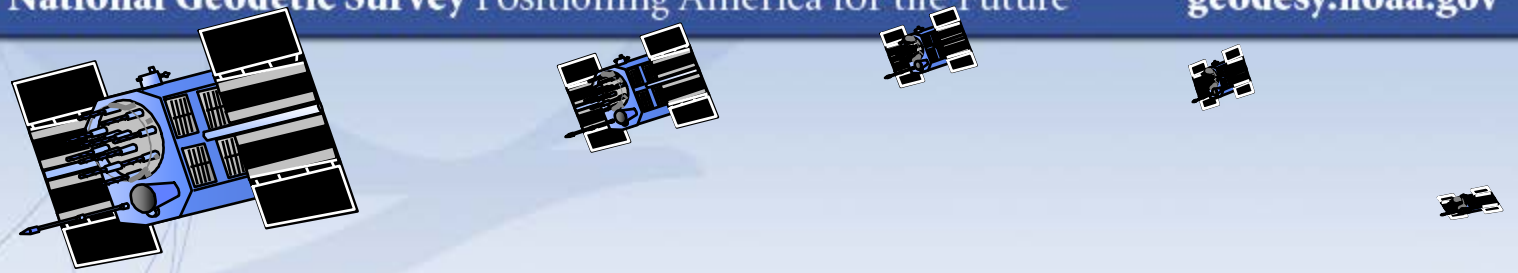


National Geodetic Survey Update: Keeping Up with the Crust … and Technology

(Replacing *NAD83 & NAVD88*)

William (Bill) Stone
Southwest Region (AZ, NM, UT) Geodetic Advisor
william.stone@noaa.gov
NOAA's National Geodetic Survey
geodesy.noaa.gov

April 12, 2019
Santa Fe

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Geodetic Survey

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

- **Latitude**
- **Longitude**
- **Height**
- Gravity
- Orientation
- Scale

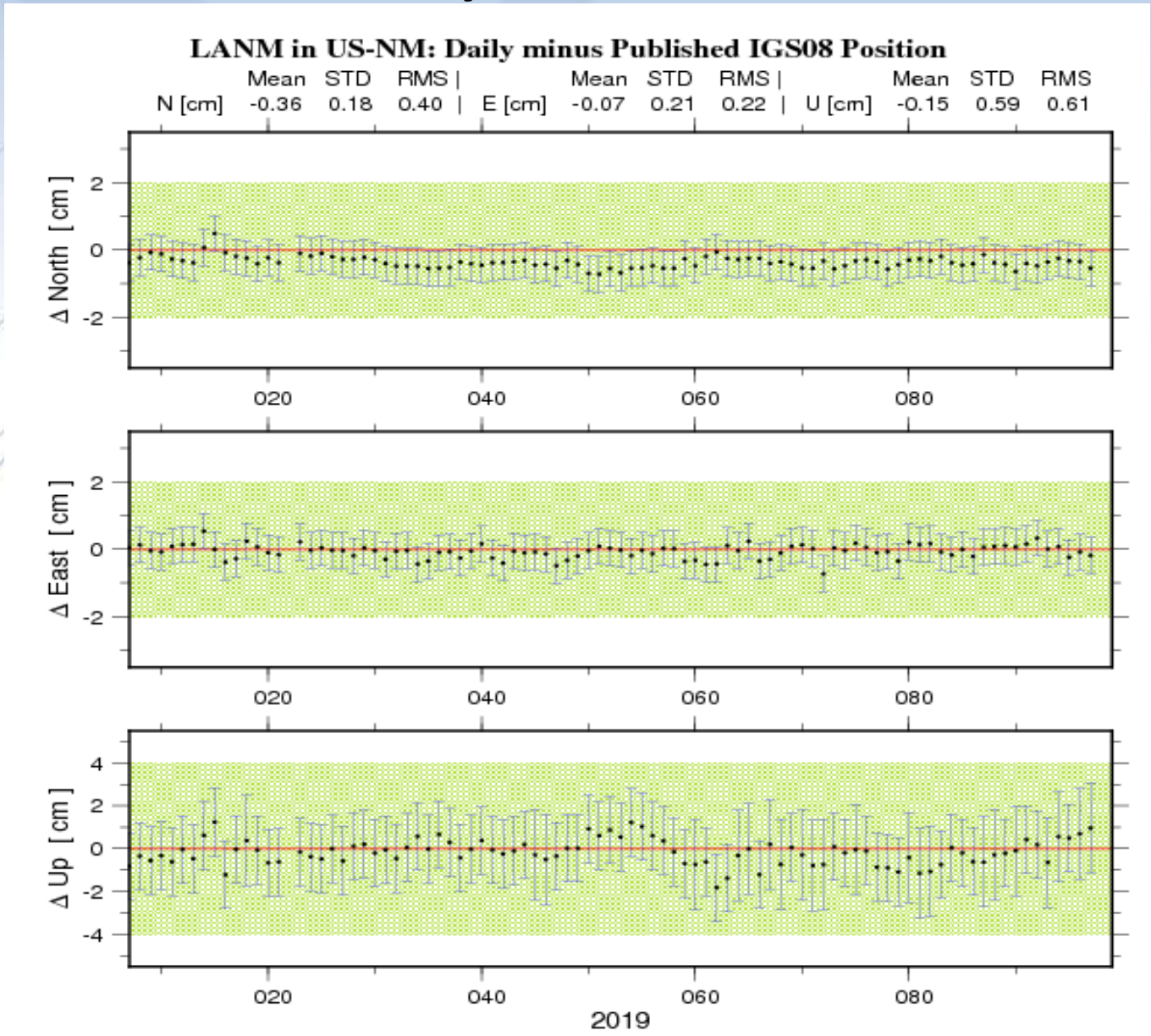
& their time variations

(& National Shoreline, etc.)

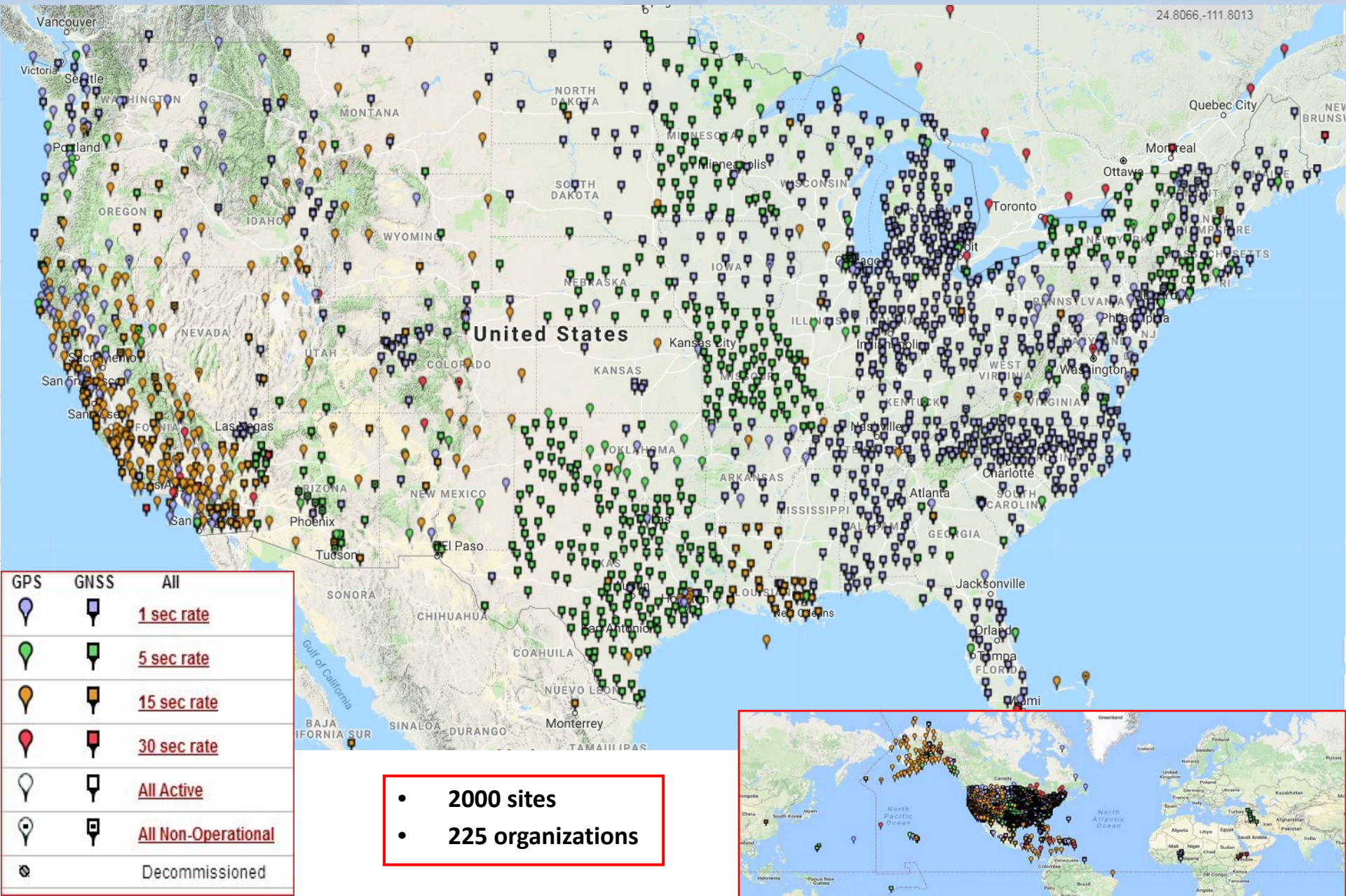
- North American Datum of 1983 (NAD83)
- North American Vertical Datum of 1988 (NAVD88)

Continuously Operating Reference Station (CORS)

CORS 90-Day Time Series Plots



Continuously Operating Reference Station (CORS) Network



- **2000 sites**
- **225 organizations**

LOS ANGELES AIR FORCE BASE

First GPS III satellite successfully launched

SMC Public Affairs / Published December 23, 2018

GPS III

GPS III will meet users' emerging needs and respond to tomorrow's threats with improved safety, signal integrity and unbelievable accuracy.

- On contract for 10 GPS III satellites
- Doubled design life of 15 years
- 3 times more accurate
- 8 times improved anti-jam capability
- L1C Global Navigation Satellite Systems (GNSS) compatibility
- Search and Rescue, Laser Reflector Array and Digital Payload at SV 11+
- Proven compatible with the current GPS constellation and the OCX ground control segment
- Designed to evolve to incorporate new technology and changing mission needs

International Terrestrial Reference Frame ITRF

International Terrestrial Reference Frame (ITRF)

4 Global Independent Positioning Technologies

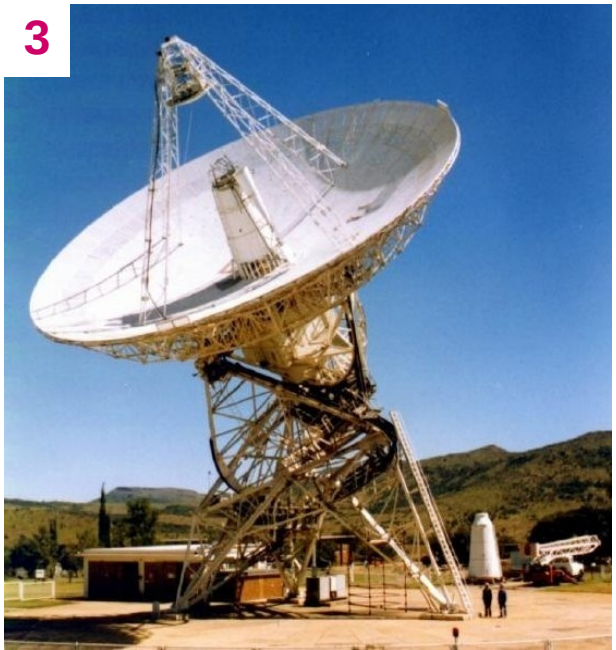
- 1. Global Navigation Satellite Systems (GNSS)
- 2. Satellite Laser Ranging (SLR)
- 3. Very Long Baseline Interferometry (VLBI)
- 4. Doppler Orbitography & Radiopositioning Integrated by Satellite (DORIS)

4

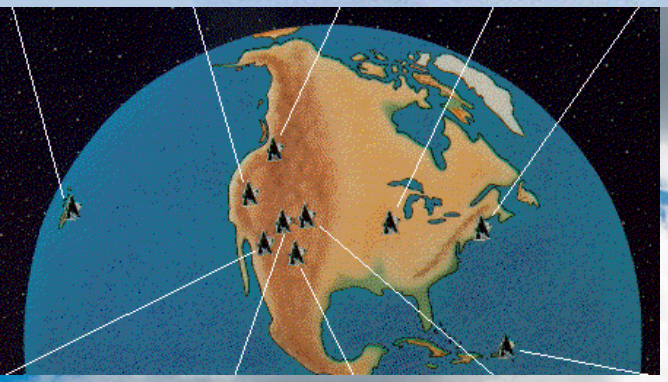
1

2

3



NOAA's National Geodetic Survey Positioning America for the Future



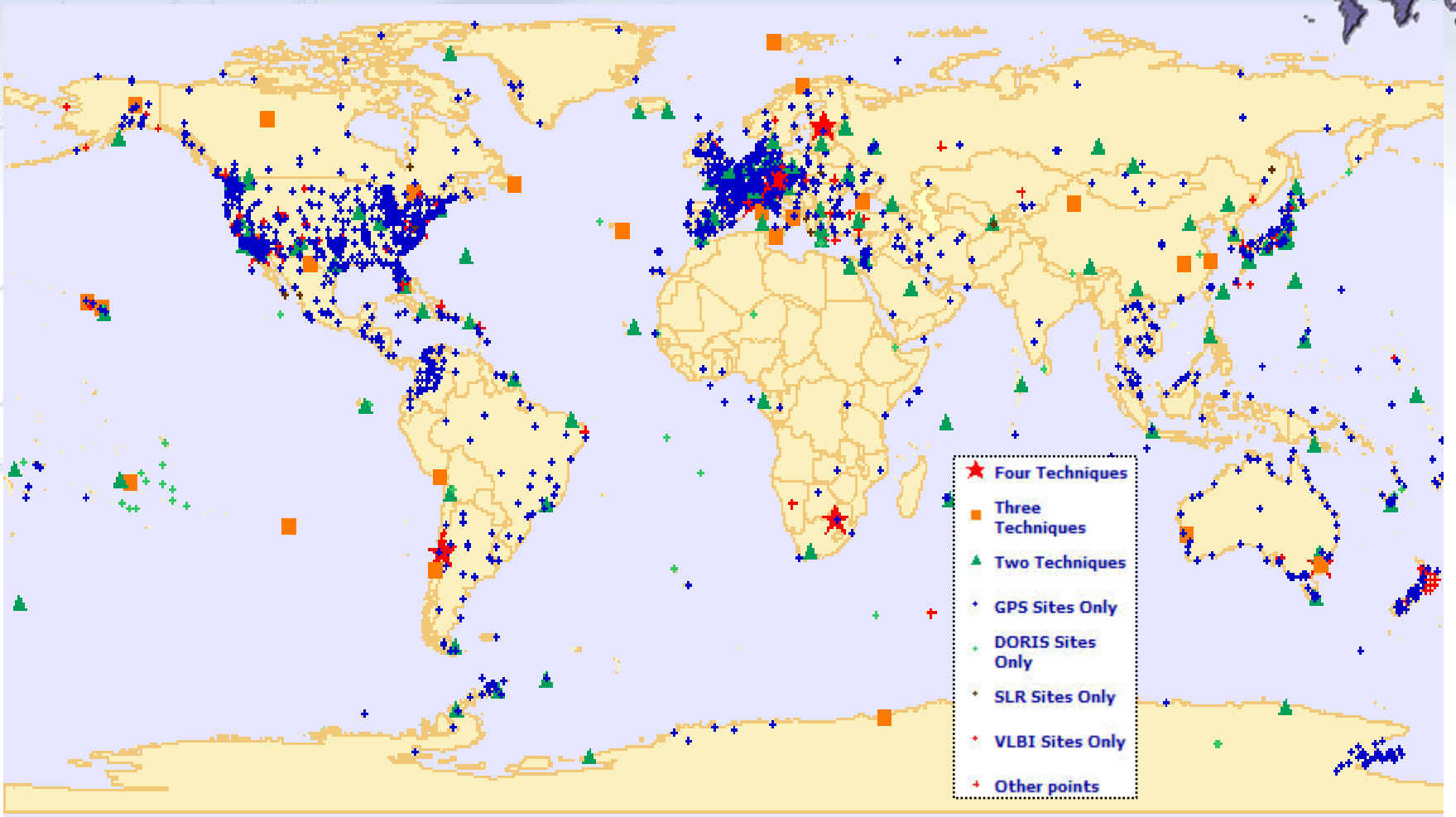
National Radio Astronomy Observatory
Enabling forefront research into the Universe at radio wavelengths

International Terrestrial Reference Frame (ITRF)

space-based techniques: VLBI, DORIS, SLR, GNSS

[International GNSS Service 2008 (IGS08) = GNSS-only realization]

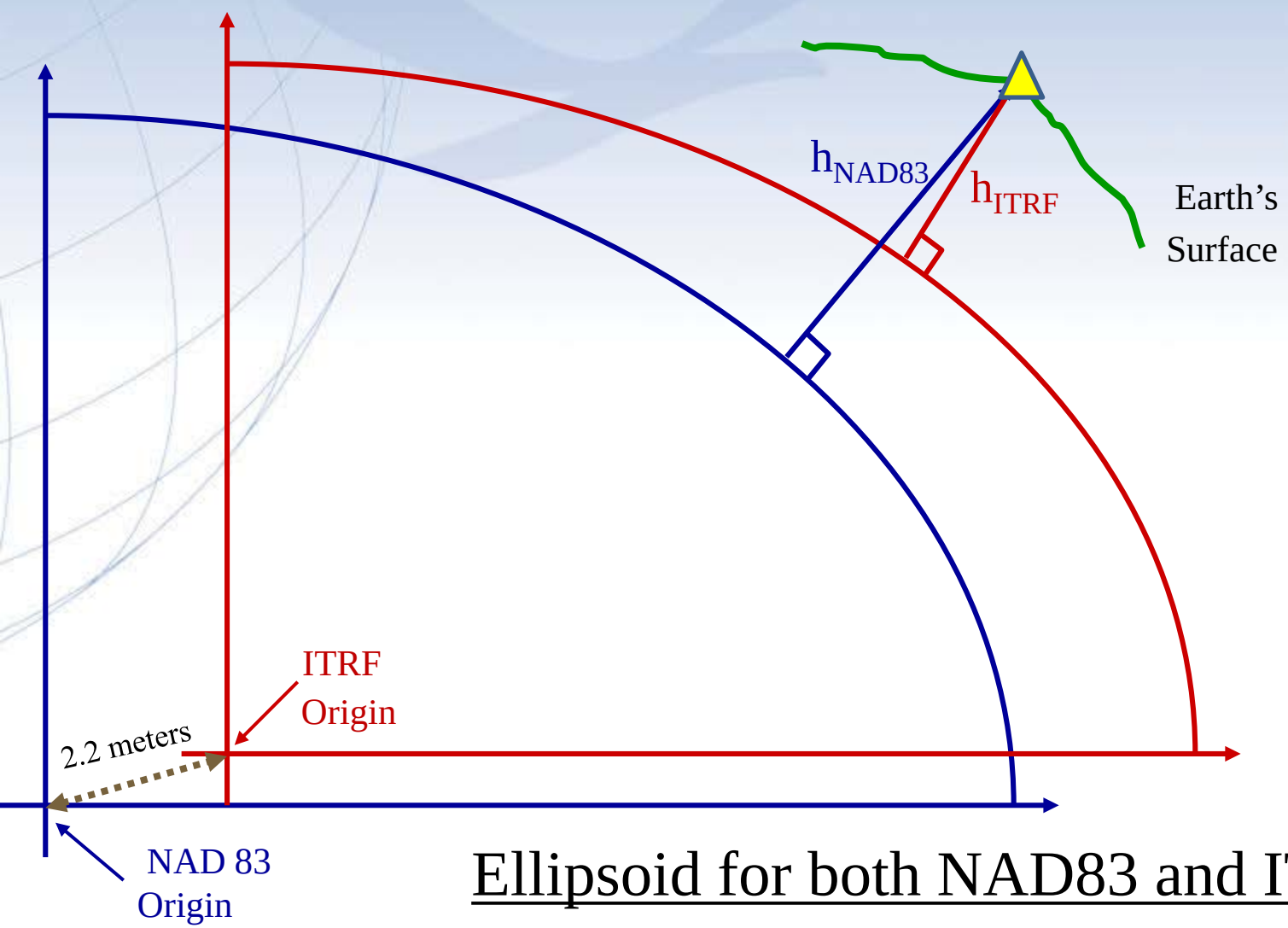
Current version (at NGS): IGS08 (epoch 2005.0)



International Earth Rotation and Reference System Service (IERS)

(http://www.iers.org)

