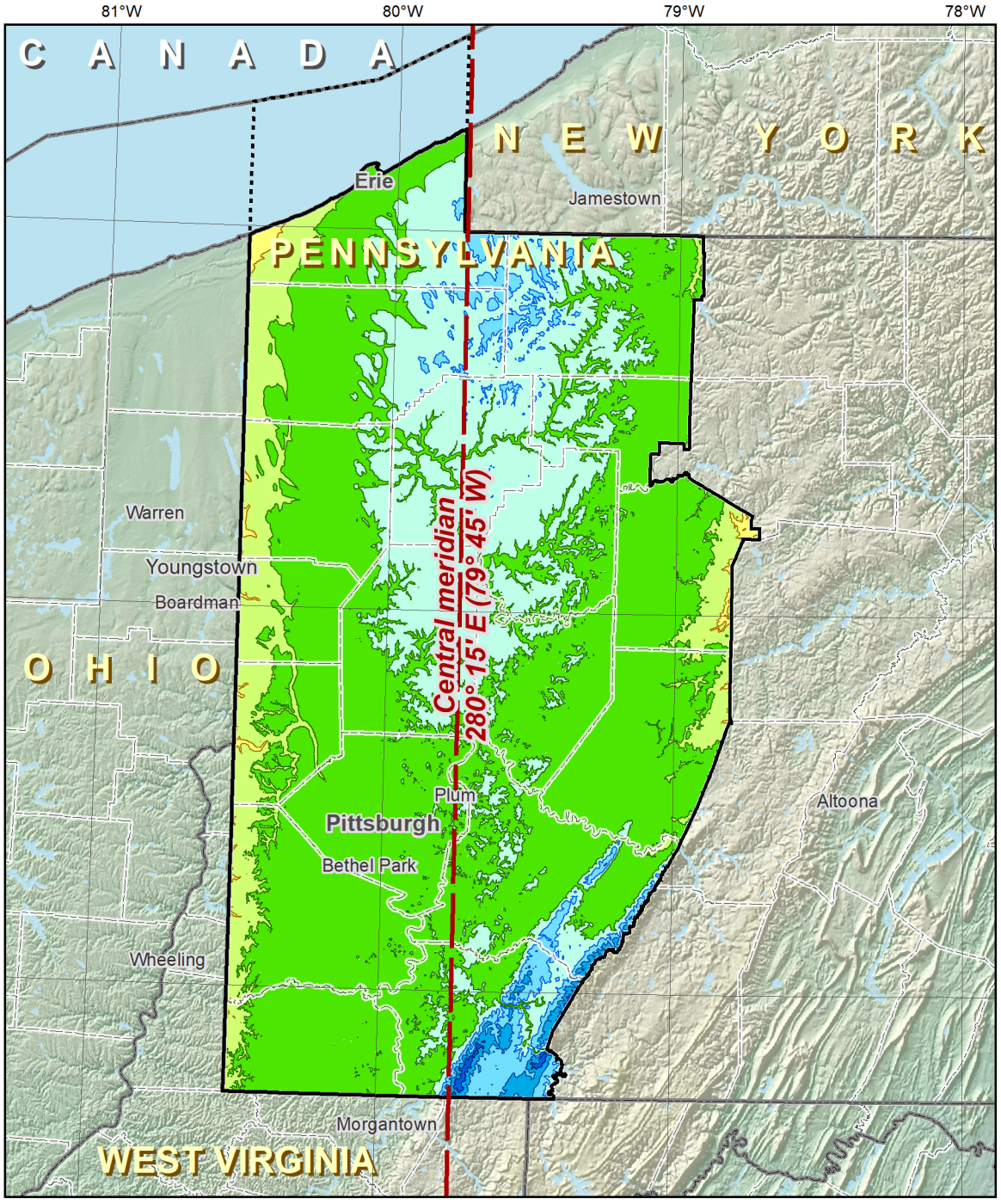
0 40 80 120 km

Created 2/11/2021 (Nagendra Paudel)

State Plane Coordinate System of 2022

SPCS2022

PA stakeholders requested 4-5 zones, which NGS designed, the following are Preliminary maps



Preliminary SPCS2022 design: Pennsylvania West Zone

NOAA's National Geodetic Survey

Transverse Mercator projection

North American Terrestrial Reference Frame of 2022

Central meridian: 280° 15' E
Cen merid scale: 1.000 030 (exact)

Areas within ±30 ppm distortion (1:33,333 = ±0.16 ft per mile):
95% of population
93% of all cities and towns
82% of entire zone area

Distortion values (ppm)

Entire zone:	***Cities and towns:***
Min, Max = -95, +58	Min = -62
Range = 153	Max = +53
Mean = -9	Range = 116
Weighted mean = -5 (weighted by population)	Mean = -2

Linear distortion at topographic surface (parts per million)

<-100	±20	to +120
to -100	to +40	to +140
to -80	to +60	to +160
to -60	to +80	to +180
to -40	to +100	>+180

0 40 80 120 Kilometers

Created 2/8/2021 (Nagendra Paudel)

Preliminary SPCS2022 design: Pennsylvania Central Zone

NOAA's National Geodetic Survey

Oblique Mercator projection

North American Terrestrial Reference Frame of 2022

Origin latitude: 41° 21' N
Origin longitude: 282° 15' E
Skew axis azimuth: +52°
Skew axis scale: 1.000 035 (exact)

Areas within ±50 ppm distortion (1:20,000 = ±0.26 ft per mile):
90% of population
89% of all cities and towns
83% of entire zone area

Distortion values (ppm)

Entire zone:	***Cities and towns:***
Min, Max = -89, +149	Min = -66
Range = 238	Max = +93
Mean = -12	Range = 159
Weighted mean = 0.0 (weighted by population)	Mean = -0.1

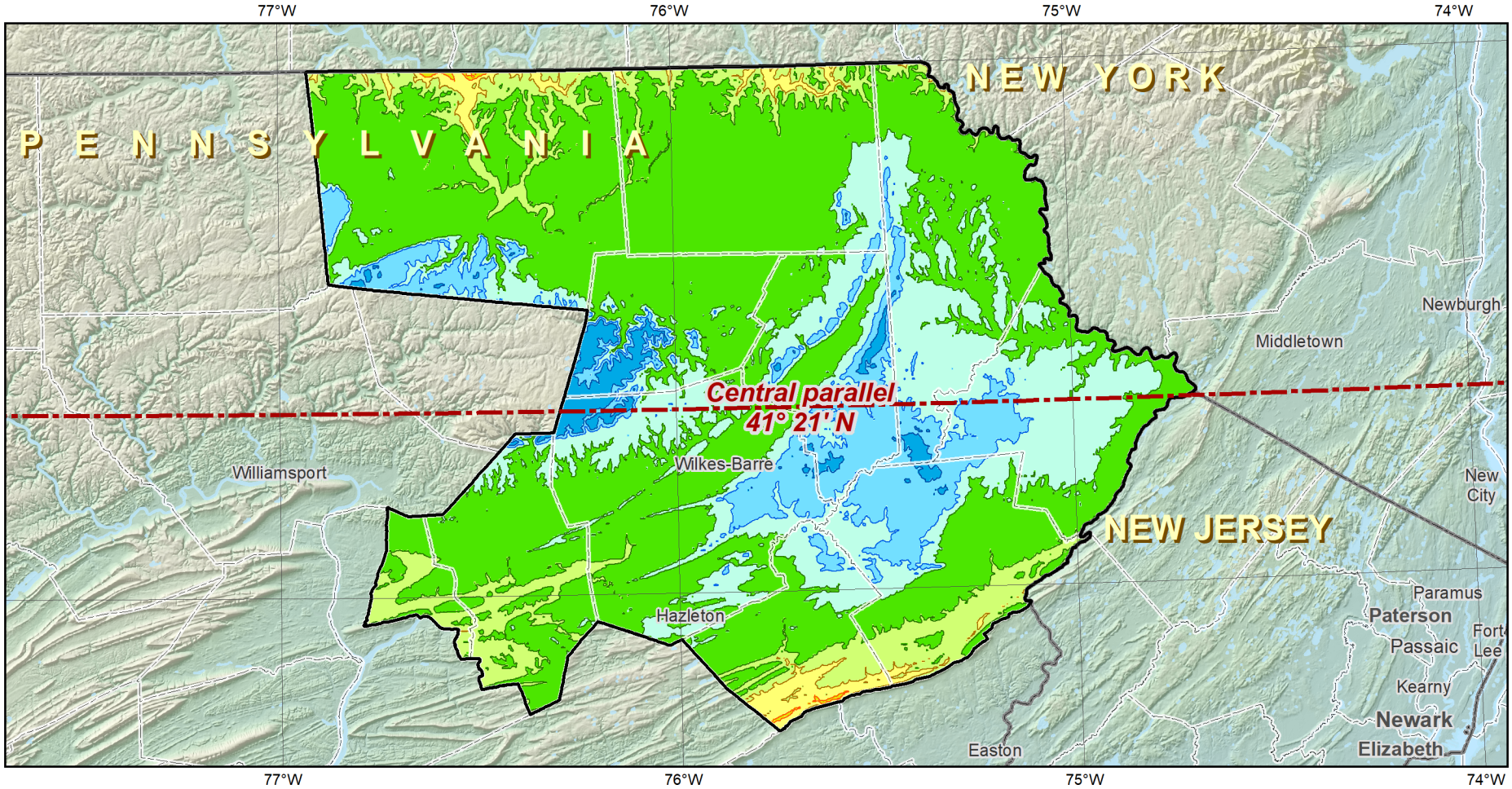
Linear distortion at topographic surface (parts per million)