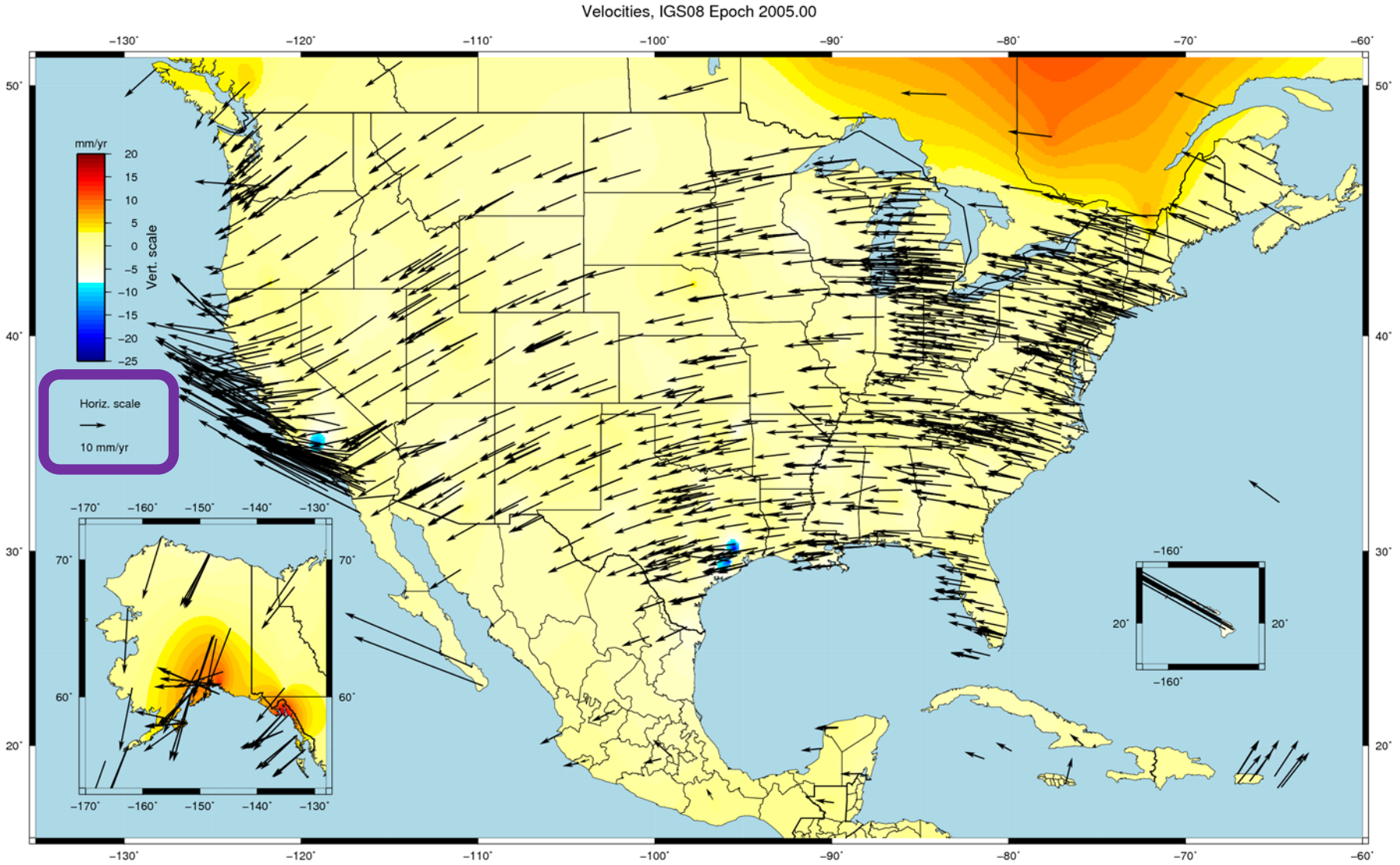
NAD 83 vs. ITRF (IGS & WGS84)



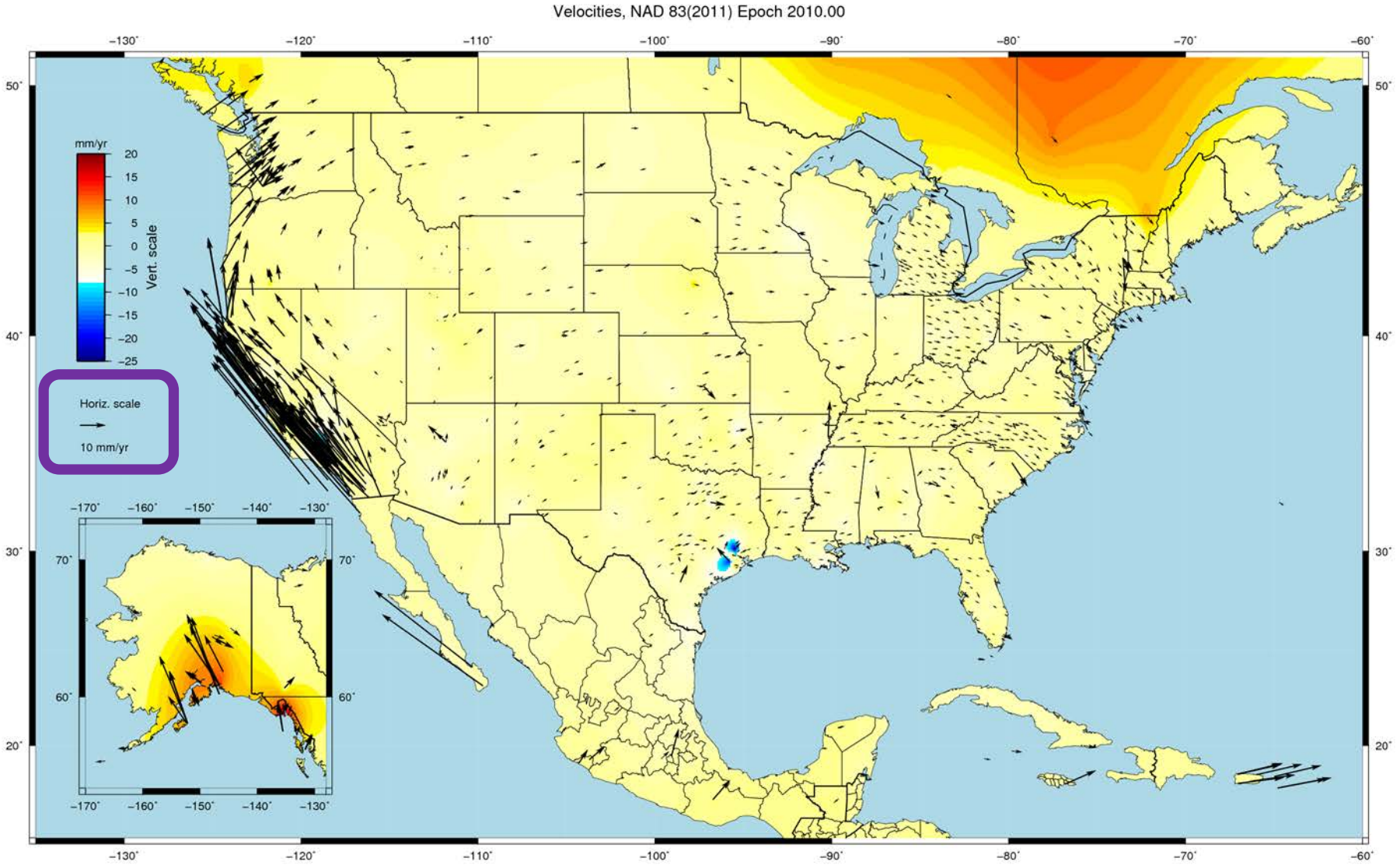
Ellipsoid for both NAD83 and ITRF:

Geodetic Reference System 1980 (GRS80)

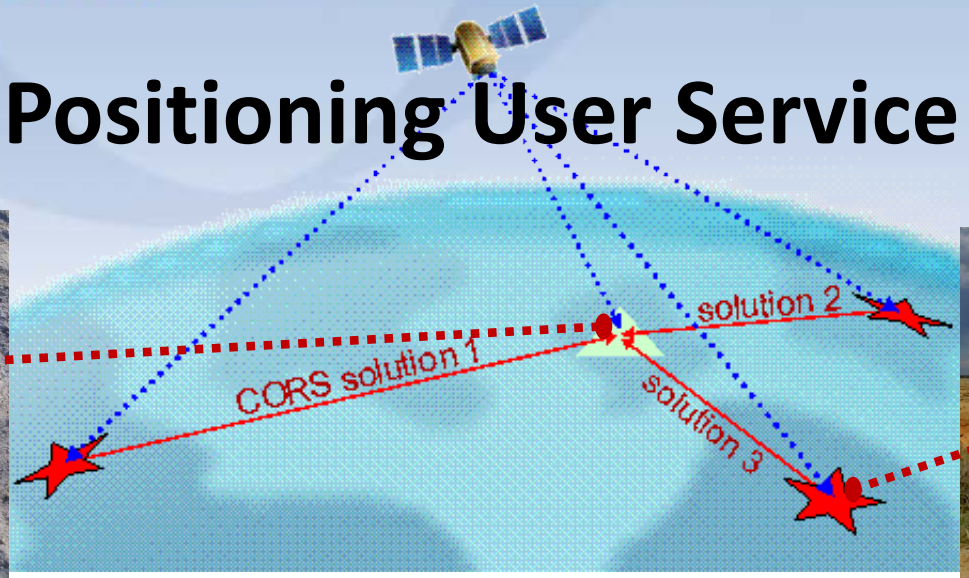
CORS Velocity Field – ITRF (IGS08 epoch2005.00)



CORS Velocity Field – NAD83(2011) epoch 2010.00



Online Positioning User Service (OPUS)



- upload L1/L2 GPS data >>> solution via email in minutes
  - OPUS-RS (Rapid Static) ----15 min to 2 hr (per CORS)
  - OPUS-S (Static) ---- 2 to 48 hr (anywhere)
  - OPUS-DB (Database) --- sharing of results
  - OPUS-Projects --- network of multi-stations/occupations

Fast, easy, consistent access to NSRS

USER: william.stone@noaa.gov DATE: February 24, 2017

RINEX FILE: 3cor054u.17o TIME: 05:29:02 UTC

SOFTWARE: page5 1209.04 master52.pl 160321 START: 2017/02/23 20:52:00

EPHEMERIS: igu19374.eph [ultra-rapid] STOP: 2017/02/23 23:59:00

NAV FILE: brdc0540.17n OBS USED: 7658 / 8153 : 94%

ANT NAME: CHCX90D-OPUS NONE # FIXED AMB: 43 / 45 : 96%

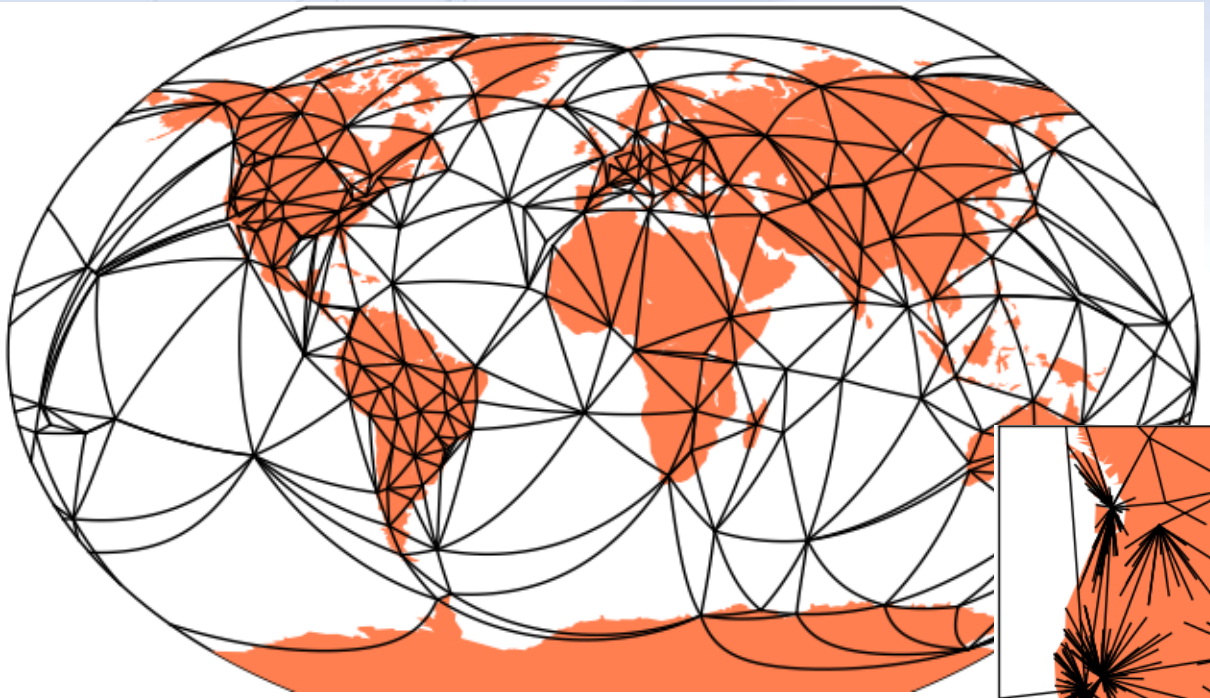
ARP HEIGHT: 0.180 OVERALL RMS: 0.014(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000)		**IGS08** (EPOCH:2017.1478)	
X:	-2078663.057(m) 0.010(m)	-2078663.936(m)	0.010(m)
Y:	-4657799.043(m) 0.014(m)	-4657797.727(m)	0.014(m)
Z:	3817863.470(m) 0.003(m)	3817863.352(m)	0.003(m)

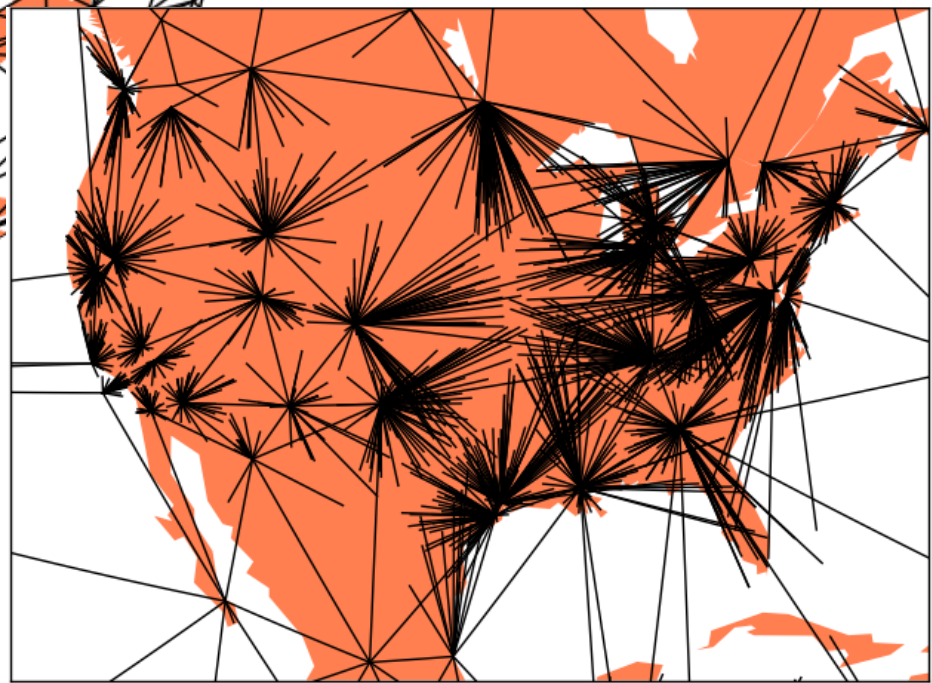
LAT:	37 0 0.69689 0.005(m)	37 0 0.71029	0.005(m)
E LON:	245 56 59.81599 0.015(m)	245 56 59.76184	0.015(m)
W LON:	114 3 0.18401 0.015(m)	114 3 0.23816	0.015(m)
EL HGT:	752.973(m) 0.009(m)	752.229(m)	0.009(m)

ORTHO HGT: 778.810(m) 0.021(m) [NAVD88 (Computed using GEOID12B)]

NGS Multi-year CORS Solution-2 Processing Transitioning to ITRF2014/IGS14 (@2010.00)

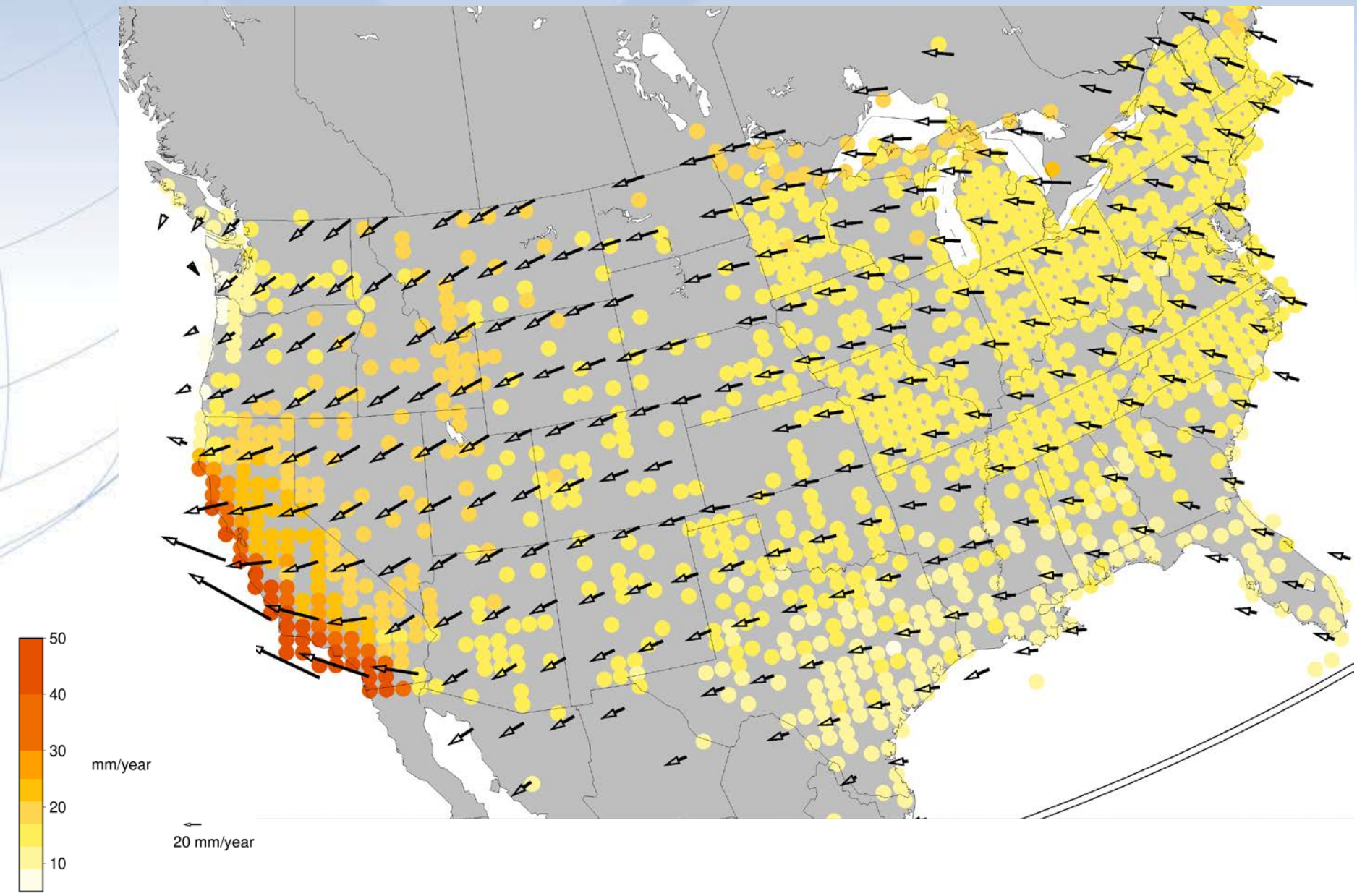


International Terrestrial Reference Frame
ITRF



- 1996 -2016 data
- 3050 stations
- 25 TerraBytes of data

CORS MYCS2 Horizontal IGS14 Velocity



BETA
This is a BETA Release Site

OPUS: Online Positioning User Service

National Geodetic Survey

OPUS menu

home / upload
about OPUS
projects
shared solutions
support / feedback

BETA OPUS: now using ITRF2014

The new ITRF2014 reference frame for CORS, used below, provides more recently updated CORS positions and velocities than are available in the older IGS08 frame.

Is the antenna list broken? clear browser history & reload page

Upload your data file.

Solve your GPS position & tie it to the National Spatial Reference System.

What is OPUS? **FAQs**

Choose File No file chosen

* **data file** of dual-frequency GPS observations. **sample**

sample solutions

NONE

antenna - choosing wrong may degrade your accuracy.

0.000 *meters above your mark.*

antenna height of your antenna's reference point.