<-100	±20	to +120
to -100	to +40	to +140
to -80	to +60	to +160
to -60	to +80	to +180
to -40	to +100	>+180

0 25 50 75 100 125 km

Created 2/5/2021 (Michael Dennis)

Preliminary SPCS2022 design: Pennsylvania North-East Zone (new)



Lambert Conformal Conic projection

North American Terrestrial Reference Frame of 2022

Central parallel: 41° 21' N

Central parallel scale: 1.000 030 (exact)

NOAA's National Geodetic Survey

Areas within ±40 ppm distortion (1:25,000 = ±0.21 ft per mile):

90% of population

90% of all cities and towns

86% of entire zone area

Distortion values (ppm)

Entire zone:

Min= -79 Range = 143

Max = +64 Mean = -9

Weighted mean = -4

(weighted by population)

Cities and towns:

Min = -54 Range = 116

Max = +62 Mean = +5

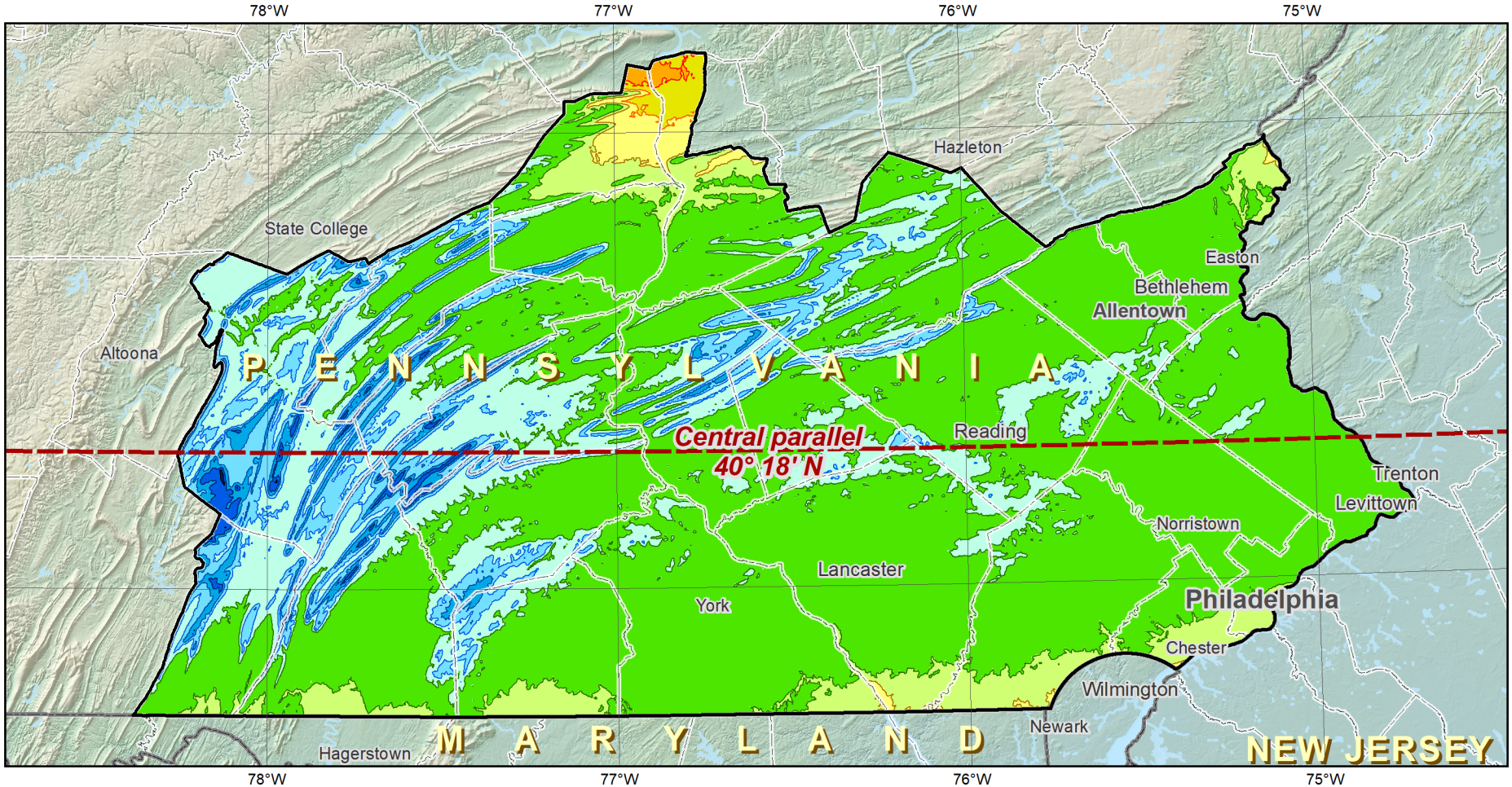
Linear distortion at topographic surface (parts per million)

<-100	±20	to +120
to -100	to +40	to +140
to -80	to +60	to +160
to -60	to +80	to +180
to -40	to +100	>+180

0 25 50 75 km

Created 2/10/2021 (Nagendra Paudel)

Preliminary SPCS2022 design: Pennsylvania South-East Zone (new)



Lambert Conformal Conic projection

North American Terrestrial Reference Frame of 2022

Central parallel: 40° 18' N

Central parallel scale: 1.000 000 (exact)

NOAA's National Geodetic Survey

Areas within ±30 ppm distortion (1:33,333 = ±0.16 ft per mile):

96% of population

94% of all cities and towns

79% of entire zone area

Distortion values (ppm)

Entire zone:

Min= -104 Range = 199

Max = +95 Mean = -11

Weighted mean = +1

(weighted by population)

Cities and towns:

Min = -87 Range = 170

Max = +82 Mean = -1

Linear distortion at topographic surface (parts per million)

<-100	±20	to +120
to -100	to +40	to +140
to -80	to +60	to +160
to -60	to +80	to +180
to -40	to +100	>+180

0 20 40 60 80 km

Created 2/10/2021 (Nagendra Paudel)

NOAA's National Geodetic Survey

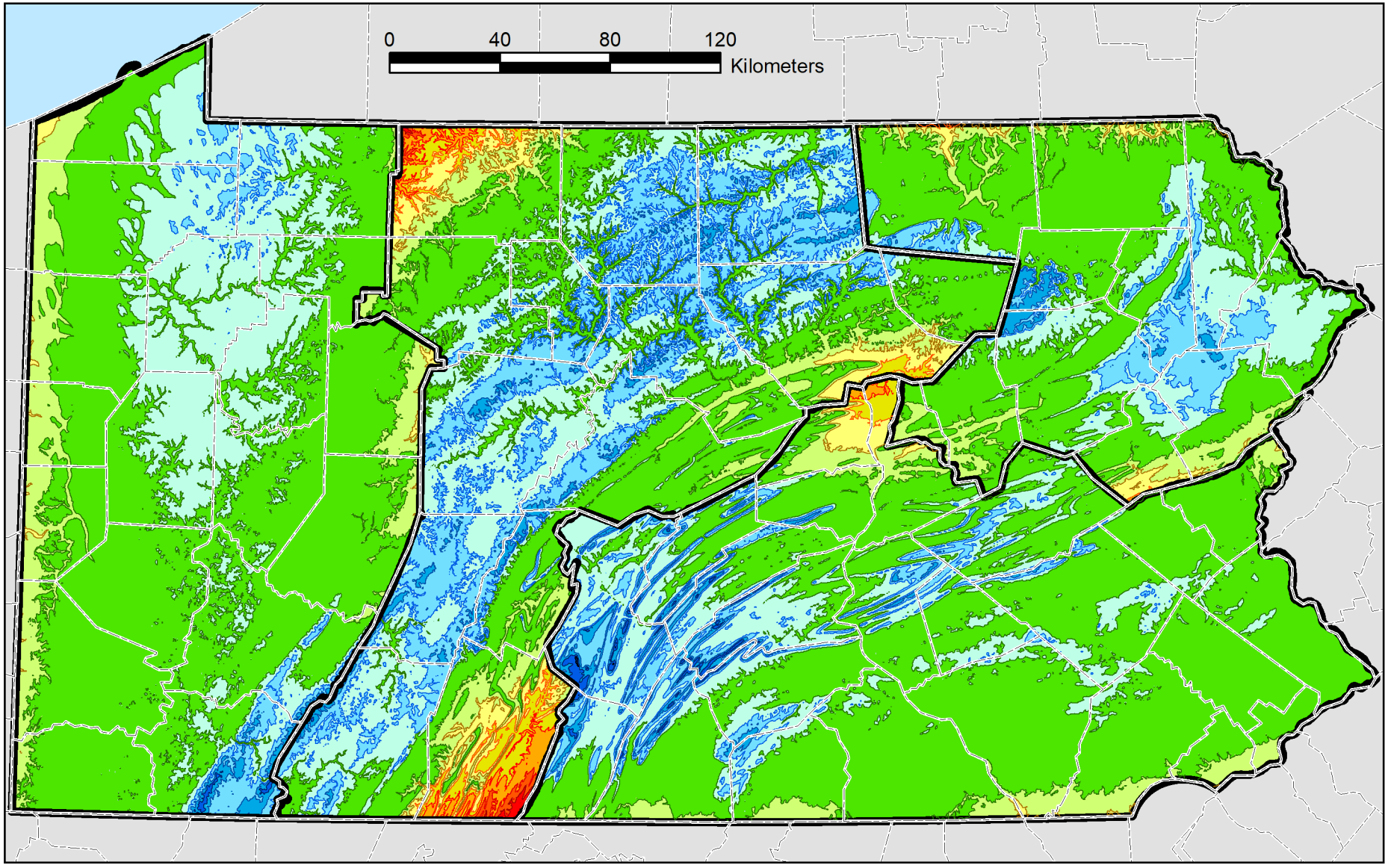
Preliminary SPCS2022 designs: Pennsylvania Zones - West, Central, Northeast and Southeast

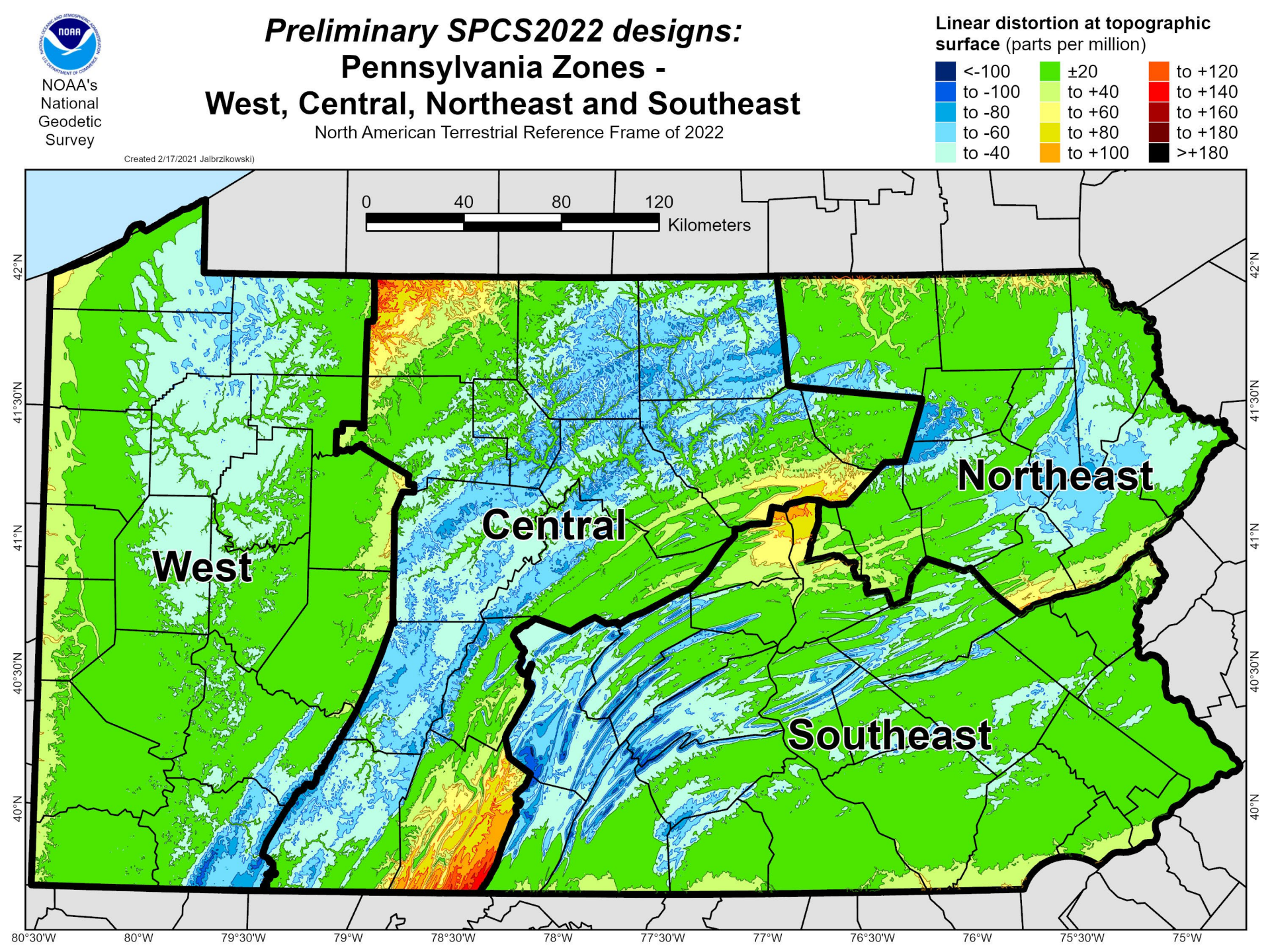
North American Terrestrial Reference Frame of 2022

Created 2/17/2021 Jalbrzikowski)

Linear distortion at topographic surface (parts per million)

<-100	±20	to +120
to -100	to +40	to +140
to -80	to +60	to +160
to -60	to +80	to +180
to -40	to +100	>+180




NOAA's National Geodetic Survey
Preliminary SPCS2022 designs:
Pennsylvania Zones -
West, Central, Northeast and Southeast
North American Terrestrial Reference Frame of 2022
Created 2/17/2021 Jalbrzikowski)
Linear distortion at topographic surface (parts per million)
<-100
to -100
to -80
to -60
to -40
±20
to +40
to +60
to +80
to +100
to +120
to +140
to +160
to +180
>+180
0
40
80
120
Kilometers
West
Central
Northeast
Southeast
42°N
41°30'N
41°N
40°30'N
40°N
80°30'W
80°W
79°30'W
79°W
78°30'W
78°W
77°30'W
77°W
76°30'W
76°W
75°30'W
75°W