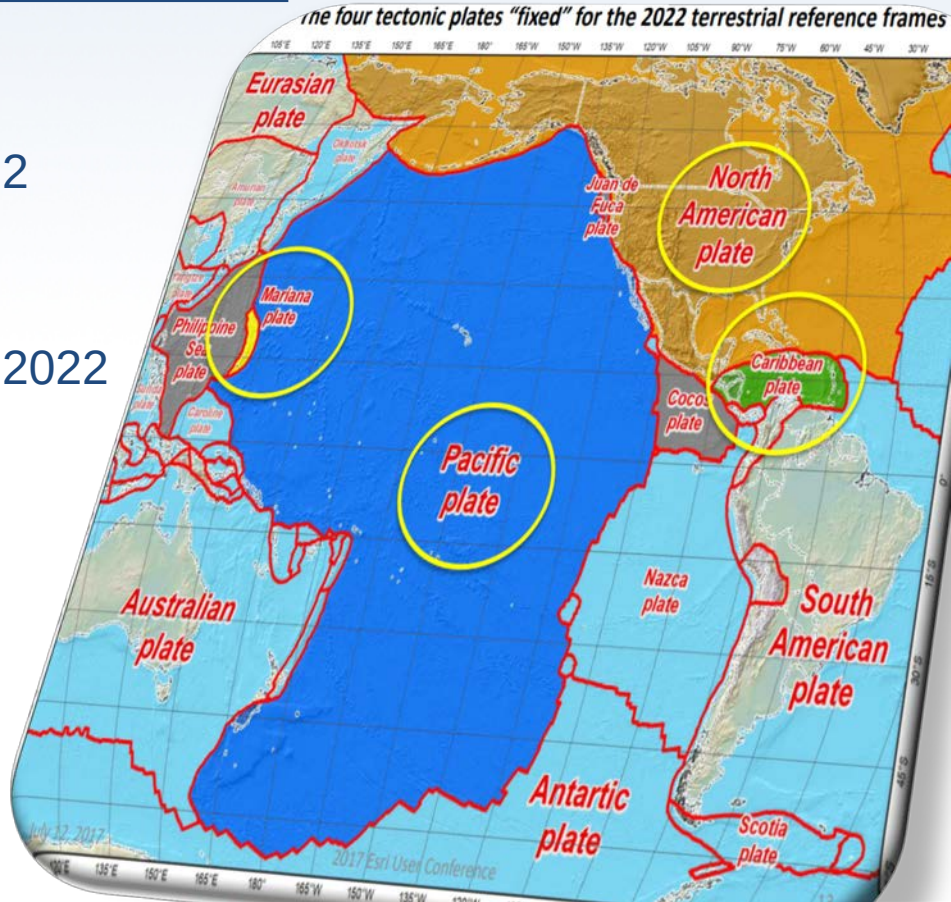
Replacing NAD83

- NAD83 replaced in 2022 by **4 "*plate-fixed*"** reference frames
- defined by **CORS** (GNSS data, coordinates, velocities, antennas)
- removes **non-geocentricity** of NAD 83 by aligning w/ global International Terrestrial Reference Frame of 2014 (**IGS14**)
- identical to **IGS14 at 2020.00**, then diverges
- removes most of tectonic plate rotation from IGS14 using plate rotation modeling
- CORS velocities deviating from rigid-plate rotation captured in **3-D velocity model** (to transform to fixed epoch)

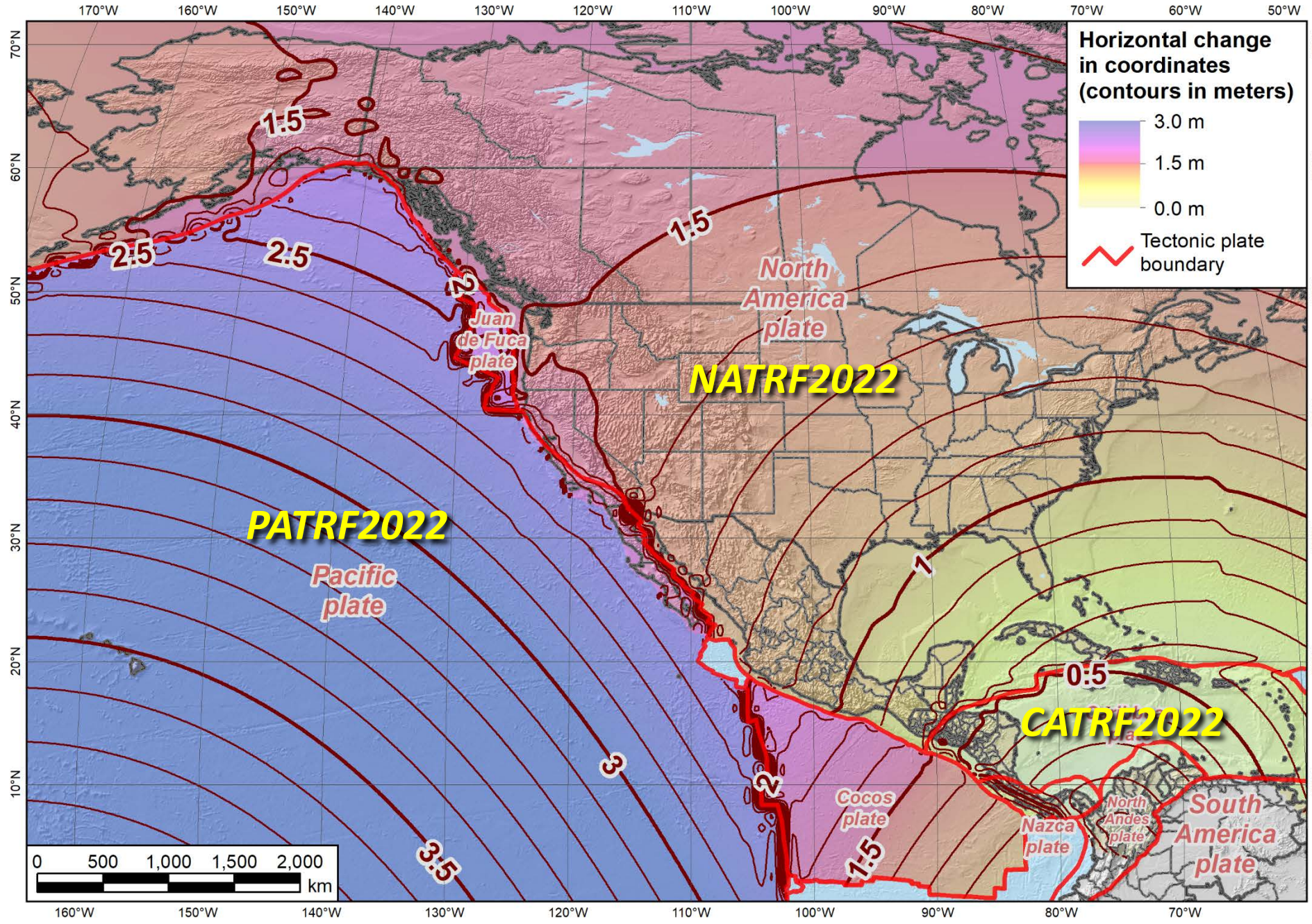
4 Reference Frames & Tectonic Plates

In 2022, the National Spatial Reference System will be modernized with
4 new geometric reference frames:

- **North American Terrestrial Reference Frame of 2022** (NATRF2022)
- Pacific Terrestrial Reference Frame of 2022 (PATRF2022)
- Caribbean Terrestrial Reference Frame of 2022 (CATRF2022)
- Mariana Terrestrial Reference Frame of (MATRF2022)

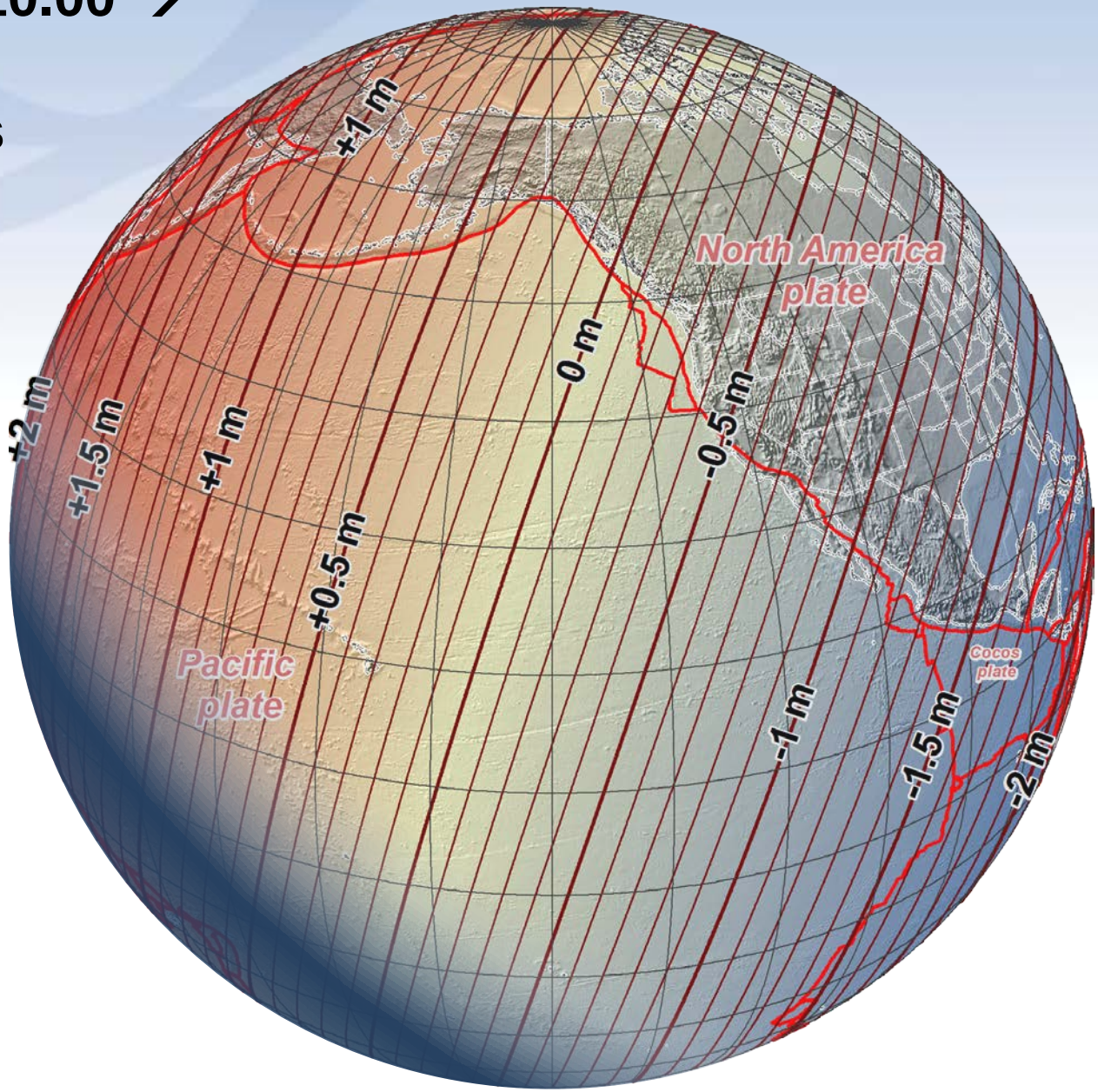


Horizontal change in coordinates: NAD 83 epoch 2010.0 → TRF2022 epoch 2020.0



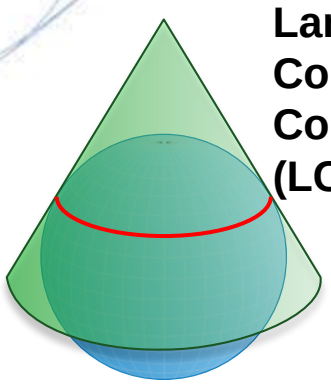
NAD 83 epoch 2010.00 → 2022 Terrestrial Reference Frames

Change in ellipsoid heights at epoch 2020.00
(contours in meters)

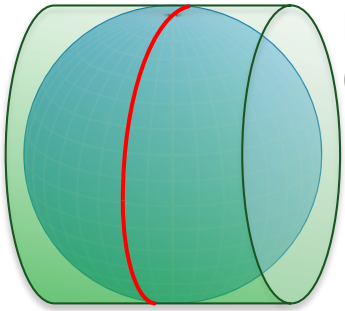


A New State Plane Coordinate System

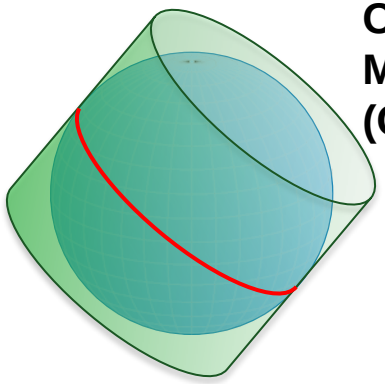
- **State Plane Coordinate System of 2022 (SPCS2022)**
  - Referenced to 2022 Terrestrial Reference Frames (TRFs)
  - Based on same ellipsoid as NAD83 / SPCS 83 (GRS 80)
  - Same 3 ***conformal*** projection types as SPCS 83 and 27:



Lambert Conformal Conic (LCC)



Transverse Mercator (TM)



Oblique Mercator (OM)

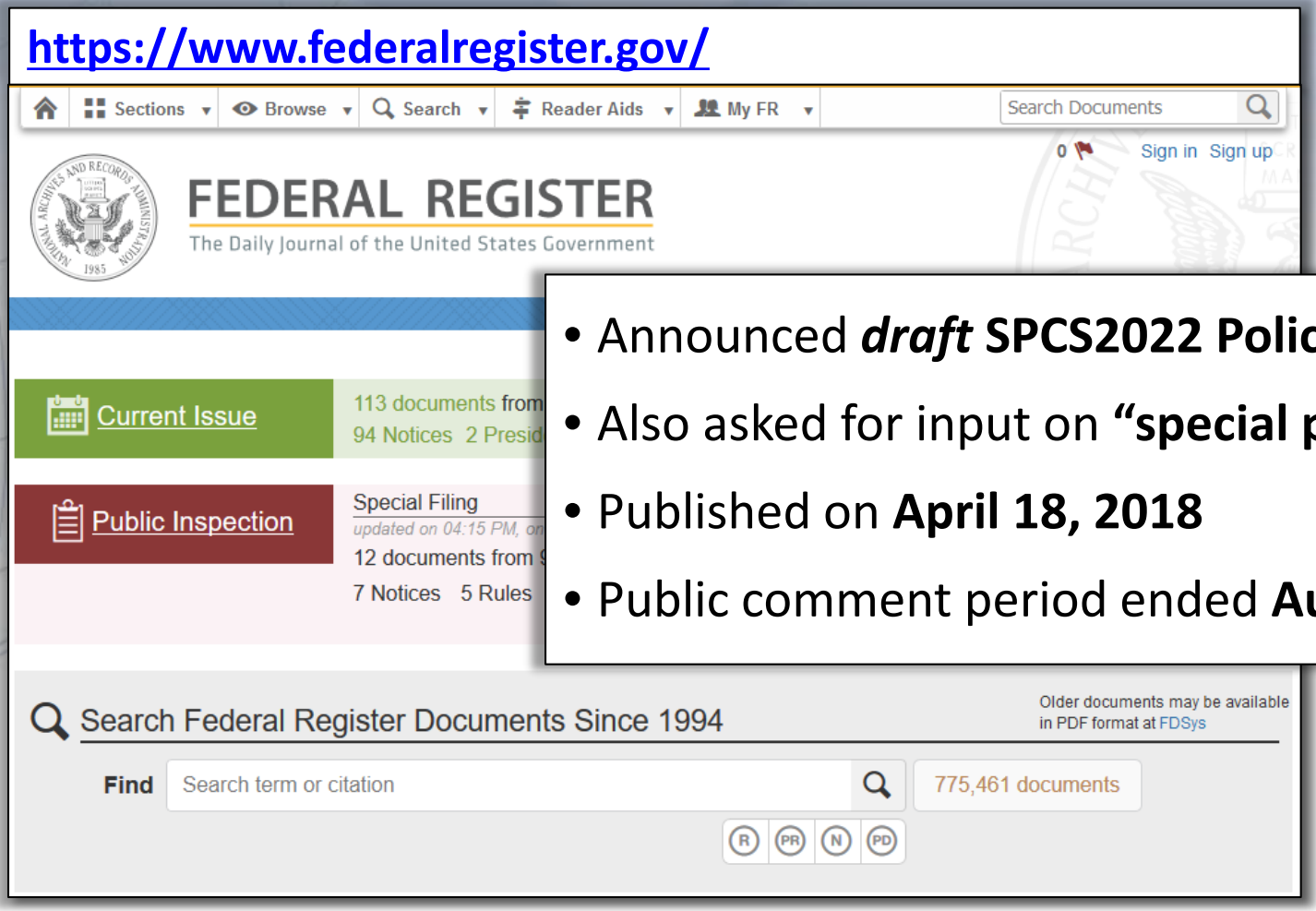
Past Year's NGS SPCS2022 Activity

- Publish State Plane history report: **March 2018**
- Webinars on **March, April 2018; March 2019**
- Launch new SPCS web pages: **March 2018**
- Publish Federal Register Notice (FRN) and

  draft SPCS2022 Policy & Procedures: **April 2018**
- FRN response deadline: **August 2018**
- First preliminary design maps: **October 2018**
- Finalizing policy & procedures: ***Right now … any day!***

Federal Register Notice

https://www.federalregister.gov/



- Announced ***draft*** **SPCS2022 Policy and Procedures**
- Also asked for input on **"special purpose"** zones
- Published on **April 18, 2018**
- Public comment period ended **Aug 31, 2018**

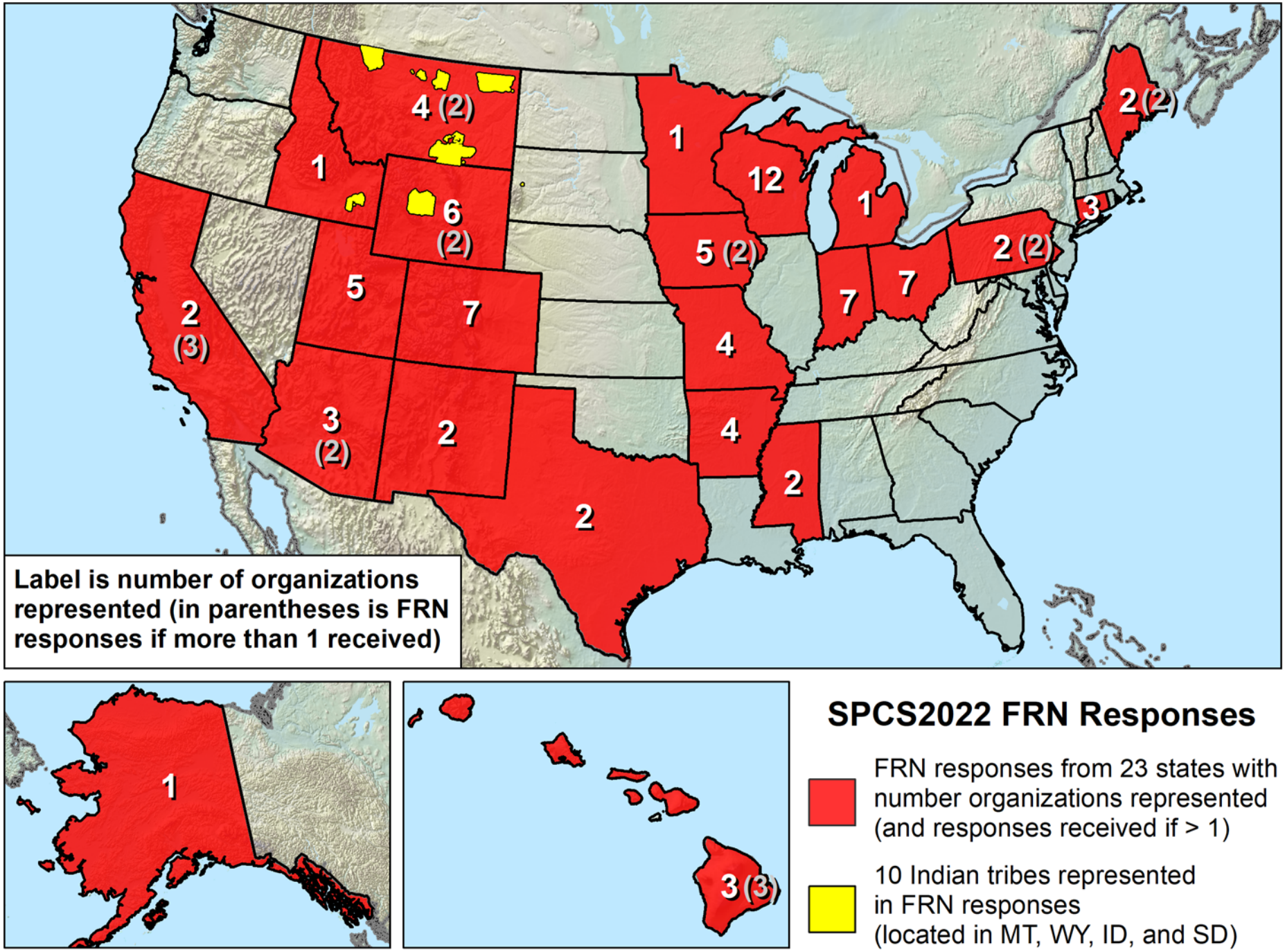
Overview of SPCS2022 Federal Register Notice feedback

- FRN public comment period April 18-Aug 31, 2018
  - For ***draft*** SPCS2022 policy & procedures
  - Wide variety of formats and content
  - Individuals, organizations, and groups of organizations
- Received 41 unique responses:
  - 4 national in scope (3 from USGS)
  - 3 for Native American tribes
  - 1 regional (3 states)
  - 33 from states
- 105 people represented by name
- 97 organizations represented

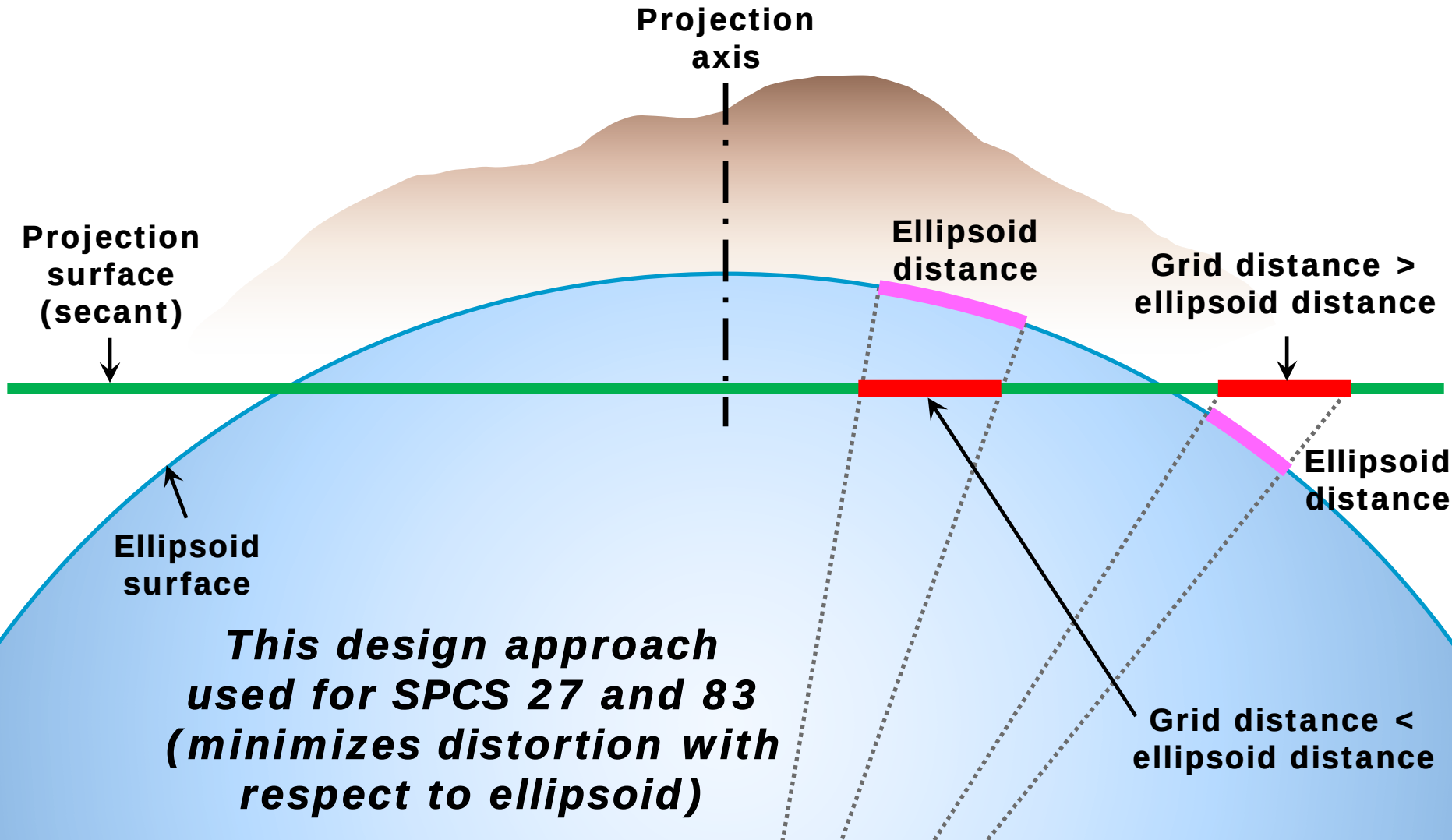
Changes to SPCS2022 Policies

Summary of main changes

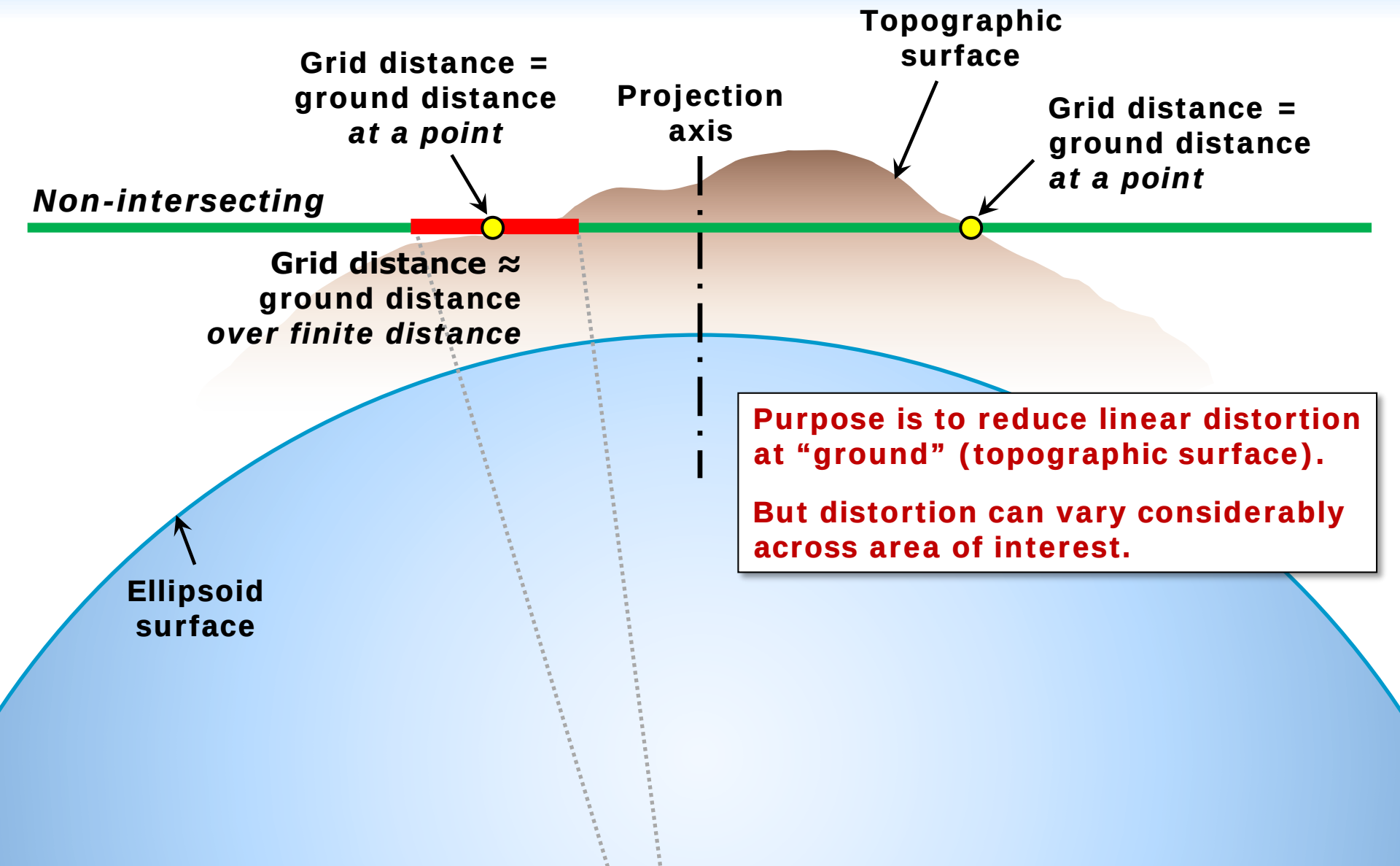
- Allow "special use" zones
  - But only for zone areas in more than 1 state
- NGS will design statewide zone for every state
  - Also will design default zones if no consensus request for something different from state stakeholders
- Allow max of 3 layers (1 statewide + 2 multi-zone)
  - But most states will have 1 or 2 layers
- Added requirement that all zones be unique
- Require positive east longitudes


4 (2)
1
6 (2)
5
7
2 (3)
3 (2)
2
2
1
12
1
5 (2)
4
4
2
7
7
2 (2)
3
2 (2)
Label is number of organizations represented (in parentheses is FRN responses if more than 1 received)
1
3 (3)
SPCS2022 FRN Responses
FRN responses from 23 states with number organizations represented (and responses received if > 1)
10 Indian tribes represented in FRN responses (located in MT, WY, ID, and SD)

Linear distortion *with respect to ellipsoid*



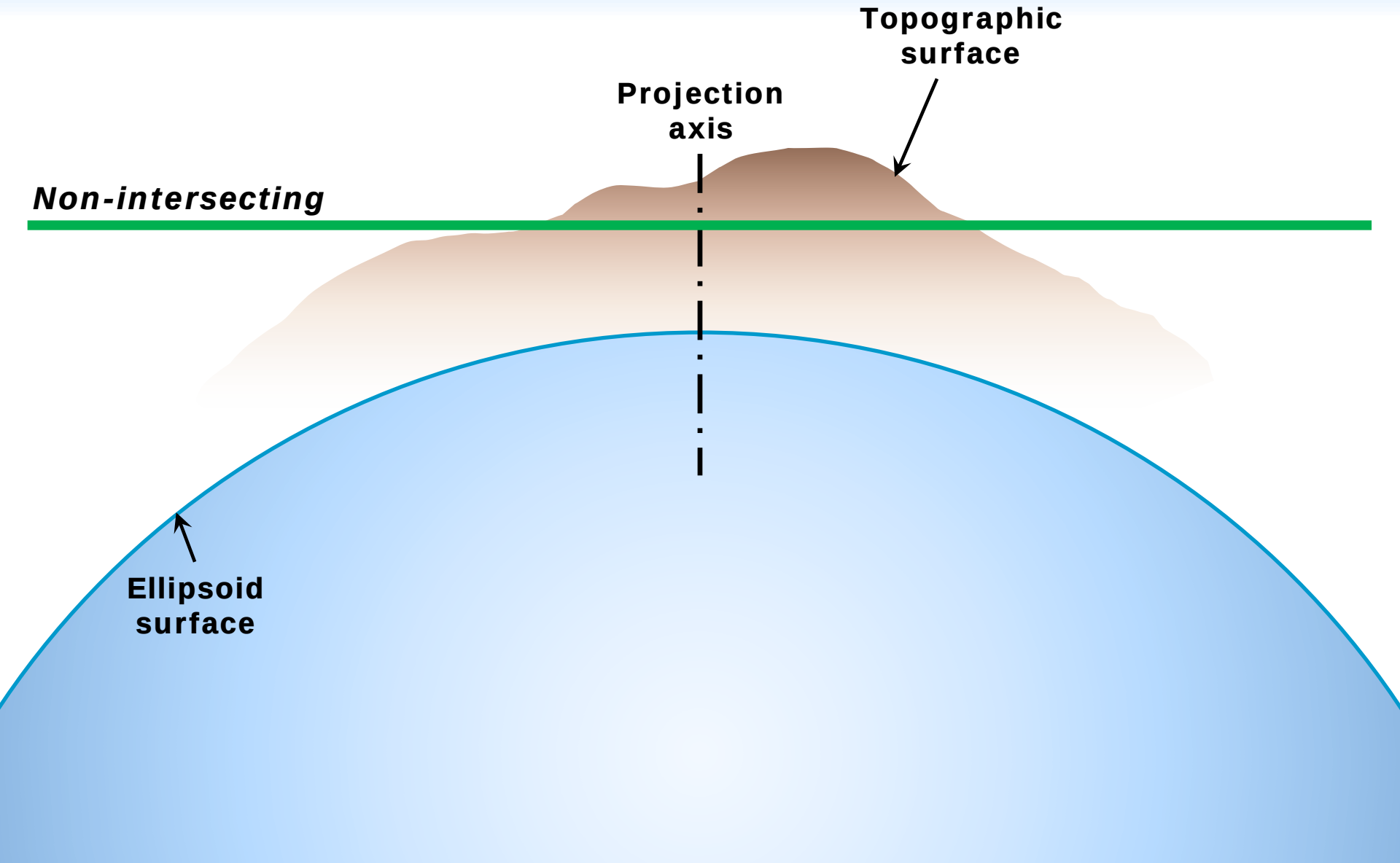
“Non-intersecting” conformal map projection



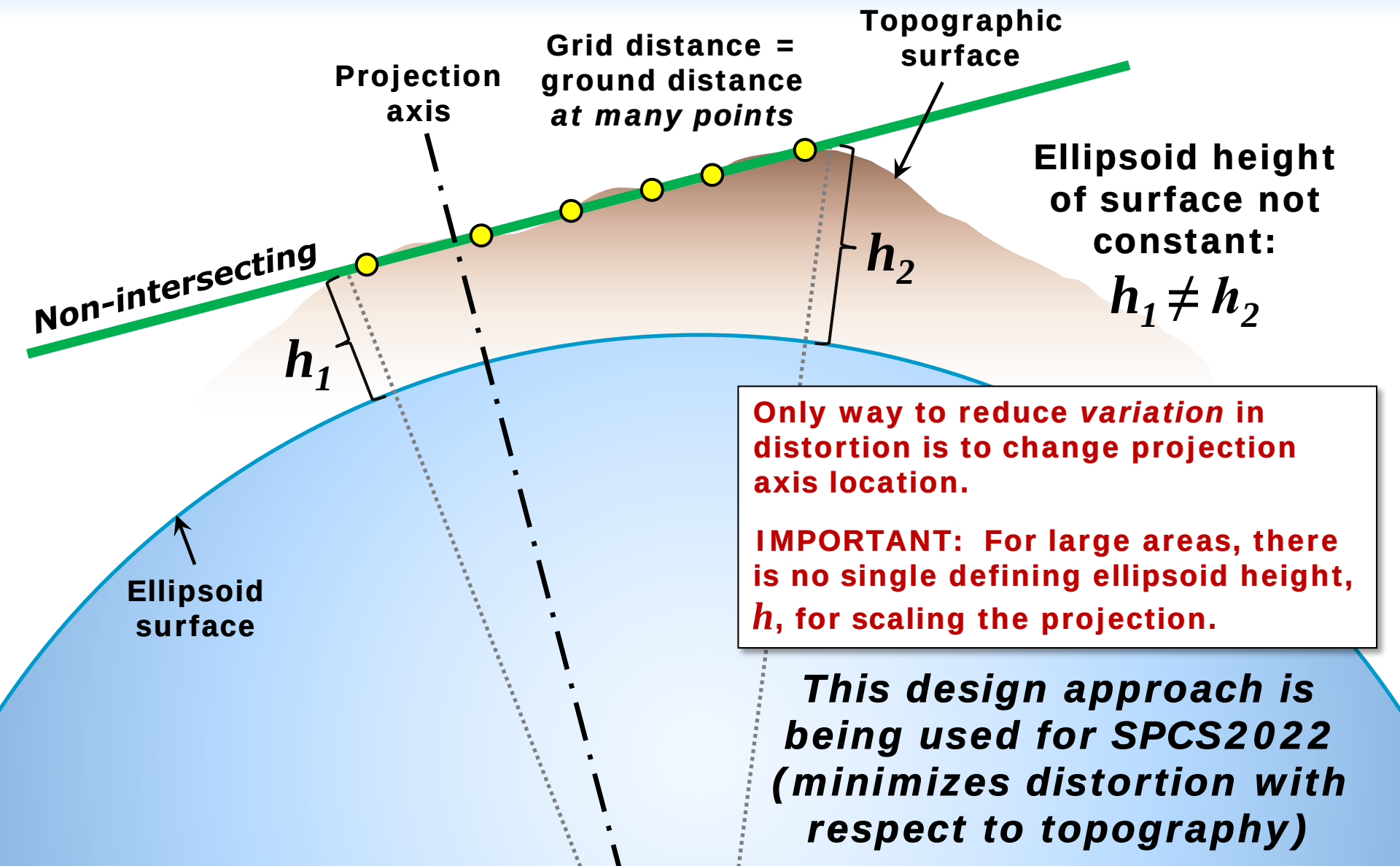
Purpose is to reduce linear distortion at “ground” (topographic surface).

But distortion can vary considerably across area of interest.

“Non-intersecting” conformal map projection



Changing projection axis to reduce distortion variation



Only way to reduce *variation* in distortion is to change projection axis location.

IMPORTANT: For large areas, there is no single defining ellipsoid height, h, for scaling the projection.

This design approach is being used for SPCS2022 (minimizes distortion with respect to topography)

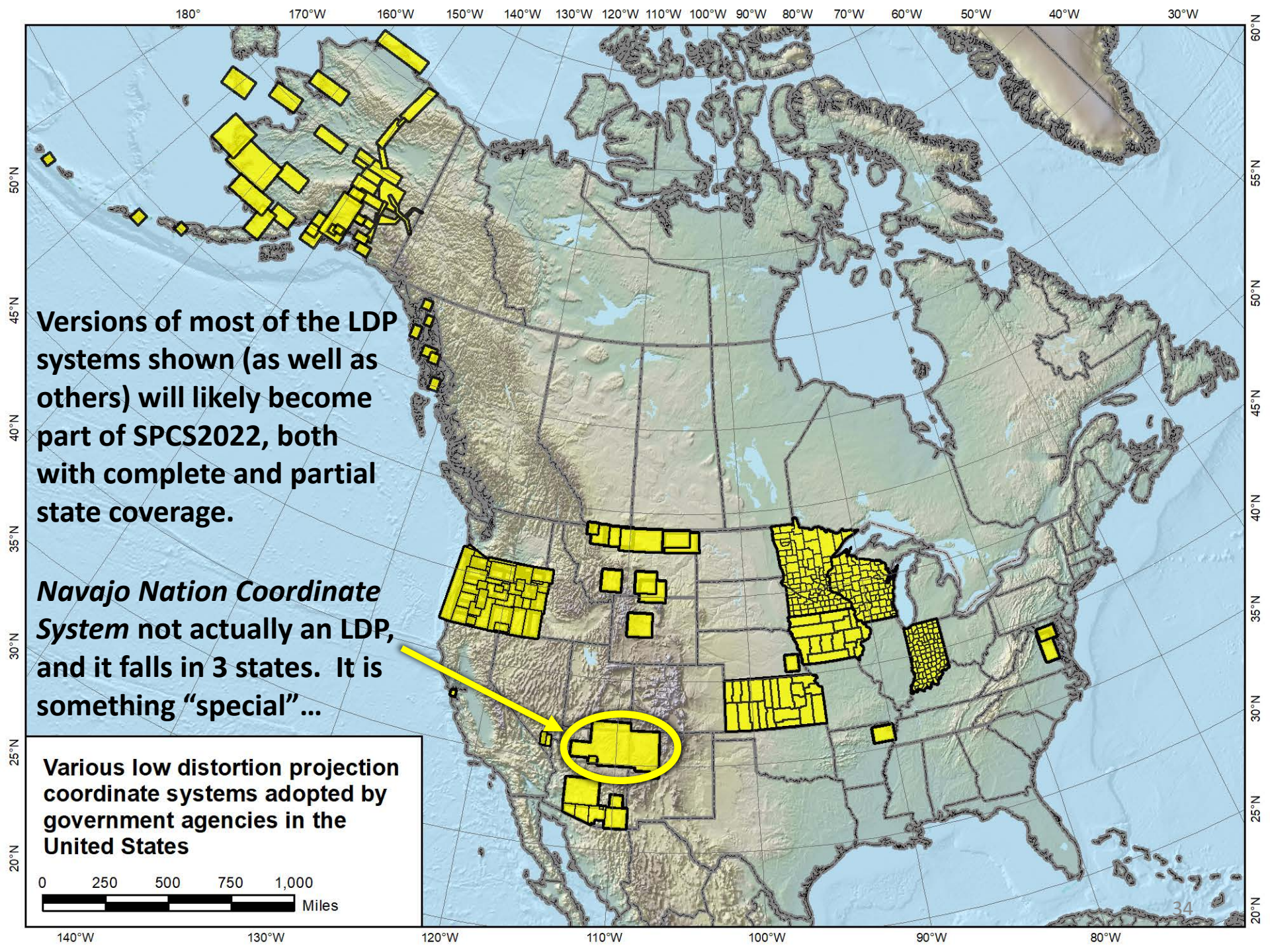
Default SPCS2022 zones

- To ensure ***all*** states and U.S. territories covered
  - For complete system if no consensus stakeholder input
  - Nearly same as SPCS 83 but with some changes
  - Almost all zone projection types and extents the same
- Modify existing zones to meet SPCS2022 policy
  - Scale redefined with respect to **topographic surface**
  - Use 1-parallel Lambert and local Oblique Mercator
- Will also create a statewide zone for ***all*** states

Zone "layers" and LDPs

- Each state may have max of ***THREE*** zone "layers"
  - One layer *must* be statewide zone (designed by NGS)
  - Other layers have two or more zones ("multi-zone")
  - Only one layer can have discontinuous coverage