NOAA's National Geodetic Survey

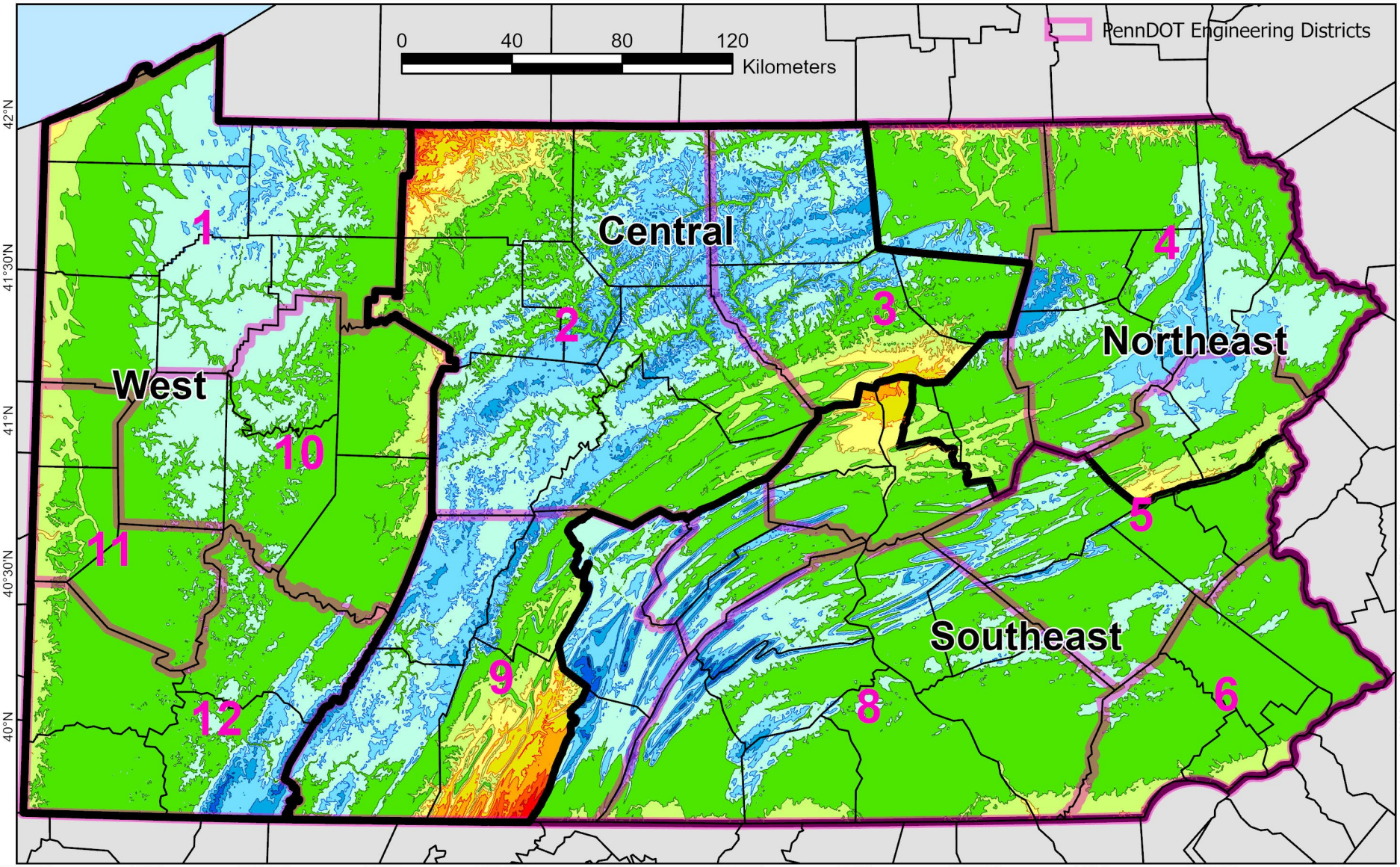
Preliminary SPCS2022 designs:
Pennsylvania Zones - West, Central, Northeast and Southeast

North American Terrestrial Reference Frame of 2022

Created 2/17/2021 Jalbrzikowski)

Linear distortion at topographic surface (parts per million)

<-100	±20	to +120
to -100	to +40	to +140
to -80	to +60	to +160
to -60	to +80	to +180
to -40	to +100	>+180

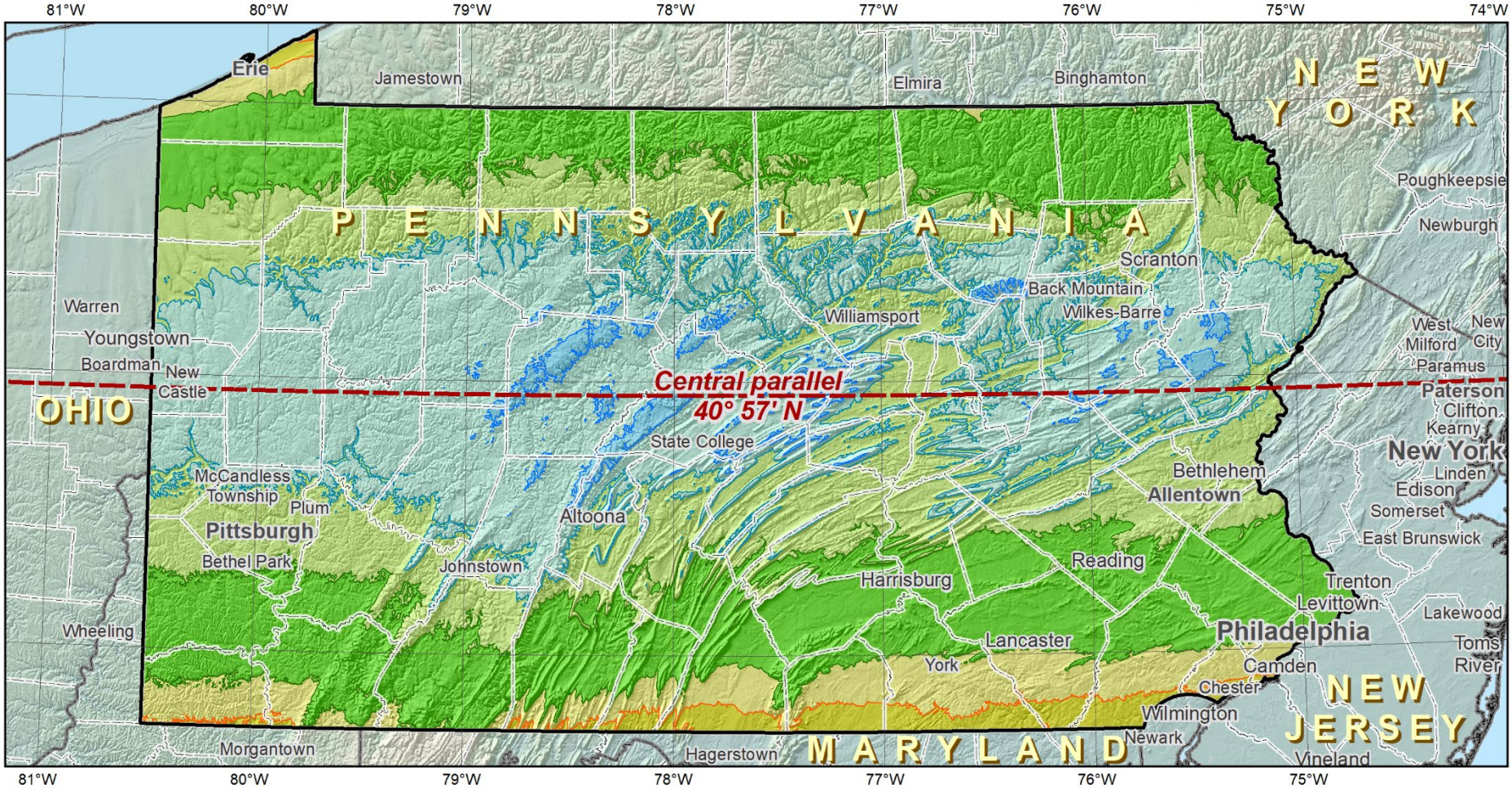


State Plane Coordinate System of 2022

SPCS2022

*NGS will create a **Single Statewide Zone** for every State, the following is a Preliminary map*