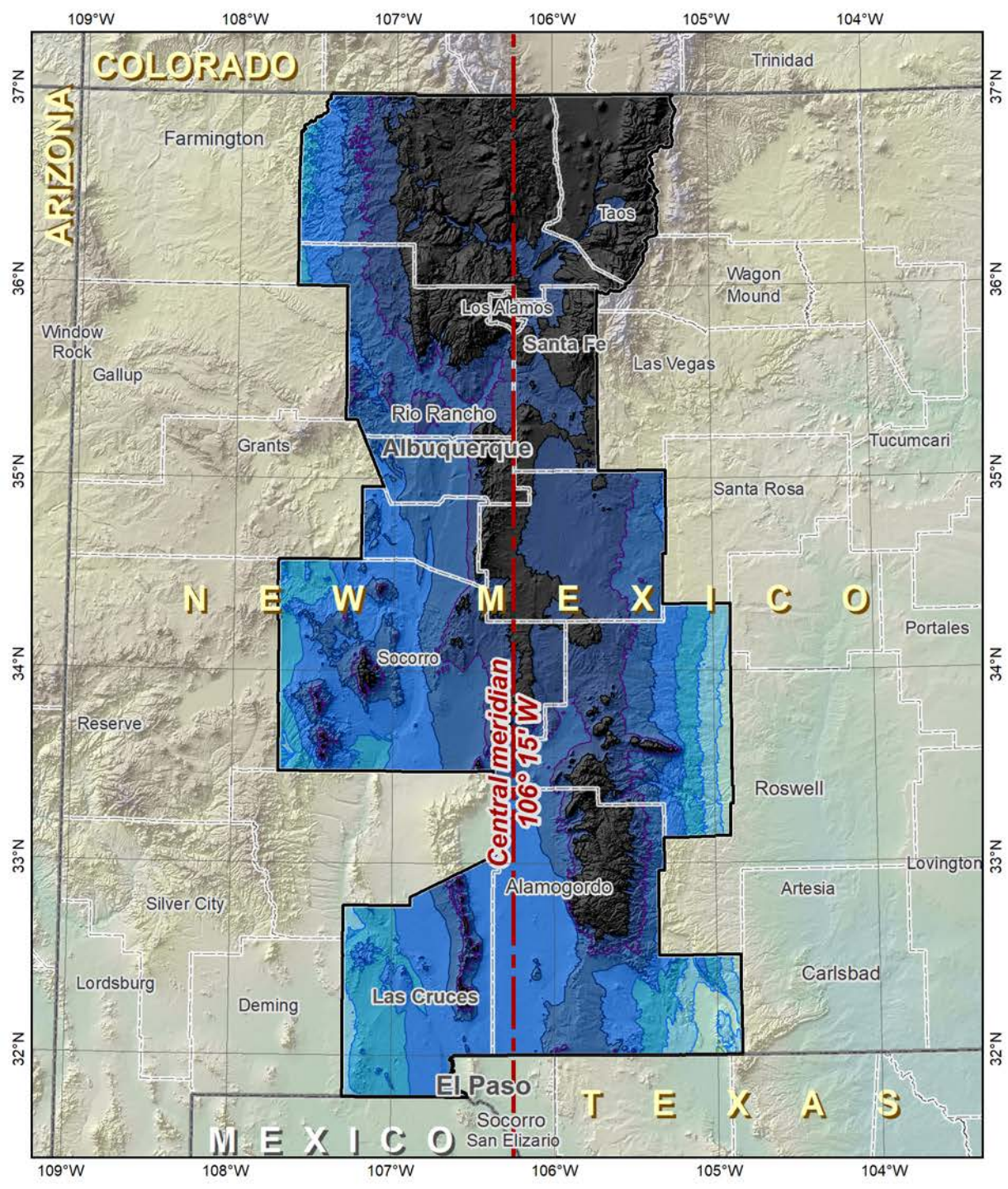
- Multi-zone layer can consist of LDPs
  - Designed by stakeholder "contributing partners"
  - Minimum zone width 50 km (if height range < 250 m)
    OR 10 km (if height range > 250 m)
  - LDP coverage can be discontinuous


Versions of most of the LDP systems shown (as well as others) will likely become part of SPCS2022, both with complete and partial state coverage.
Navajo Nation Coordinate System not actually an LDP, and it falls in 3 states. It is something "special"…
Various low distortion projection coordinate systems adopted by government agencies in the United States
0 250 500 750 1,000
Miles
180° 170°W 160°W 150°W 140°W 130°W 120°W 110°W 100°W 90°W 80°W 70°W 60°W 50°W 40°W 30°W
60°N 55°N 50°N 45°N 40°N 35°N 30°N 25°N 20°N
140°W 130°W 120°W 110°W 100°W 90°W 80°W

"Special use" SPCS2022 zones

- Zones for regions in ***more than one state***
- Categories:
  - Major urban areas (e.g., New York, Chicago, St. Louis)
  - Large American Indian reservations (e.g., Navajo Nation)
  - Large federal jurisdictions or applications

    (e.g., Yellowstone National Park, mapping of Atlantic Coast)
- Requires NGS Director approval (case-by-case basis)



Existing SPCS 83 design: New Mexico Central Zone

NOAA's National Geodetic Survey

Transverse Mercator projection

North American Datum of 1983

Central meridian: 106° 15' W
Cen merid scale: 0.999 9 (exact)

Areas within ±100 ppm distortion (±0.53 ft per mile):
0% of entire zone
0% of all cities and towns
0% of population

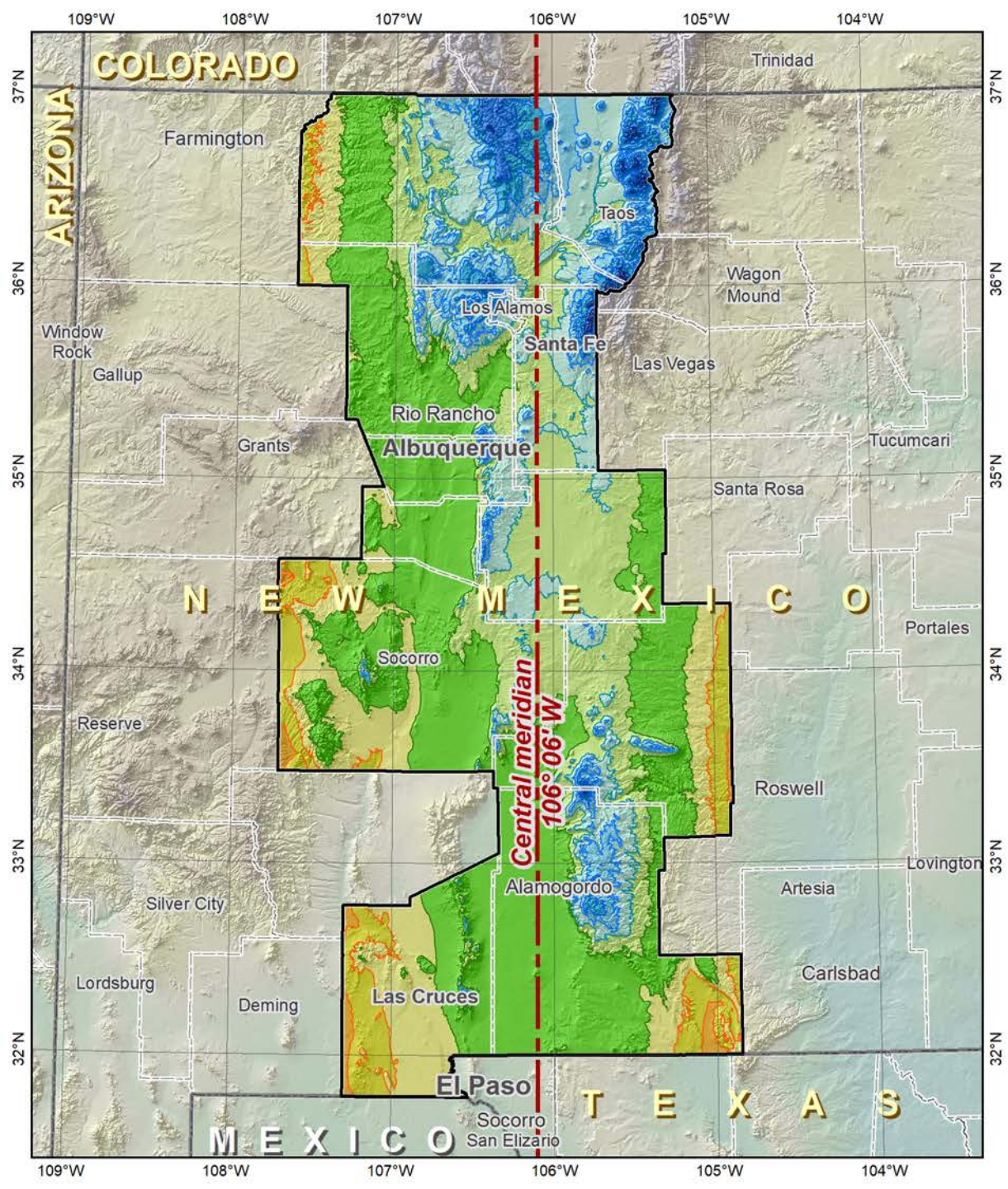
Distortion values (ppm)

Entire zone:	*Cities and towns:*
Min = -670	Min, Max = -484, -151
Max = -94	Range = 333
Range = 576	Median = -364
Mean = -346	Mean = -323 (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 50 100 150 200 250 km



Preliminary SPCS2022 default design: New Mexico Central Zone

NOAA's National Geodetic Survey

Transverse Mercator projection

North American Terrestrial Reference Frame of 2022

Central meridian: 106° 06' W
Cen merid scale: 1.000 21 (exact)

Areas within ±100 ppm distortion (±0.53 ft per mile):
70% of entire zone
76% of all cities and towns
90% of population

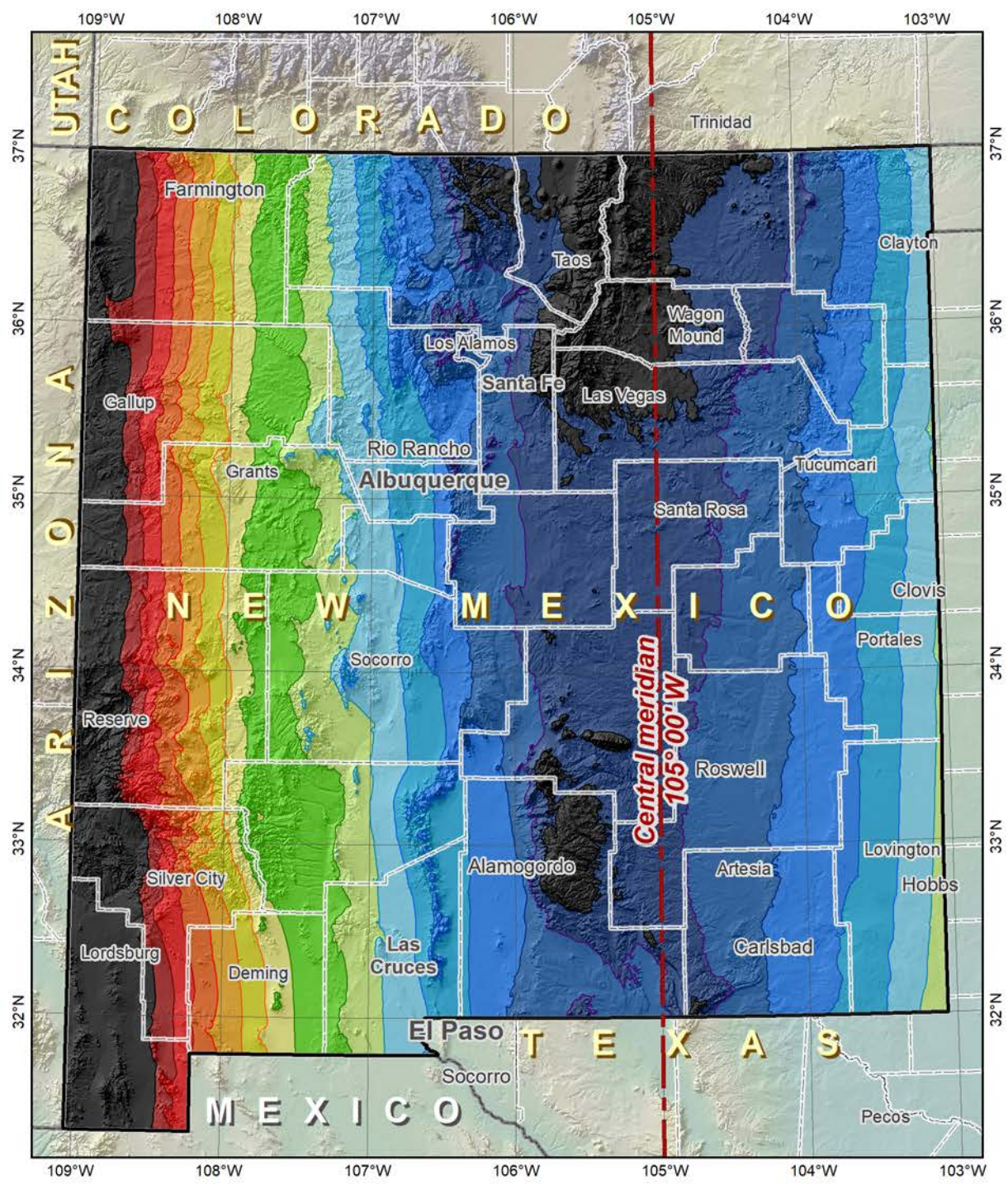
Distortion values (ppm)

Entire zone:	***Cities and towns:***
Min = -376	Min, Max = -188, +164
Max = +117	Range = 352
Range = 493	Median = -58
Mean = -32	Mean = -2 (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 50 100 150 200 250 km



Existing UTM Zone 13 North used as statewide zone: New Mexico

NOAA's National Geodetic Survey

Transverse Mercator projection

North American Datum of 1983

Central meridian: 105° 00' W
Cen merid scale: 0.999 6 (exact)

Areas within ±400 ppm distortion (±2.11 ft per mile):
37% of entire zone
37% of all cities and towns
71% of population

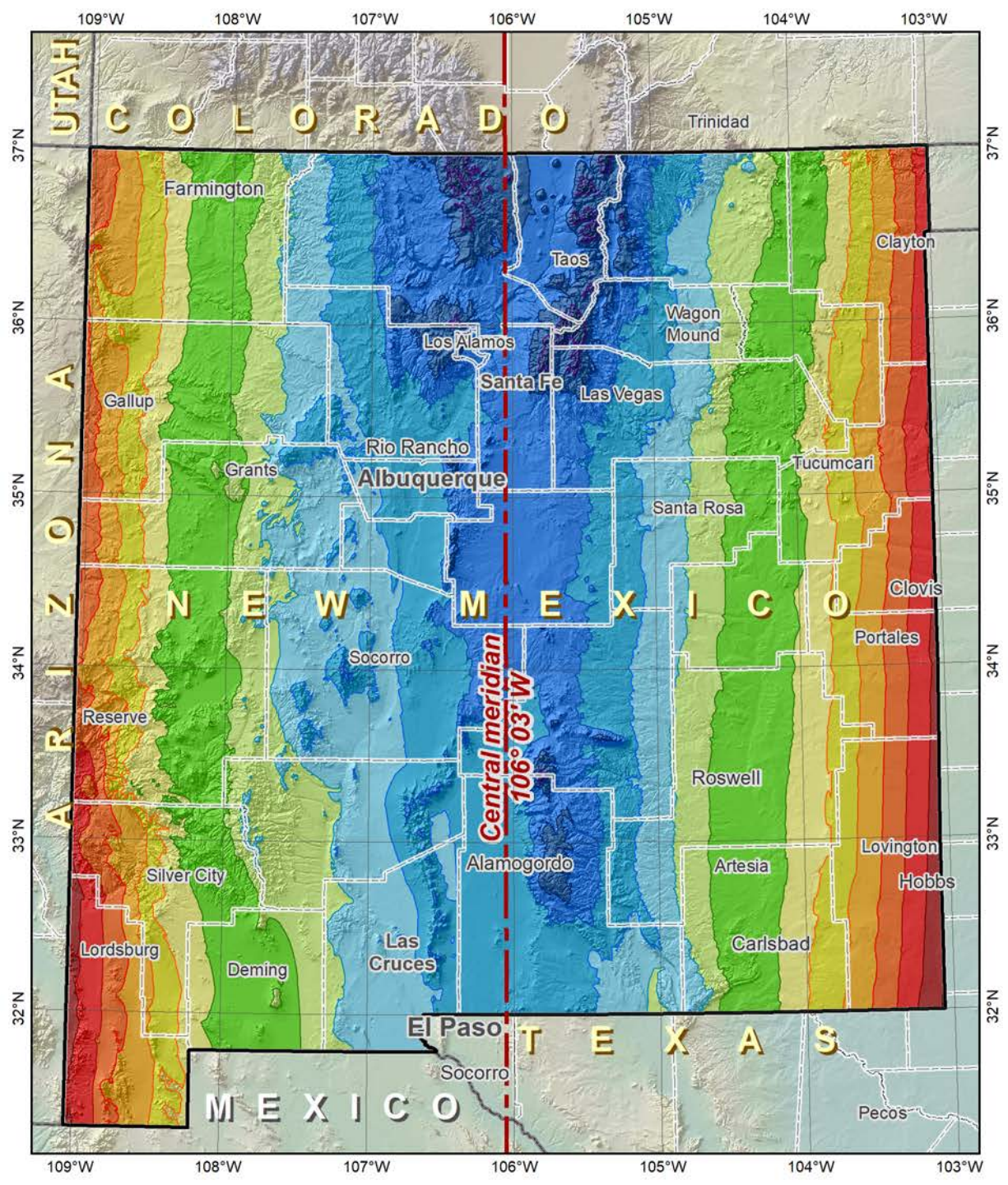
Distortion values (ppm)

Entire zone:	*Cities and towns:*
Min = -1000	Min, Max = -796, +1203
Max = +1223	Range = 1999
Range = 2223	Median = -426
Mean = -226	Mean = -294 (weighted by population)

Linear distortion at topographic surface (parts per million)

< -700	to -300	to +400
to -700	to -200	to +500
to -600	±100	to +600
to -500	to +200	to +700
to -400	to +300	> +700

0 50 100 150 200 250 km



Preliminary SPCS2022 statewide zone design: New Mexico

NOAA's National Geodetic Survey

Transverse Mercator projection

North American Terrestrial Reference Frame of 2022

Central meridian: 106° 03' W
Cen merid scale: 0.999 87 (exact)

Areas within ±400 ppm distortion (±2.11 ft per mile):
75% of entire zone
66% of all cities and towns
82% of population

Distortion values (ppm)

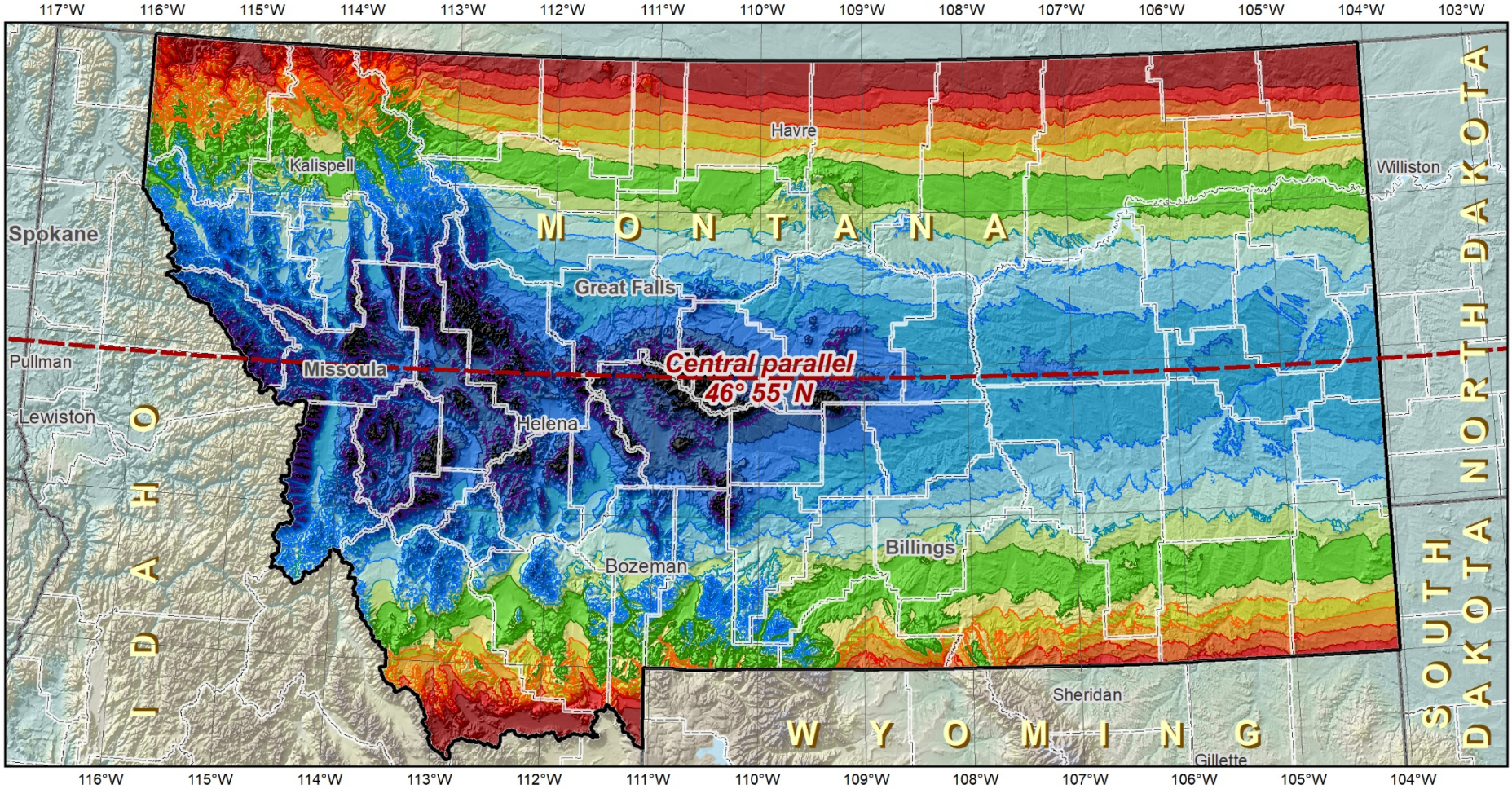
Entire zone:	*Cities and towns:*
Min = -724	Min, Max = -531, +659
Max = +713	Range = 1190
Range = 1437	Median = -271
Mean = -85	Mean = -199 (weighted by population)

Linear distortion at topographic surface (parts per million)

< -700	to -300	to +400
to -700	to -200	to +500
to -600	±100	to +600
to -500	to +200	to +700
to -400	to +300	> +700

0 50 100 150 200 250 km

Preliminary SPCS2022 default design: Montana Zone



Lambert Conformal Conic projection

North American Terrestrial Reference Frame of 2022

Central parallel: 46° 55' N

Cen parallel scale: 0.999 9 (exact)

NOAA's National Geodetic Survey

Areas within ±300 ppm distortion (±1.58 ft per mile):

98% of population

90% of all cities and towns

83% of entire zone area

Distortion values (ppm)

Entire zone:

Min = -534 Range = 1000

Max = +467 Mean = -79

Cities and towns:

Min = -380 Mean = -113

Max = +441 (weighted by

Range = 822 population)

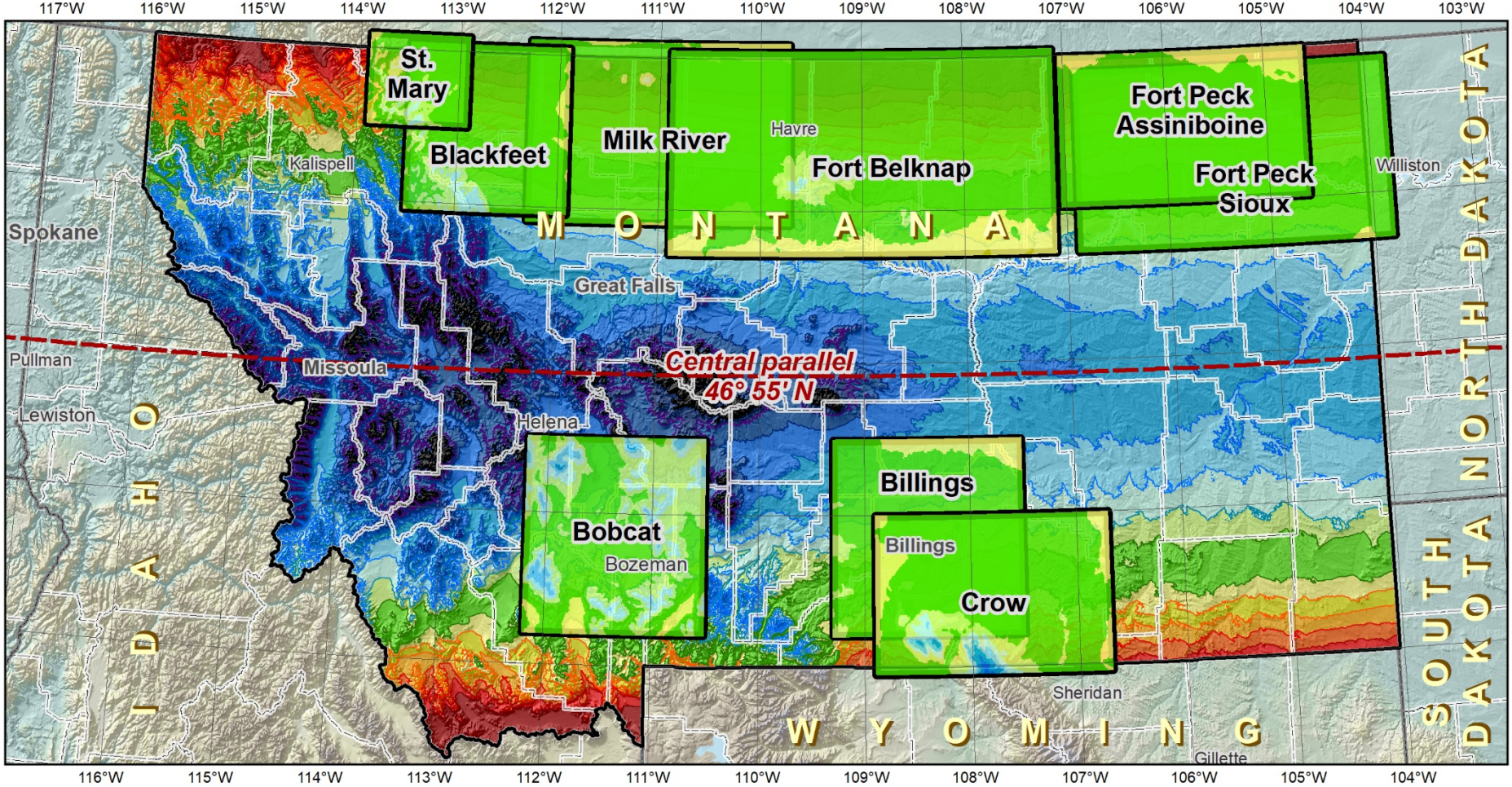
Created 01/13/2019

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 50 100 150 200 250 300 km

SPCS2022 zone layers: Montana statewide zone and *discontinuous* LDP zones



Lambert Conformal Conic projection

North American Terrestrial Reference Frame of 2022

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Min = -380 Mean = -113

Max = +441 (weighted by

Range = 822 population)

Created 01/13/2019

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 50 100 150 200 250 300 km

Making requests and proposals

- Two (***draft***) fillable PDF forms
  - Intent: make easy for stakeholders and NGS
  - Simple: pick lists, radio buttons, few free-form fields

- SPCS2022 Zone Request and Proposal Form
  - Request zone designs or modifications by NGS
  - Propose zones designed by stakeholders (usually LDPs)

- SPCS2022 Zone Design Submittal Form
  - For stakeholders to submit their own zone designs
  - Based on a previous proposal approved by NGS
  - Not required for requests

SPCS2022 deadlines

- **Consensus** input per SPCS2022 procedures
  - ***Requests*** for designs done by NGS
  - ***Proposals*** for designs by contributing partners
- Submittal of **approved** designs
  - Proposal must first be approved by NGS
  - Designs must be complete for NGS to review
- Later requests will be for ***changes*** *to* SPCS2022

NGS.SPCS@noaa.gov
by **March 31, 2020** for ***requests*** and ***proposals***
by **March 31, 2021** for ***submittal*** of ***approved*** designs

SPCS2022 stakeholders

- **State *groups*** that formally interface with NGS
  - Departments of transportation
  - Cartographer/GIS office
  - Professional surveying, engineering, GIS societies
  - Colleges/universities with geospatial curriculum
- Can submit ***requests*** and ***proposals*** for designs
  - ***Requests*** are for designs by NGS
  - ***Proposals*** are designs by contributing partners
- Stakeholder input must be ***unanimous***

geodesy.noaa.gov/SPCS/

geodesy.noaa.gov

National Geodetic Survey

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State Plane Coordinate System
- Home
- Maps
- Download Design Maps
- Convert Coordinates
- Current Policy
- 2022 Policy Changes
- Learn More

Have State Plane Questions?
- Contact Us

Preliminary Default SPCS2022 Design Maps

NGS is currently in the process of creating "default" preliminary designs for State Plane Coordinate System of 2022 (SPCS2022) zones. These preliminary designs will likely be very close to those eventually adopted by NGS, except in cases where U.S. state and territory stakeholders adopt approved alternative designs.

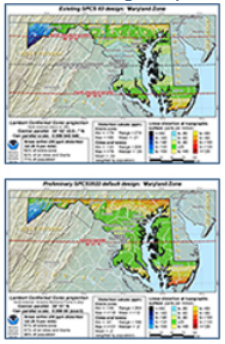
Download SPCS2022 Design Maps

A continuously updated set of **default SPCS2022 design maps** are available for download as .png image files.

The maps show linear distortion at the topographic surface for SPCS2022, along with existing State Plane and Universal Transverse Mercator (UTM) for comparison. Only projection parameters that affect linear distortion are given in the maps. Other parameters, such as false northing and easting, will be defined for the final SPCS2022 designs. Linear distortion rasters and other GIS feature datasets used to create the maps are **available for download**. If the state, territory, or subzone you require is not yet listed, please contact the **SPCS Team**.

Download SPCS2022 Design Maps

Example of Downloaded Default Design Maps



Learn More

Documents

Related documents are listed below.

- **Policy on Changes to State Plane Coordinates** (PDF, 141 KB)
- **Policy of the National Geodetic Survey Concerning Units of Measure for the State Plane Coordinate System of 1983** (PDF, 136 KB)
- **NOAA Manual NOS NGS 5** (PDF, 2 MB)
- **NOAA Special Publication NOS NGS 13** (PDF, 7 MB)

Webinars

NGS has and will host various webinars about State Plane. These will be added to the following list as they are developed.

- **The State Plane Coordinate System: History, Policy, Future Directions (March 8, 2018)**
- **Building a State Plane Coordinate System for the Future (April 12, 2018)**

Website Owner: National Geodetic Survey / Last modified by **NGS Infocenter** Mar 08 2018

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SPCS2022 summary

- **SPCS2022 characteristics different from SPCS 83:**
  - Minimize distortion at ***topo surface***, *not* ellipsoid
  - NGS will design ***statewide*** and ***default*** zones
  - Up to ***3 zone "layers"*** allowed (including an ***LDP layer***)
  - Allow ***"special use" zones*** (if in multiple states)
  - Coordinate changes of ***at least 10,000 m*** everywhere
  - Longitudes defined as ***positive east*** (0° -360°)
  - Stakeholders can request and propose preferences
- ***Consensus*** state stakeholder input ***required*** for SPCS2022 zone requests, proposals, and designs
- ***Can still change/add/remove zones after 2022***

Your NAD 83-Based State Plane-Legislated Coordinates *Will Not* Be Maintained after 2022!

What will you and your fellow professionals do?
Panic? Ignore the Issue? *or Act?*
Please let us know!

What is changing?

The North American Datum of 1983 (NAD 83) will be replaced in 2022.
The new datum will have a different name.

The North American Vertical Datum of 1988 (NAVD 88) will also be replaced in 2022.
Its replacement will also have a new name.

Expected horizontal shifts from NAD 83 to the new datum are in the 1-2 meter range.
The National Geodetic Survey will provide a coarse, map-grade transformation tool (such as NADCON and GEOCON) to connect NAD 83 with the new datum.

Who will be affected?

All states and territories will be transitioned to the new datums.
Forty-eight states have a state-specific coordinate system law tied to NAD 83.
Your state law will not reflect the National Spatial Reference System after 2022.

Who can help?

The National Geodetic Survey (NGS), the National Society of Professional Surveyors (NSPS) and the American Association for Geodetic Surveying (AAGS) are here to help your state make these changes in legislation!

You can help by understanding your own state's laws and how these changes will impact you.

Should you change or modify your state law?

NGS, NSPS and AAGS believe it would benefit state surveyors and mapping professionals for laws or regulations to reflect the latest federal geodetic infrastructure, namely **the National Spatial Reference System.**

Why should you change or modify your state law?

1. Federal agencies will adopt the new datum, so national products like **Federal Emergency Management Agency (FEMA) flood insurance rate maps** will no longer reference NAD 83, nor NAVD 88. Using the current (most updated) datum will avoid confusion and increase consistency with federal engineering or constructions projects.

3. More geospatial data is being collected and shared every day. A consistent and regularly updated NSRS will provide greater efficiency across surveying and mapping sectors.

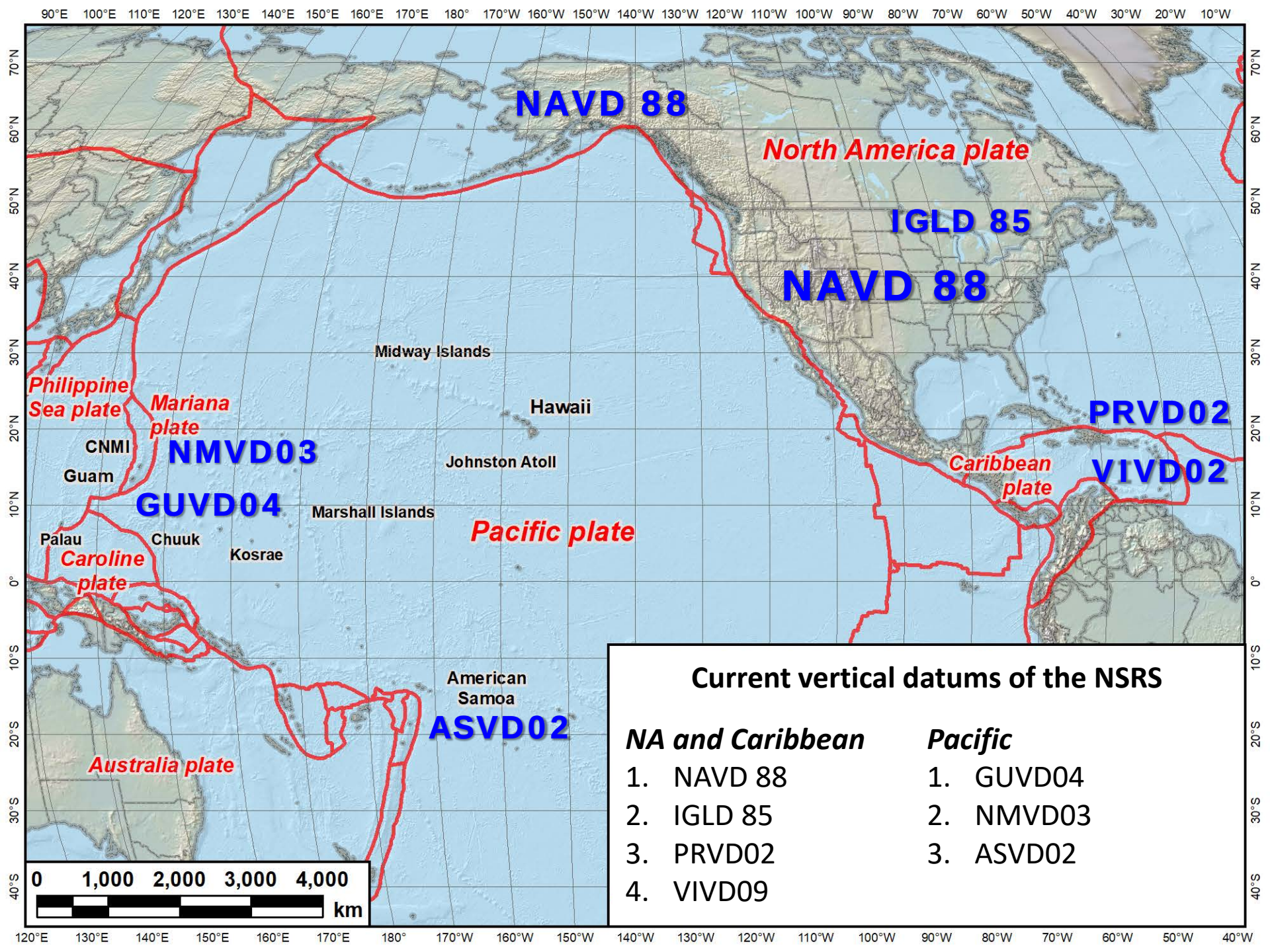
What do you think?

We welcome your feedback! Please provide any feedback you like to one of our committee members, below.

NSPS/AAGS/NGS Advisory Committee on National Spatial Reference System Legislation

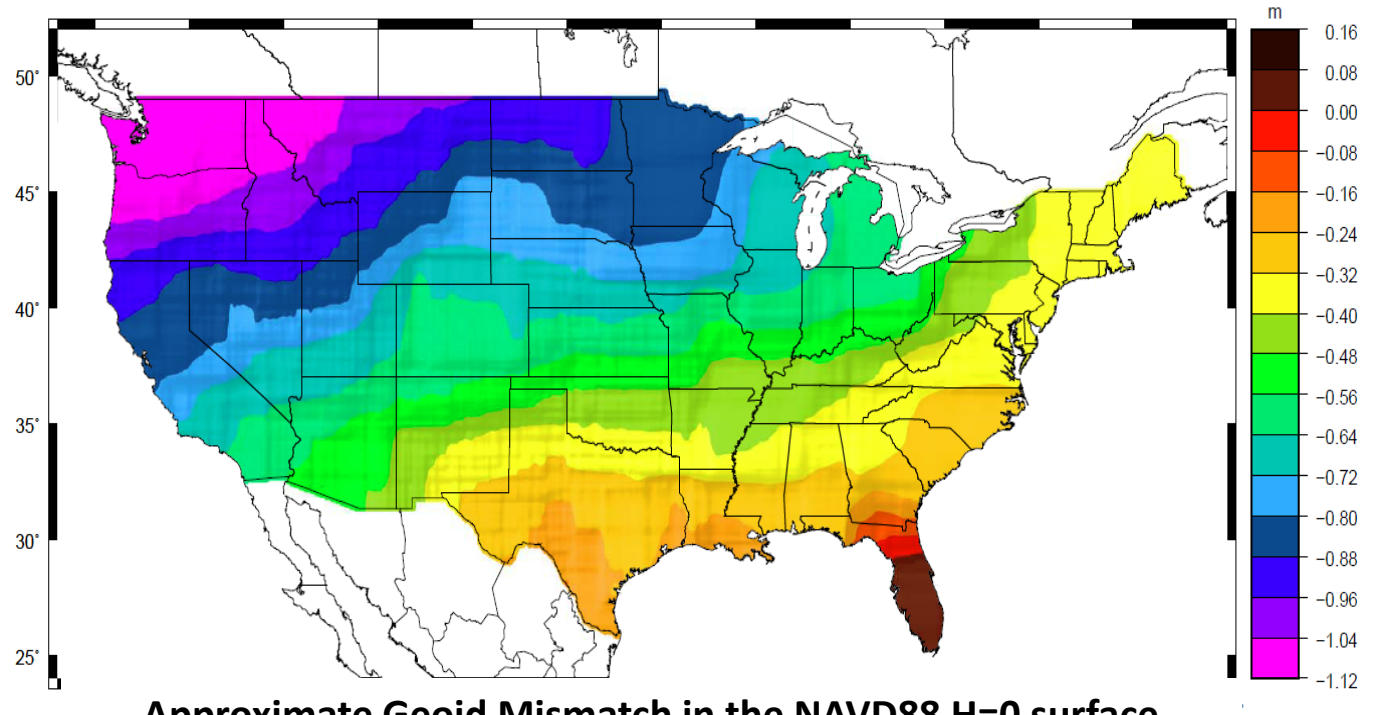
J.B. Byrd	NSPS	jbyrd@jmpa.us
Dave Doyle	NSPS	base9geodesy@gmail.com

- **Template Draft NSRS Legislation** **How to use this template:**
- 1) Whenever the word "state" is used below, it should be taken to mean "state or territory"
- 2) The intent of this template is to augment, not fully replace, existing state laws dealing with a state-specific coordinate system and its relationship to existing or prior datums of the National Spatial Reference System (NSRS).
- 3) The National Geodetic Survey (NGS) intends to release a new State Plane Coordinate System (SPCS) as part of the release of any new geometric datum, including that planned for release in 2022. As such, it is imperative that each state do the following:
- a. Ensure that any changes from the 1983 SPCS which the majority of geospatial professionals in the state wish to make, be agreed at the state level and communicated to NGS, prior to 2022 and
- b. Ensure that any law naming the state-specific coordinate system contains a definition of how that state-specific coordinate system relates to the SPCS.
- i. For example, if Michigan wishes to legislate that the "Michigan Plane Coordinate System" be used in the state of Michigan, then the law should specify that the "Michigan Plane Coordinate System" is identical to (or in some other way, defined in the law, related to) the "Michigan portion of the State Plane Coordinate System as defined by the National Geodetic Survey".
- 4) Related to #2 above, language should connect the state-desired coordinate system to the federally-defined SPCS, while leaving state and federal responsibilities independent.
- a. For example, both NGS and the California Spatial Reference Center (CSRC) cannot be jointly responsible for the California Plane Coordinate System (if that is the name chosen by California). If the CSRC is going to define the California Plane Coordinate System, they should solely define it, and have the law reflect how it relates to the federal (NGS-specified) SPCS.
- 5) Reference to specific years or datum names within the NSRS should be avoided, as the intent of the template is to provide legislation that will be accurate and relevant both today (under NAD 83), through the new datum (in 2022) and beyond to whatever datums come after 2022.
- 6) Wherever the phrase "<state>" is used in the template below, insert the name of your specific state or territory.
- 7) Sections which are considered optional are set aside (in parentheses and in red)
- 8) Sections which are explanatory and not to be copied into the law are in bold and italic.
- 9) Parts of the law where a choice of options must be made are set <in brackets and highlighted>
- 10) While most states legislate the use of a planar coordinate system, this template addresses both planar and geodetic coordinates, to provide the greatest flexibility across all states.


NAVD 88
North America plate
IGLD 85
NAVD 88
Midway Islands
Philippine Sea plate
Mariana plate
Hawaii
PRVD02
CNMI
NMVD03
Johnston Atoll
Guam
Caribbean plate
VIVD02
GUVD04
Marshall Islands
Pacific plate
Palau
Chuuk
Kosrae
Caroline plate
American Samoa
ASVD02
Australia plate
0 1,000 2,000 3,000 4,000
km
Current vertical datums of the NSRS
NA and Caribbean
1. NAVD 88
2. IGLD 85
3. PRVD02
4. VIVD09
Pacific
1. GUVD04
2. NMVD03
3. ASVD02

North American Vertical Datum 1988 (NAVD88) Shortcomings

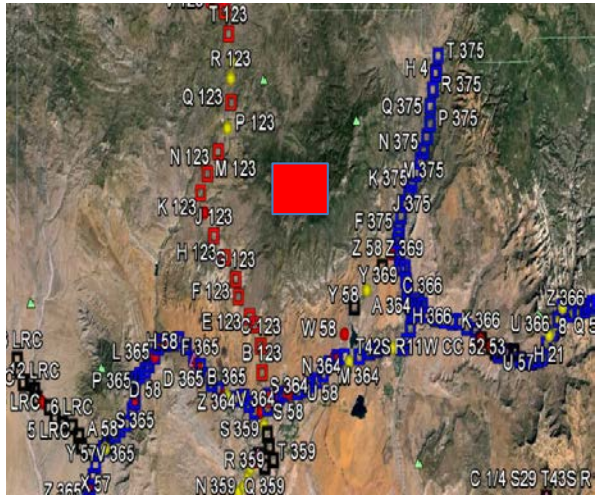
- Cross-country errors (1-m tilt)
- 0.5 m bias in reference surface vs. global mean sea level
- Subsidence, uplift, freeze/thaw invalidate BM elevations
- LIMITED AVAILABILITY / ACCESS



Approximate Geoid Mismatch in the NAVD88 H=0 surface

North American-Pacific Geopotential Datum of 2022 (**NAPGD2022**)

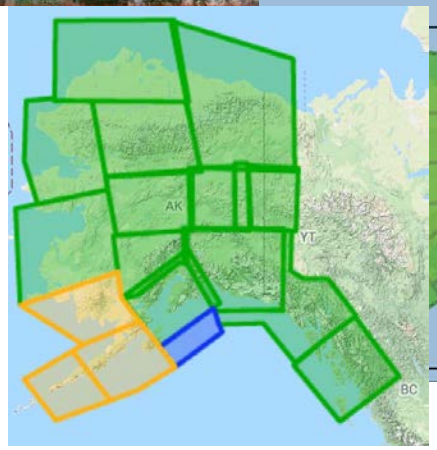
- replace NAVD88, etc. in 2022
- access via GNSS & **gravimetric geoid** (+ leveling, per needs)
- aligned: 2022 Terrestrial Reference Frames (eg **NATRF2022**)
- most accurate continental gravimetric geoid (1-2 cm goal)
- referenced to global mean sea level
- geoid coordinated w/Canada & Mexico
- monitor time-varying nature of gravity

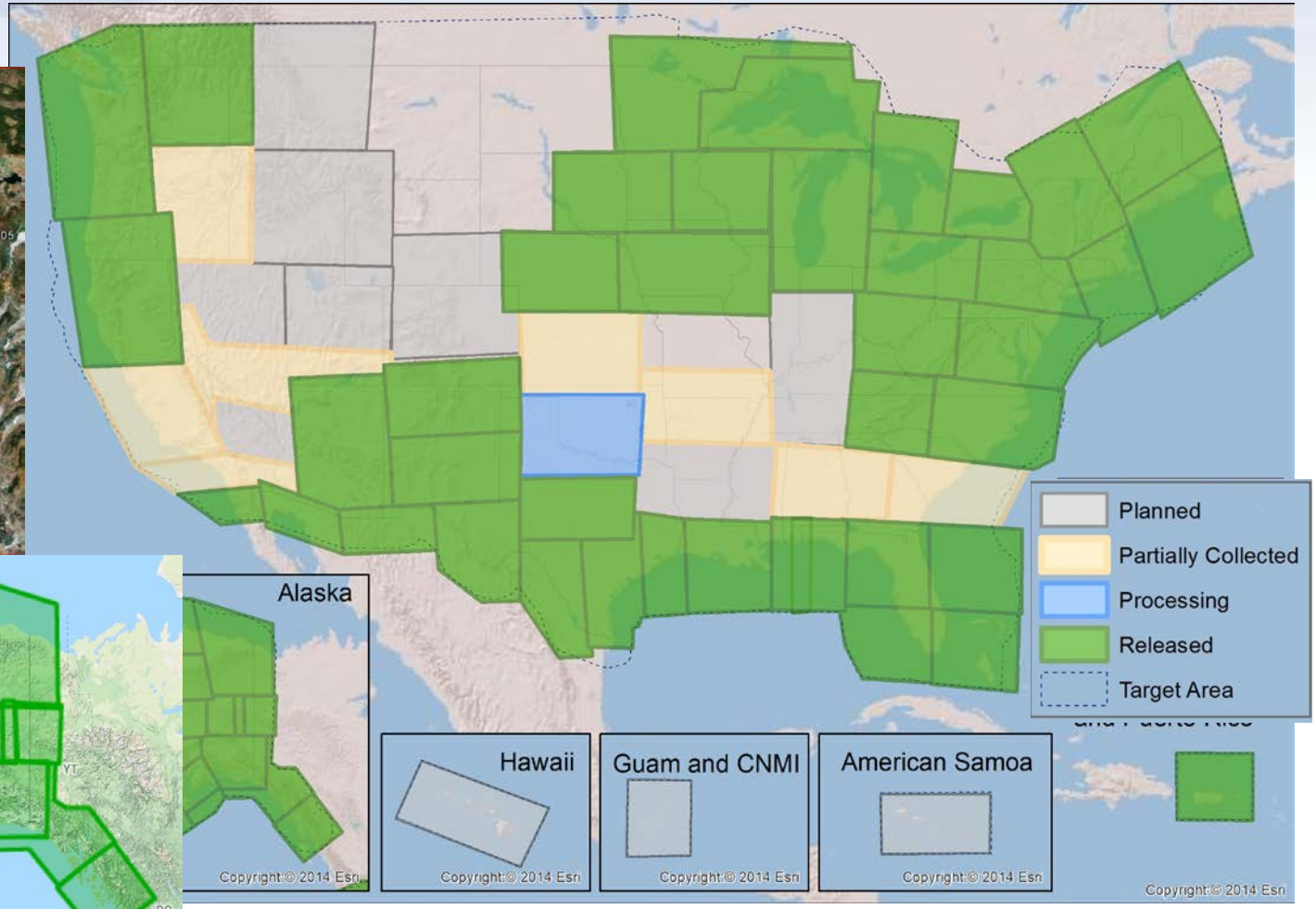


Gravity for the Redefinition of the American Vertical Datum (GRAV-D)

2019-Q1:
73% complete

- 10 km data lines
- 70 km cross lines
- 20,000 ft altitude
- 230 kt flight speed

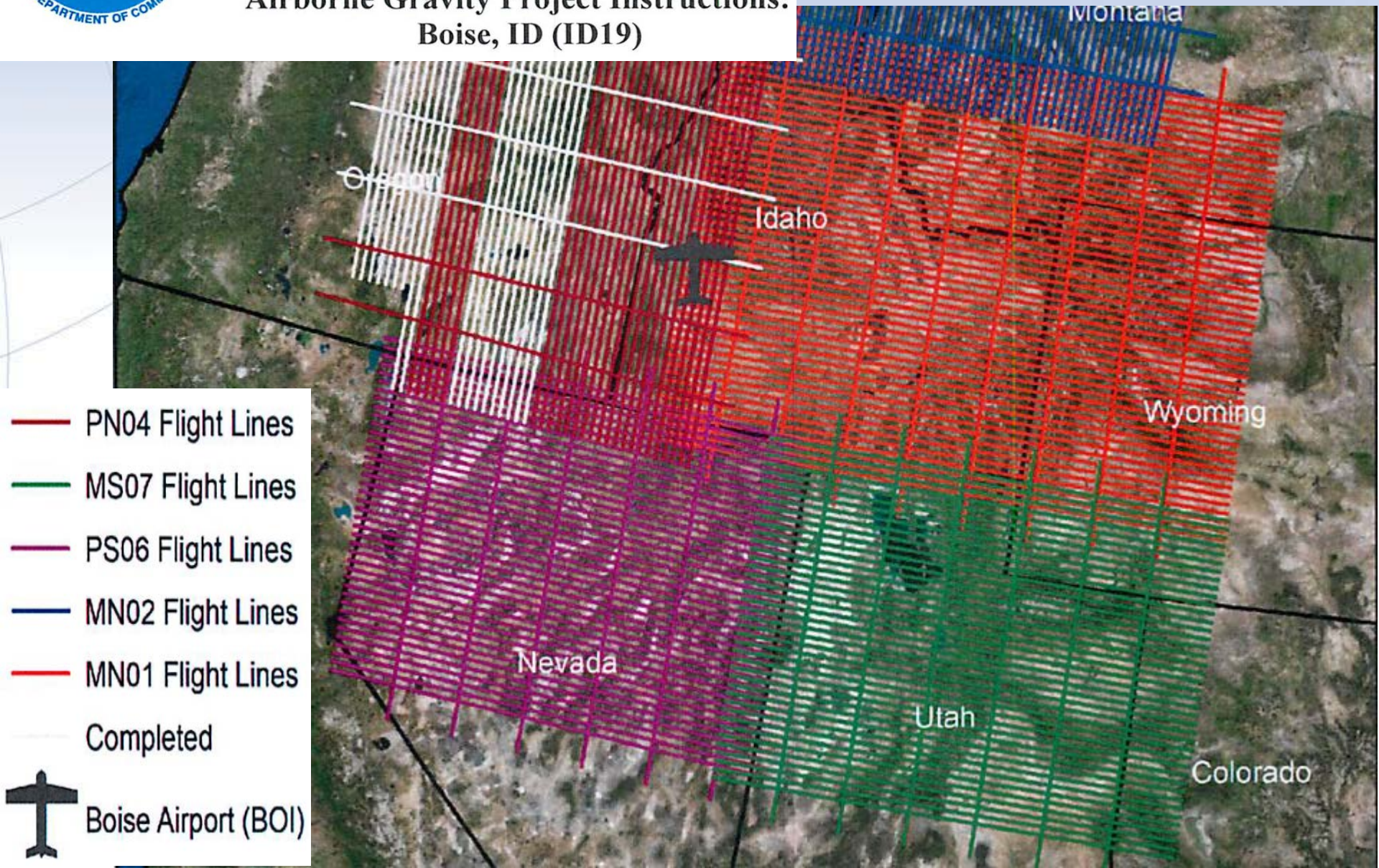




Gravity for the Redefinition of the American Vertical Datum (GRAV-D)

Airborne Gravity Project Instructions: Boise, ID (ID19)

geodesy.noaa.gov



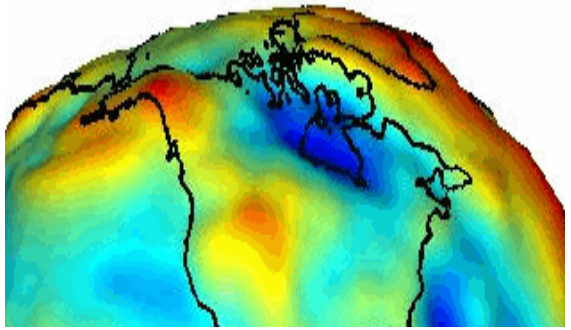
North American-Pacific Geopotential Datum of 2022 (NAPGD2022)

Gravity Potential Energy

$$V^{(1)}(r,\theta,\lambda) = \frac{(GM)_1}{r}\sum_{n=0}^{N}\left(\frac{a_1}{r}\right)^n \sum_{m=0}^{n}\left(\bar{C}_{n,m}cos(m\lambda) + \bar{S}_{n,m}sin(m\lambda)\right)\bar{P}_{n,m}(cos\theta)$$

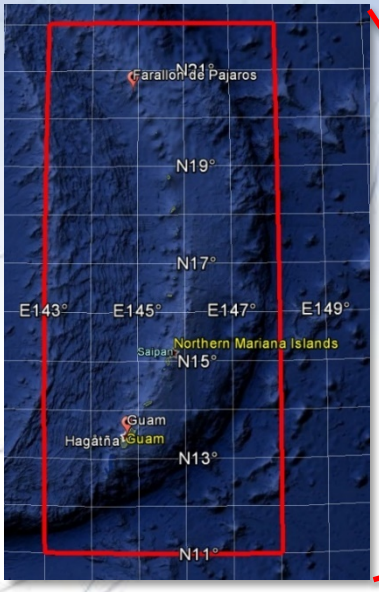
>>> <u>global</u> geopotential field model (GM2022)

- orthometric height (elevation; via GNSS)
- geoid undulation (GEOID2022; 0 elev.)
- deflection of the vertical (DEFLEC2022)
- gravity anomalies (GRAV2022)

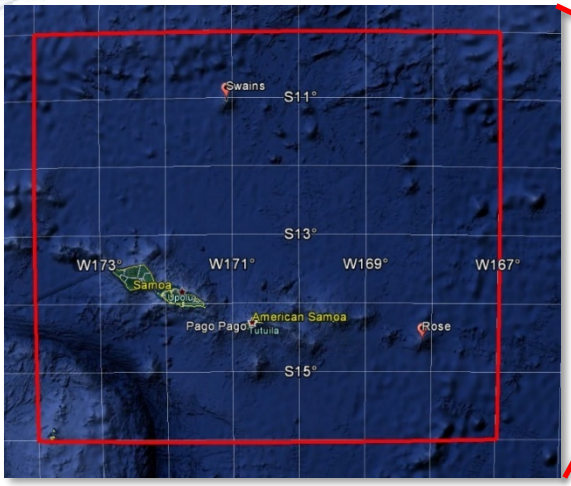


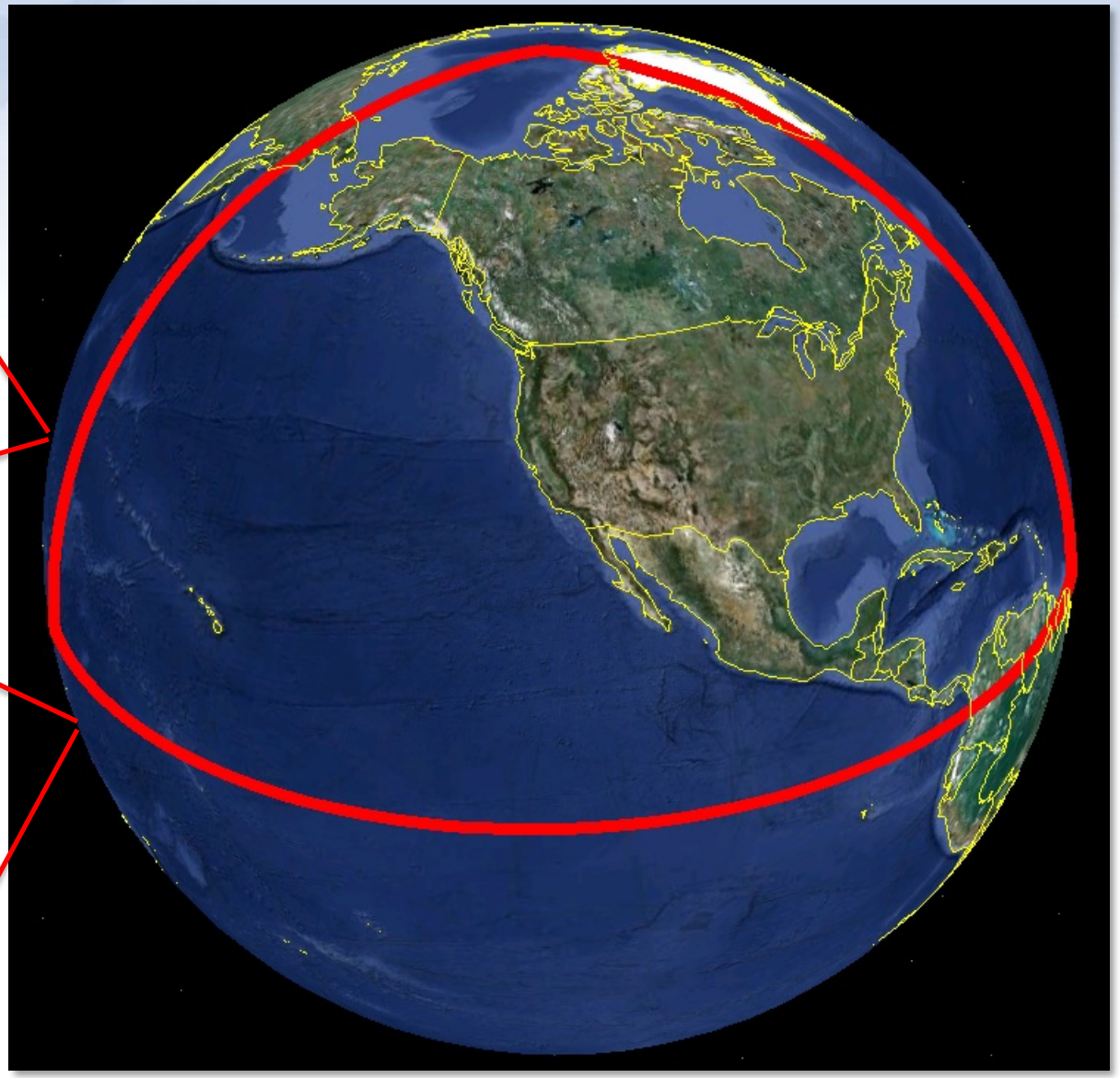
Extent of NAPGD2022 Gravimetric Geoid Model (GEOID2022)