Preliminary SPCS2022 statewide zone design: Pennsylvania



Lambert Conformal Conic projection

North American Terrestrial Reference Frame of 2022

Central parallel: 40° 57' N

Cen parallel scale: 0.999 93 (exact)

Areas within ±100 ppm distortion (±0.53 ft per mile):

65% of entire zone

78% of all cities and towns

88% of population

NOAA's National Geodetic Survey

Distortion values (ppm)

Entire zone:

Min = -182 Range = 356

Max = +174 Mean = -58

Cities and towns:

Min = -155 Range = 297

Max = +142 Median = -60

Mean = -6

(weighted by population)

Linear distortion at topographic surface (parts per million)

< -400	to -200	to +150
to -400	to -150	to +200
to -350	to -100	to +250
to -300	±50	to +300
to -250	to +100	> +300

0 50 100 150 km

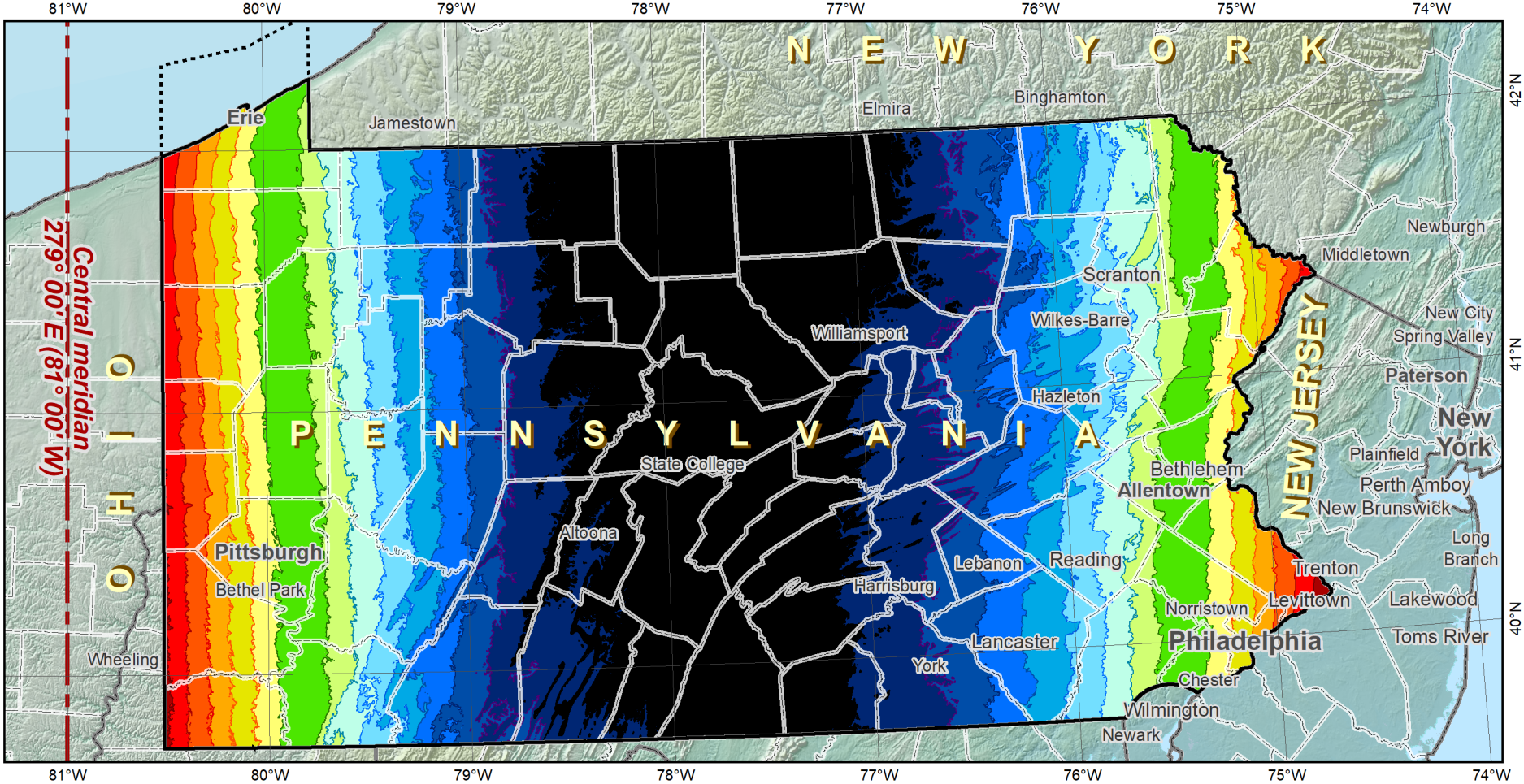
UTM (NAD83) Zones as

UTM

The following are maps using existing UTM zones as a Single Statewide Zone

*(included to highlight the **lower performance** as compared to Preliminary NGS Zone)*

Existing UTM Zone 17 North used as statewide zone: Pennsylvania



Transverse Mercator projection

North American Datum of 1983

Central parallel: 81° 00' W

Central parallel scale: 0.999 6 (exact)

NOAA's National Geodetic Survey

Areas within ±100 ppm distortion (1:10,000 = ±0.53 ft per mile):

3% of population

6% of all cities and towns

9% of entire zone area

Distortion values (ppm)

Entire zone:

Min= -515 Range = 860

Max = +345 Mean = -230

Weighted mean = +1311

(weighted by population)

Cities and towns:

Min = -436 Range = 3480

Max = +3045 Mean = +727

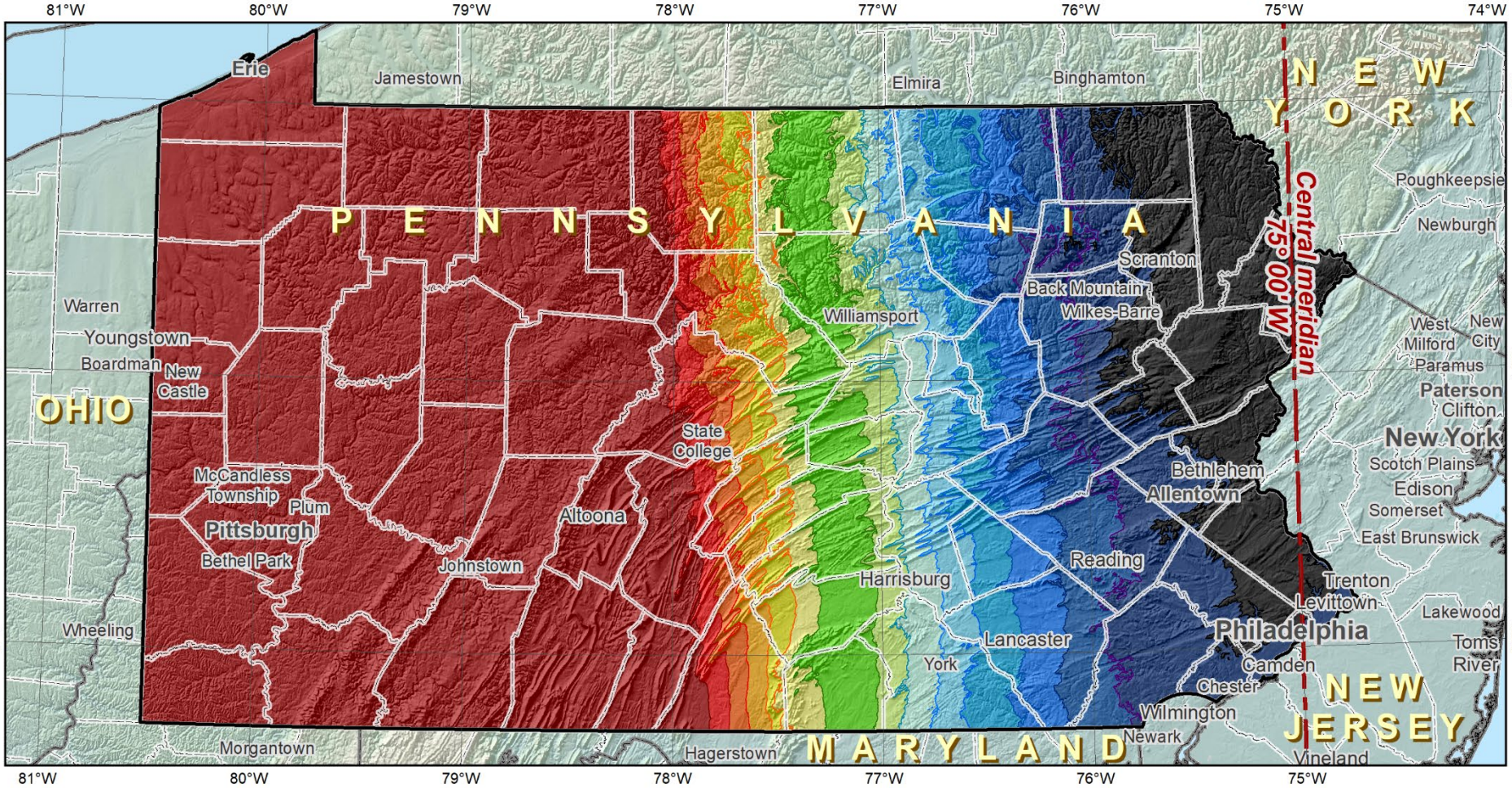
Linear distortion at topographic surface (parts per million)

< -400	to -200	to +150
to -400	to -150	to +200
to -350	to -100	to +250
to -300	±50	to +300
to -250	to +100	> +300

0 60 120 180 km

Created 1/21/2020 (Nagendra Paudel)

Existing UTM Zone 18 North used as statewide zone: Pennsylvania



Transverse Mercator projection

North American Datum of 1983

Central meridian: 75° 00' W

Cen merid scale: 0.999 6 (exact)

Areas within ±100 ppm distortion (±0.53 ft per mile):

10% of entire zone

7% of all cities and towns

4% of population

NOAA's National Geodetic Survey

Distortion values (ppm)

Entire zone:

Min = -501 Range = 2811

Max = +2310 Mean = +452

Cities and towns:

Min = -474 Range = 2731

Max = +2257 Median = +268

Mean = +277

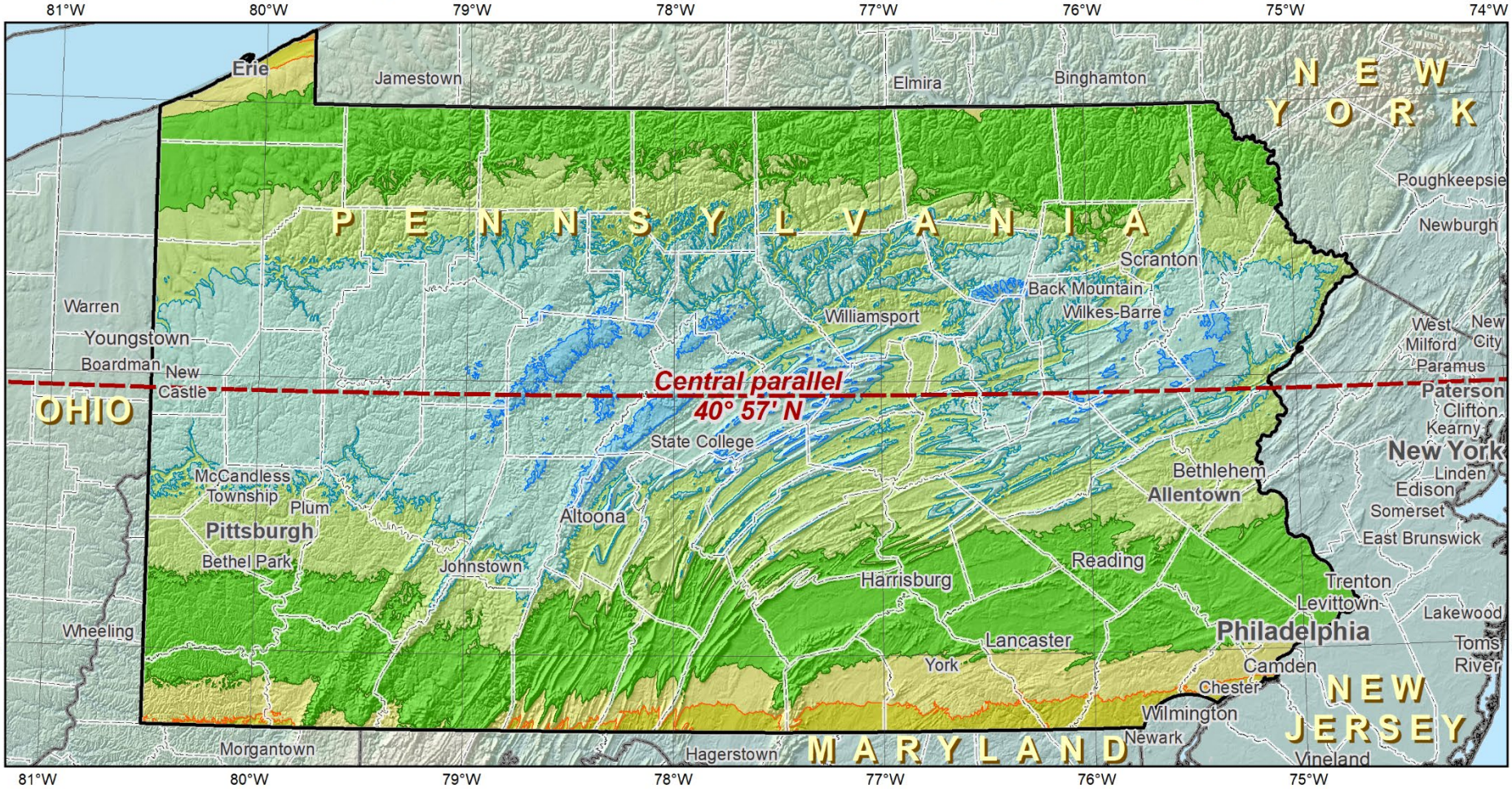
(weighted by population)

Linear distortion at topographic surface (parts per million)

< -400	to -200	to +150
to -400	to -150	to +200
to -350	to -100	to +250
to -300	±50	to +300
to -250	to +100	> +300

0 50 100 150 km

Preliminary SPCS2022 statewide zone design: Pennsylvania



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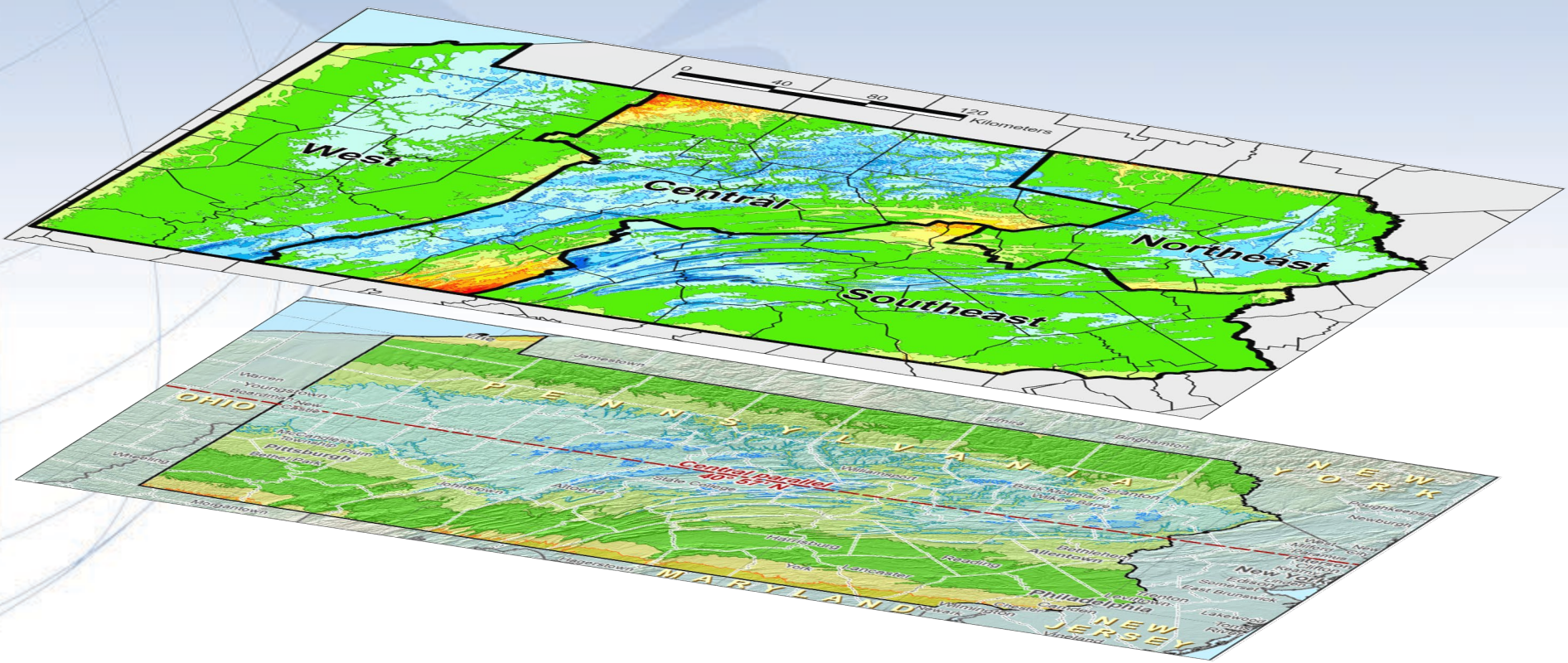
to -300	±50	to +300
to -250	to +100	> +300

0 50 100 150 km

SPCS2022 Zone Layers in PA



- Both Single Statewide and Multi-Zone Layers will coexist
- Think about your data, your goals, your customers
  - Remember that geographic coordinates are your friend!
- Smaller zones not "the best" … it all depends on usage & goals

SPCS2022 Zone Layers and LDPs

- Each state may have max of 3 zone "layers"
  - One layer must be statewide zone
    - *PA Single Statewide*
  - Other layers have two or more zones
    - *PA Multi-Zone (West, Central, Northeast, Southeast)*
  - Only one layer can have discontinuous coverage
    - *Left open for possibilities*
- Multi-zone layer can consist of LDPs
  - Designed by stakeholder "contributing partners"
    - NGS will not do this for stakeholders
  - LDP coverage can be discontinuous

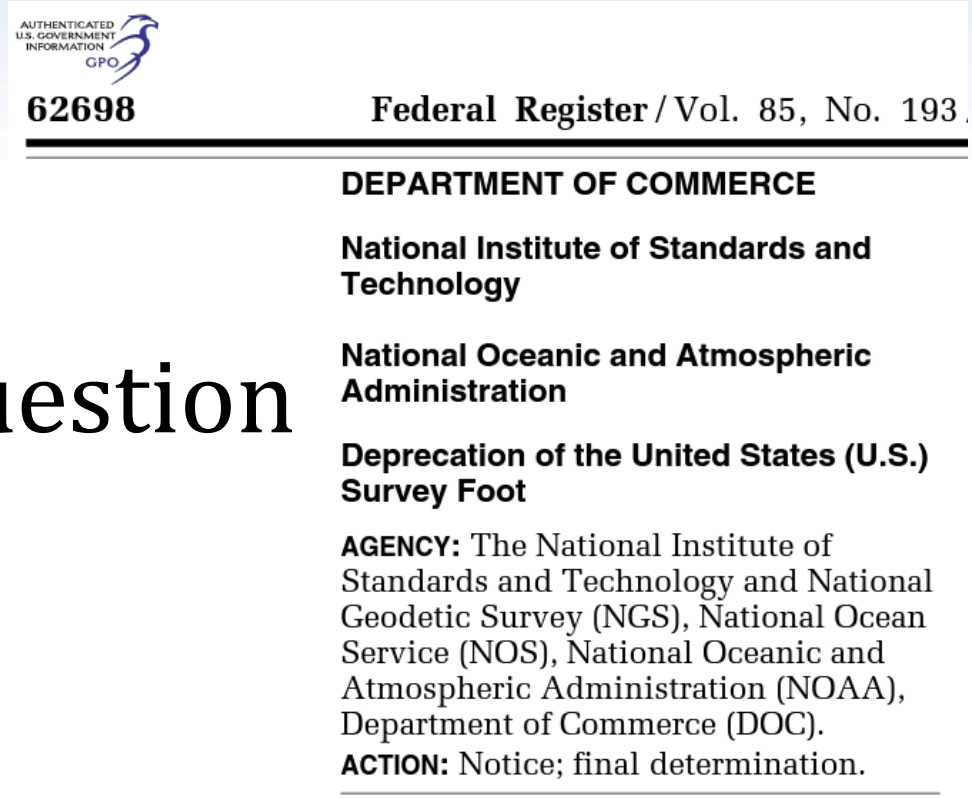
The Survey Foot is dead!

Long live the Survey Foot!

US Survey Foot was deprecated 31 December 2022… *now what?!?*

What happened to the US Survey Foot?

- Deprecated **31 December 2022**



AUTHENTICATED U.S. GOVERNMENT INFORMATION GPO

62698 **Federal Register** / Vol. 85, No. 193

DEPARTMENT OF COMMERCE

National Institute of Standards and Technology

National Oceanic and Atmospheric Administration

Deprecation of the United States (U.S.) Survey Foot

AGENCY: The National Institute of Standards and Technology and National Geodetic Survey (NGS), National Ocean Service (NOS), National Oceanic and Atmospheric Administration (NOAA), Department of Commerce (DOC).

ACTION: Notice; final determination.

- Which begs the question
  - **What should you be doing now?**

What should you be doing now?

- Prepare for this *along with new datums*
- Understand this is not enforced
  - Neither NIST or NGS are a regulatory agency
  - We support education/outreach of course
  - But OPUS, NCAT, etc. will **not** have US Survey Foot options/output in SPCS2022 zones

2 parts per million (ppm)?

- 1,000,000.00 sft = 999,99**8**.00 ift
- 10,000,000.00 sft = 9,999,9**80**.00 ift
- 1,000.00 sft = 999.99**8** ift (can you measure that?)

- International → 1 ft = .3048 m
- US → 1 ft = .30480061 m (approx.)

The Survey Foot is dead!

Long live the Survey Foot!

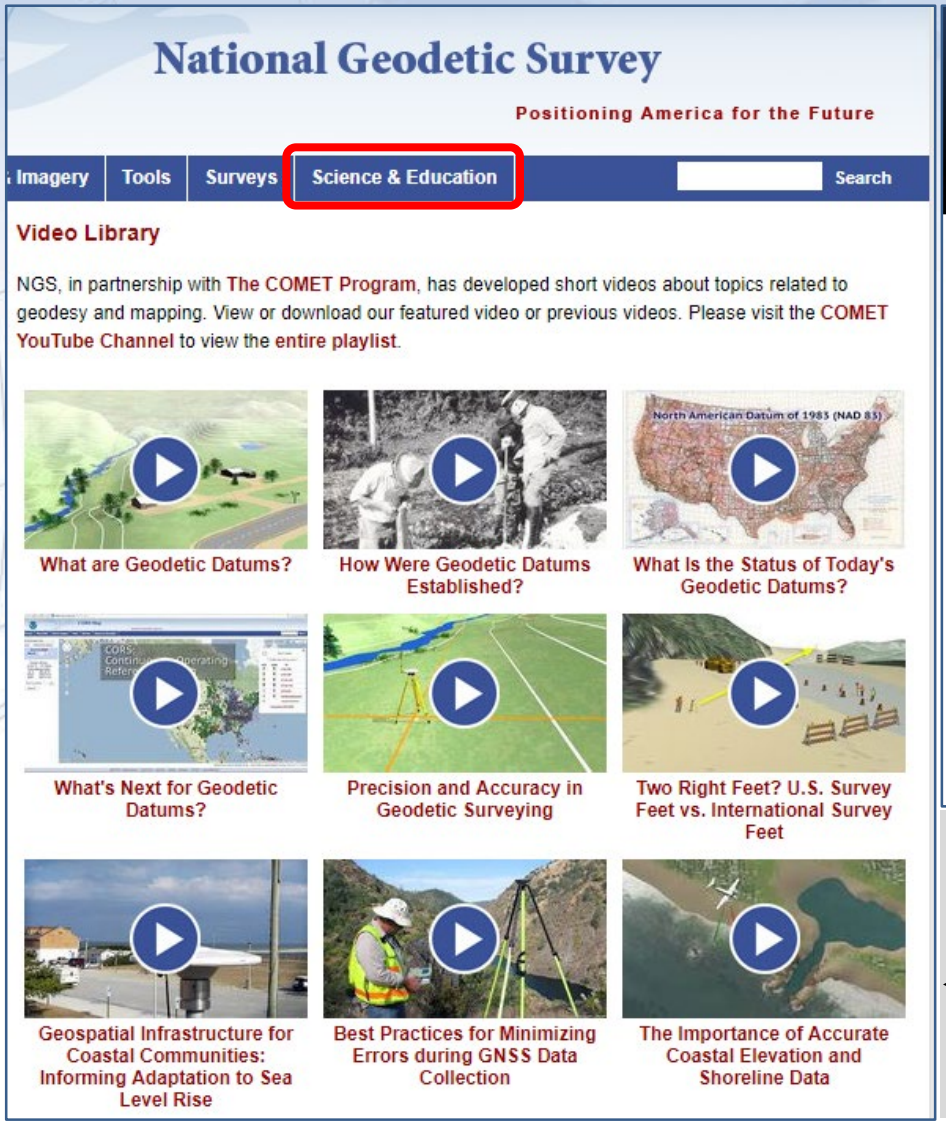
US Survey Foot was deprecated 31 December 2022…

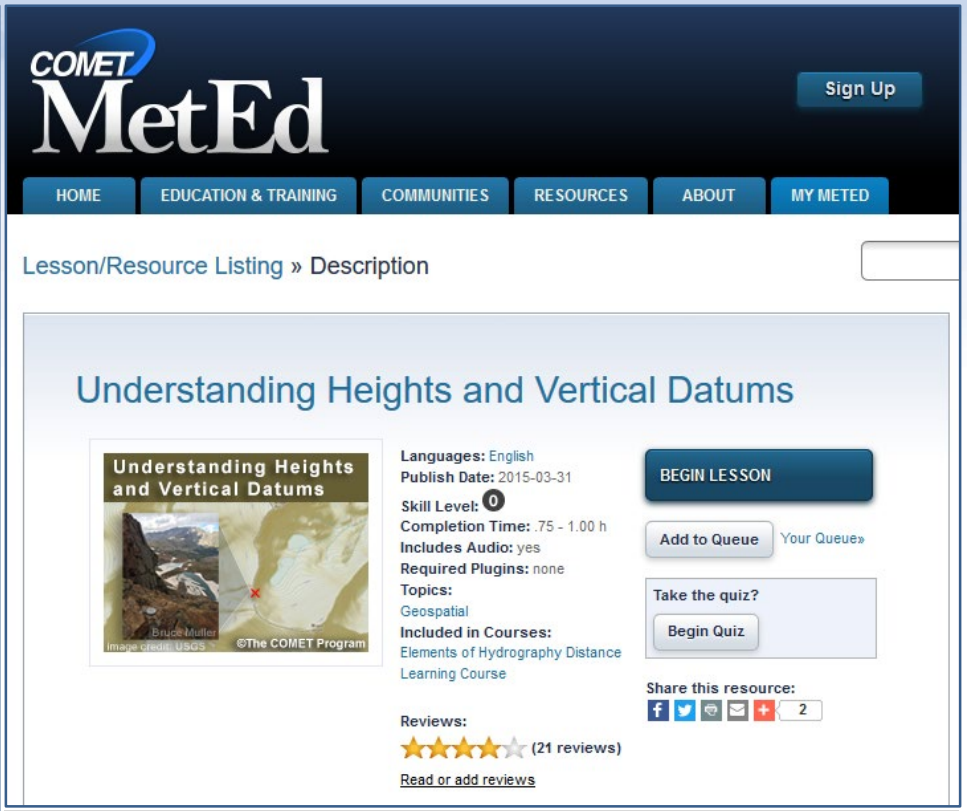
*But will **always** be available in NGS tools for NAD83 and NAD27*

ADDITIONAL RESOURCES

Resources at **geodesy.noaa.gov**

Resources at **geodesy.noaa.gov**

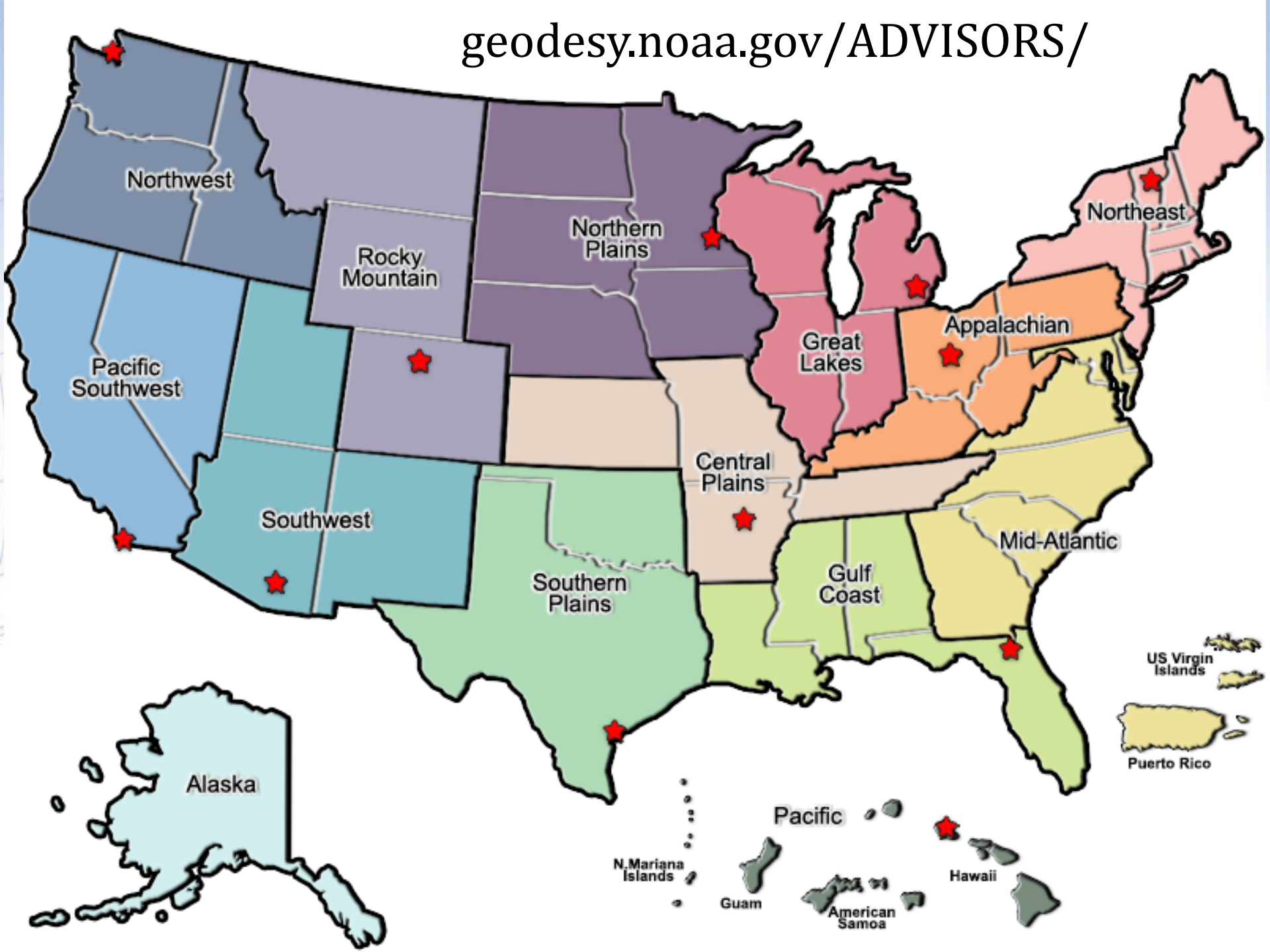




Educational Videos <5 minutes

Online Lesson (via MetEd/COMET) ~1 hour

geodesy.noaa.gov/ADVISORS/



Regional Geodetic Advisor Program

geodesy.noaa.gov/ADVISORS/

- query any major search engine: "ngs advisors"

Appalachian (KY, OH, PA, and WV)

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use any major search engine: "NGS advisors"