Guam and Northern Marianas Islands

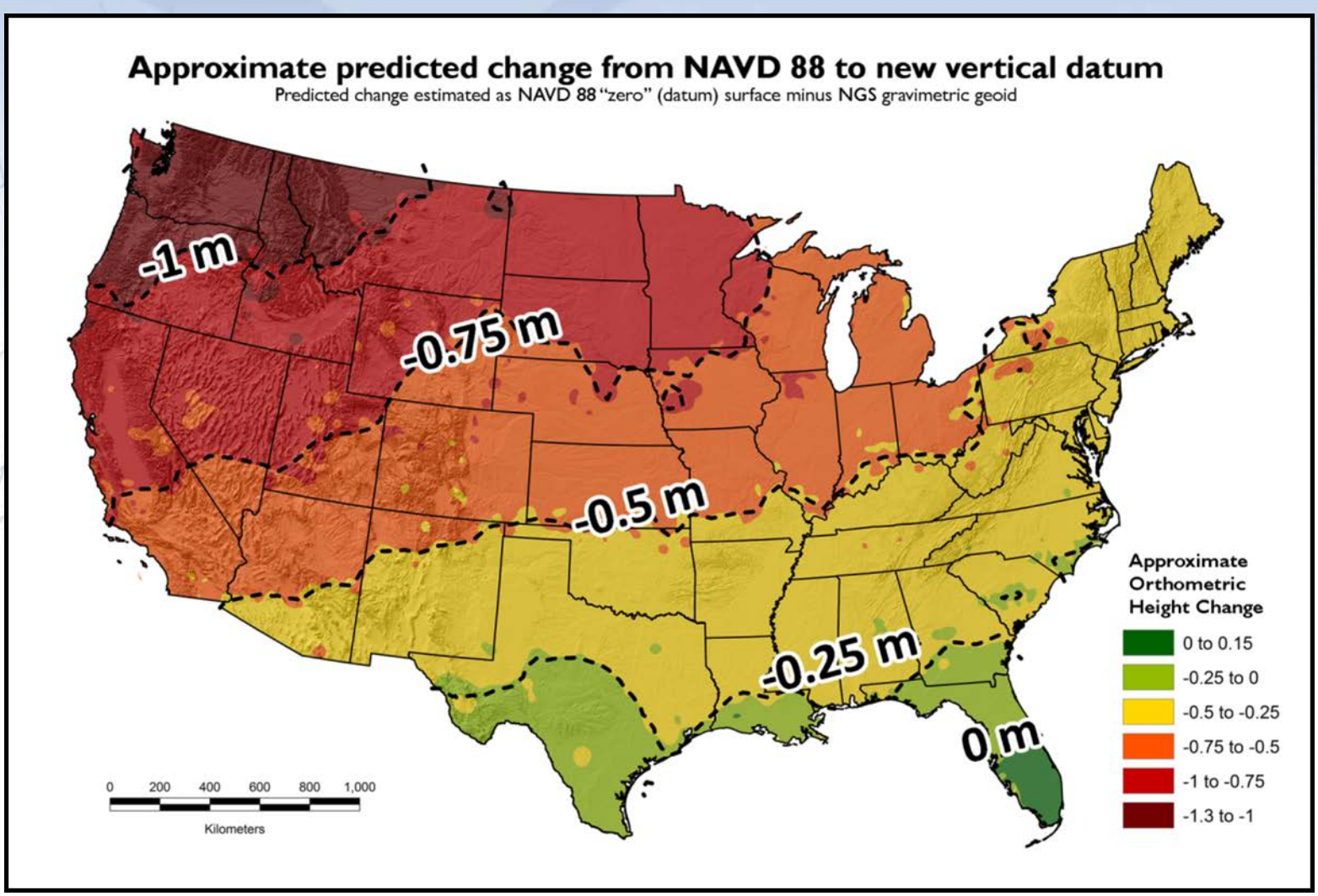


American Samoa

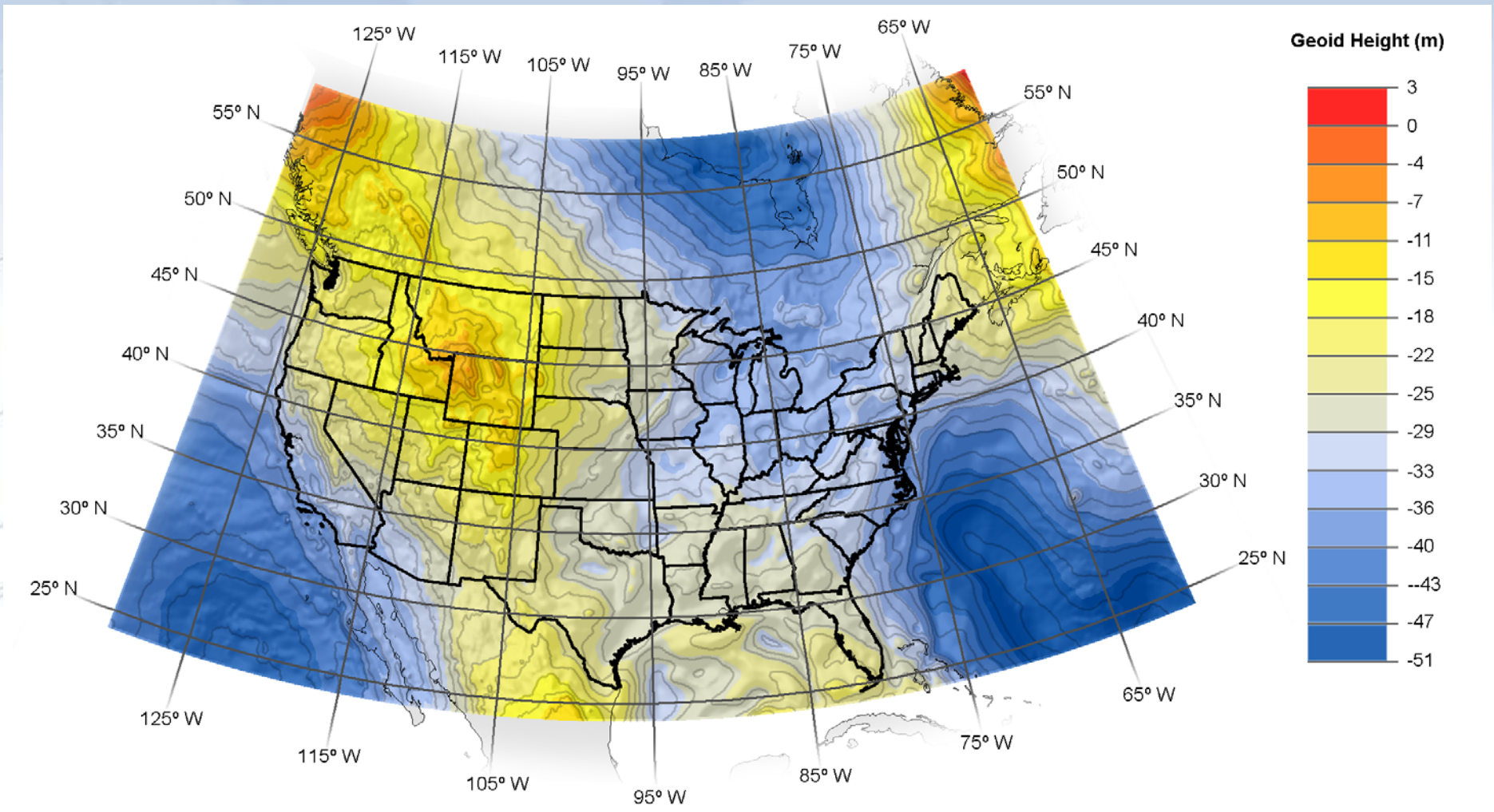




Predicted Change – NAVD88 to NAPGD2022

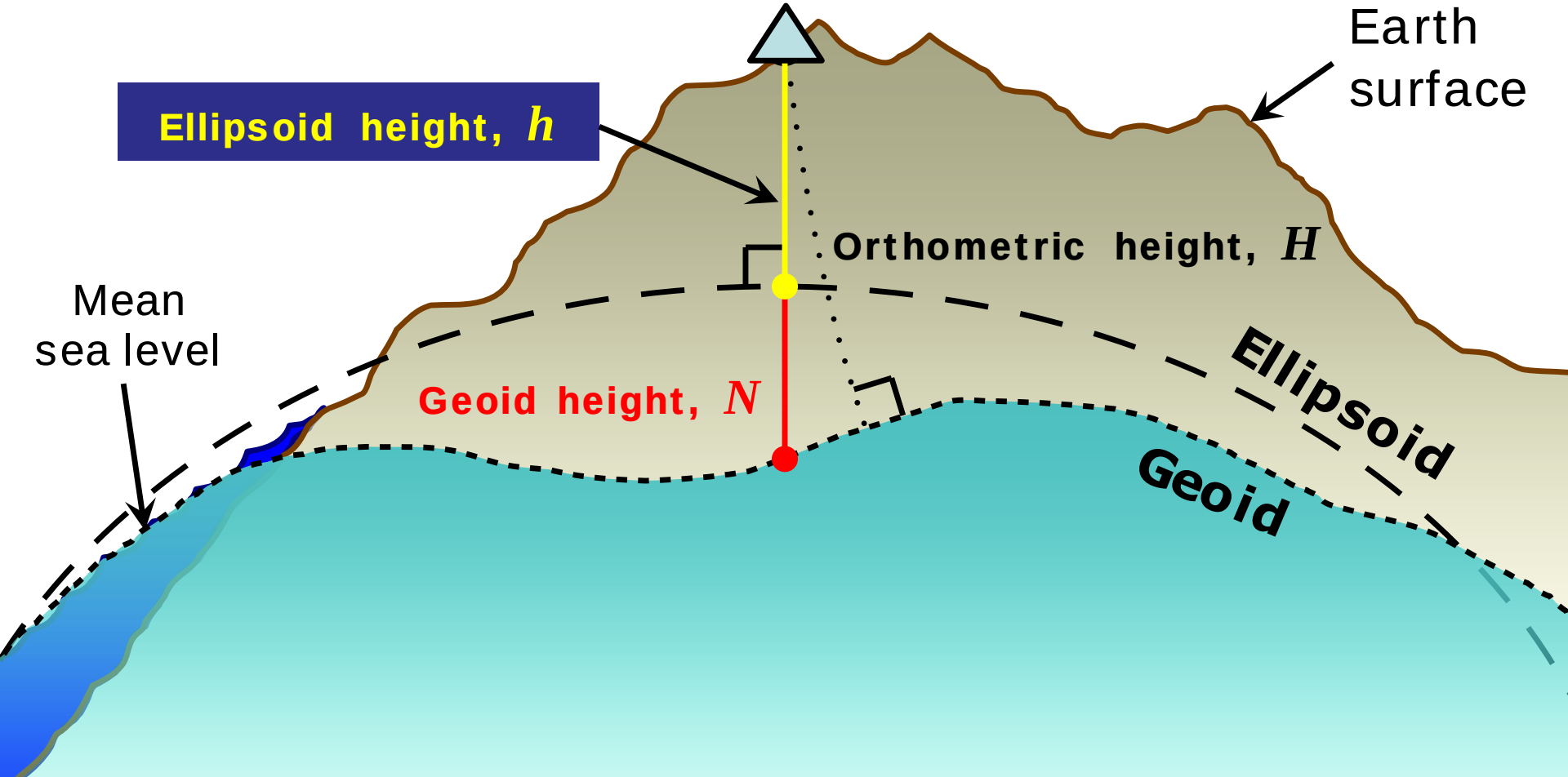


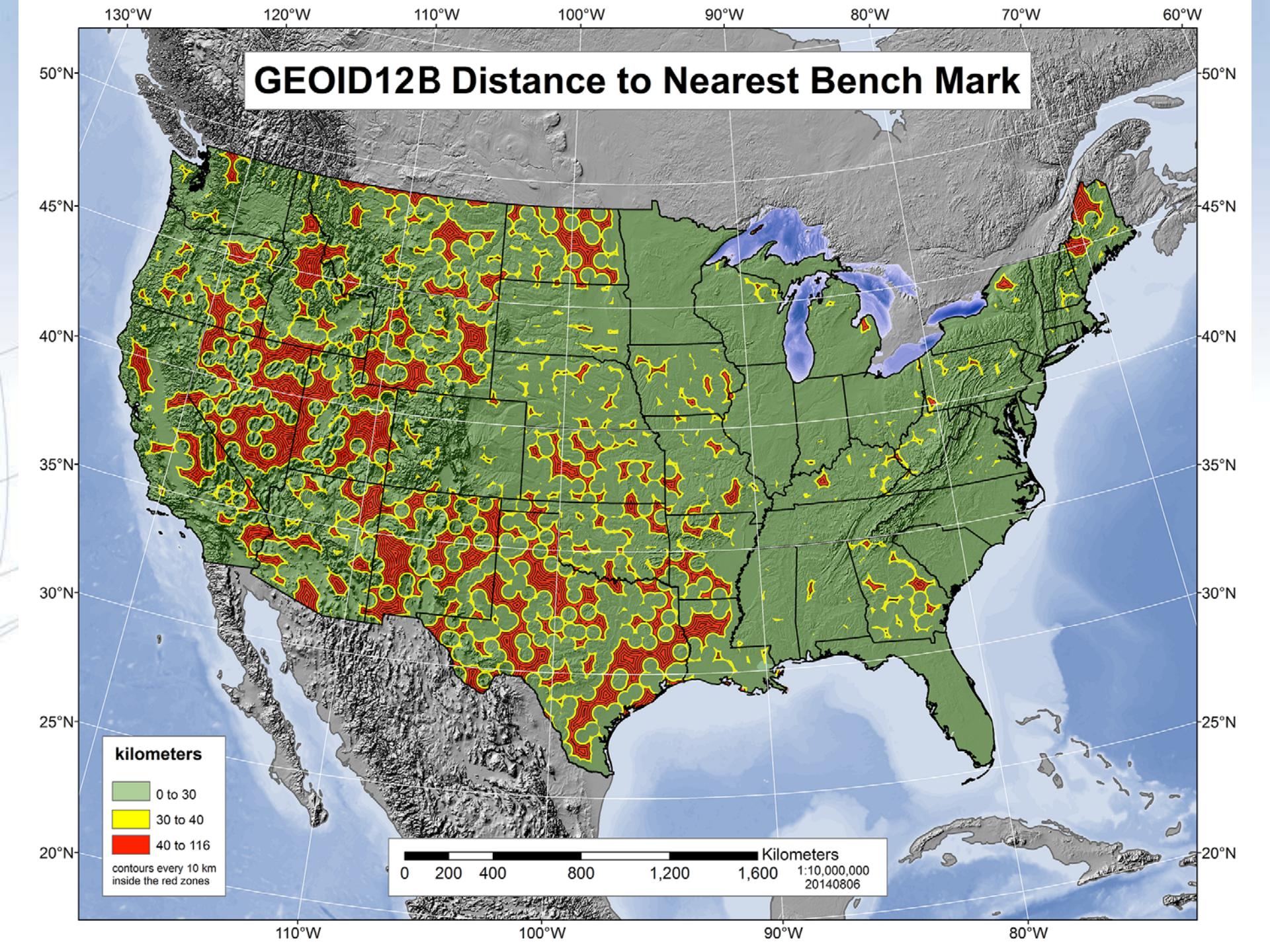
GEOID12B (Hybrid Geoid Model)



The Relationship of Heights

$$H \approx h - N$$




GEOID12B Distance to Nearest Bench Mark
130°W
120°W
110°W
100°W
90°W
80°W
70°W
60°W
50°N
45°N
40°N
35°N
30°N
25°N
20°N
kilometers
0 to 30
30 to 40
40 to 116
contours every 10 km
inside the red zones
Kilometers
0 200 400 800 1,200 1,600
1:10,000,000
20140806

GPS on Bench Marks (GPSBM)

NOAA's National Geodetic Survey Positioning America for the Future geodesy.noaa.gov

National Geodetic Survey

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GPS on BM Links

- Home
- Recover
- Observe
- Report
- 2019 Temporary Web Map
- Prioritized Marks
- Training Resources
- GPS on BM FAQ

Related Links

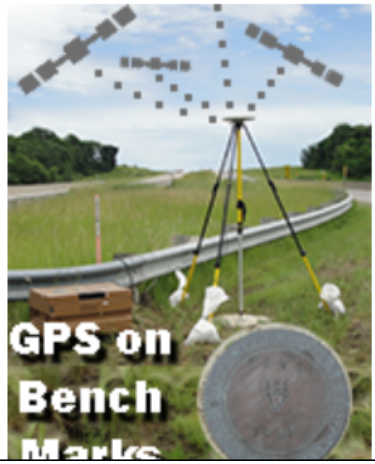
- Beta GEOID18
- Archived 2018 Campaign
- NGS Data Explorer
- DSWorld

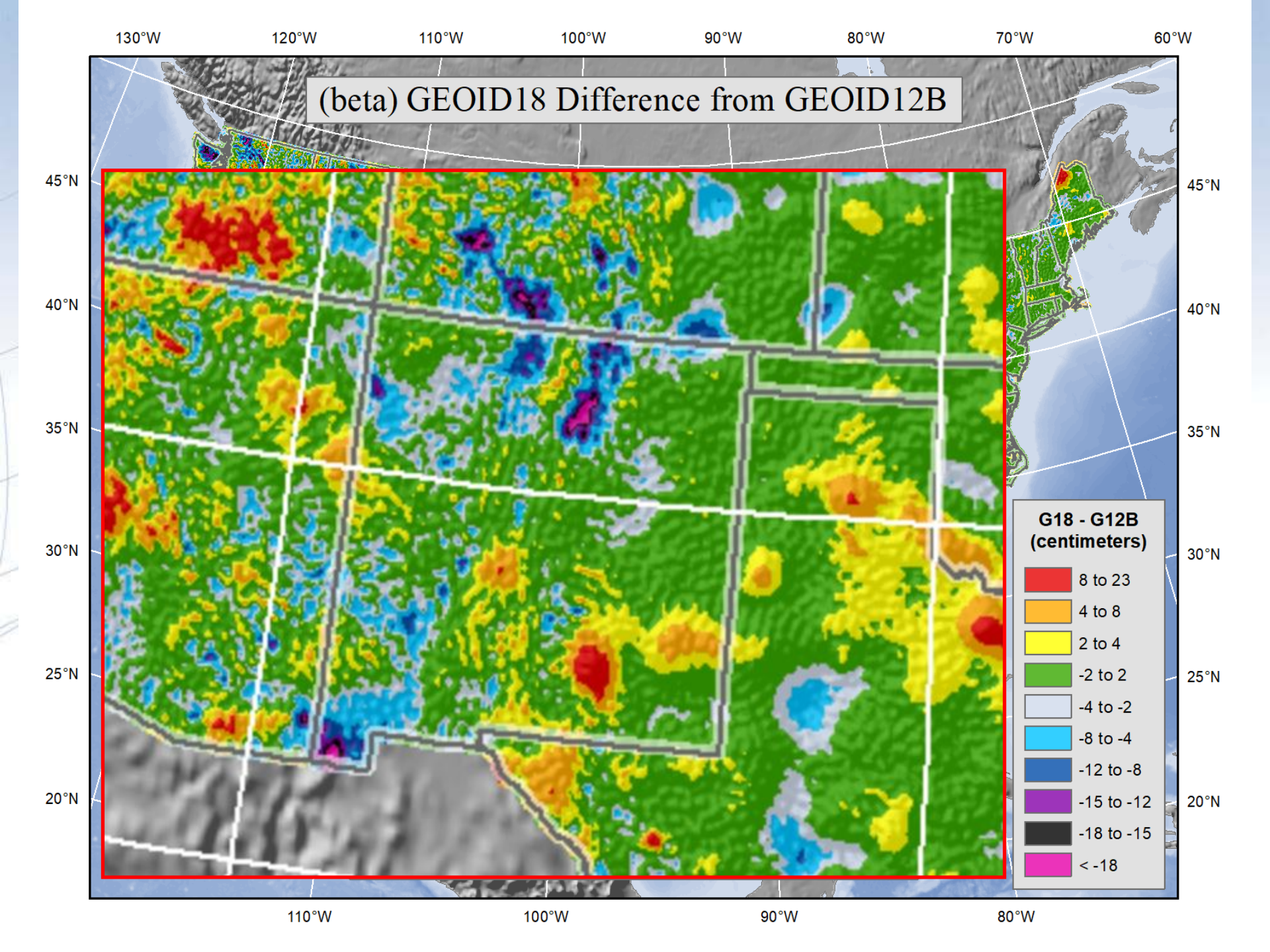
GPS on Bench Marks

Help improve the National Spatial Reference System (NSRS) by participating in the GPS on Bench Marks (GPS on BM) campaign. Your efforts will support the following objectives:

- Improve the **2022 Transformation Tool** , which will enable conversions to the new vertical datum in 2022 and be integrated into the NGS Coordinate Conversion and Transformation Tool (NCAT).
- Update Passive Control Status: shared solutions provide NGS and other users insight into the health of the passive control network and updated information for project planning.
- Automatic Reprocessing in 2022: Shared data will be automatically reprocessed and given new coordinates after the new datums are released in 2022.

Recover Observe Report




(beta) GEOID18 Difference from GEOID12B
130°W
120°W
110°W
100°W
90°W
80°W
70°W
60°W
45°N
40°N
35°N
30°N
25°N
20°N
G18 - G12B
(centimeters)
8 to 23
4 to 8
2 to 4
-2 to 2
-4 to -2
-8 to -4
-12 to -8
-15 to -12
-18 to -15
< -18

2018 Campaign Links
2018 Home
2018 Web Map
Prioritized List

Related Links
GPS on BM Home
GEOID18
NGS Data Explorer
DSWorld
OPUS Upload
Mark Recovery Form
Photo Submission

Contact information
Email us

Subscribe for GPS on Bench Mark Updates

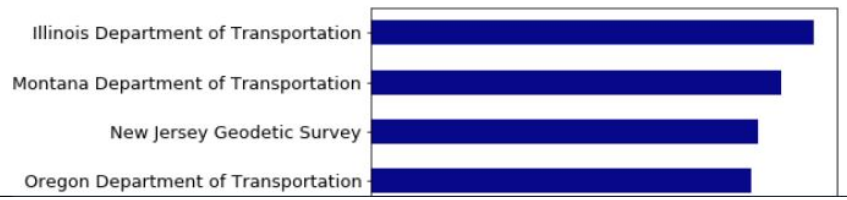
2018 GPS on Bench Marks Campaign Results

In February 2018, NGS released a list of approximately 5,800 priority bench marks where GPS data is needed to improve the modeling for **GEOID18** and the transformation tool that will be created for **NAPGD2022**.

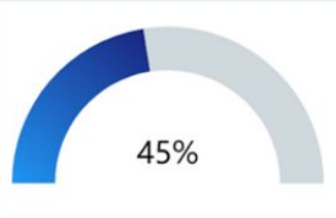
Approximately **2,469** GPS observations were submitted. We reached **45.5%** of our nationwide goal, however the number of marks requested per state varies greatly, and many states have submitted observations on a much higher percentage of the requested marks.

Each bench mark observation is at least 4 hours in length, so every submission is a significant contribution toward improving the model. Thank you to all who have contributed data. Your efforts are helping to improve NGS models and tools in your local area!

Top Ten Submitting Agencies



Percent of Goal Reached



Progress Tracking Map

View Progress by State

Who's Submitting Bench Marks?

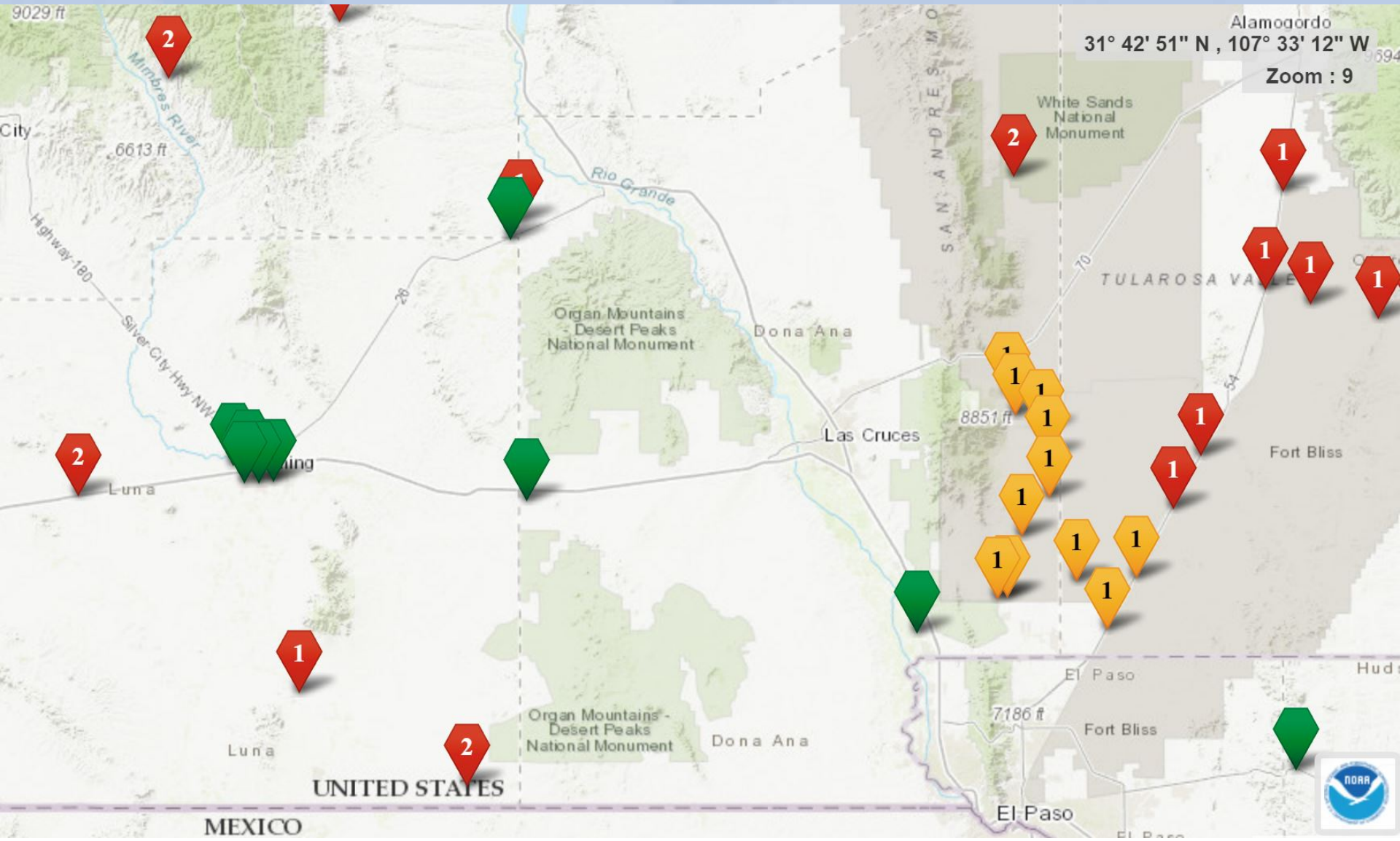
73% **State agencies**(Transportation, Agriculture, Natural Resources, Water Resources, Public Utilities, Geodetic Surveys)

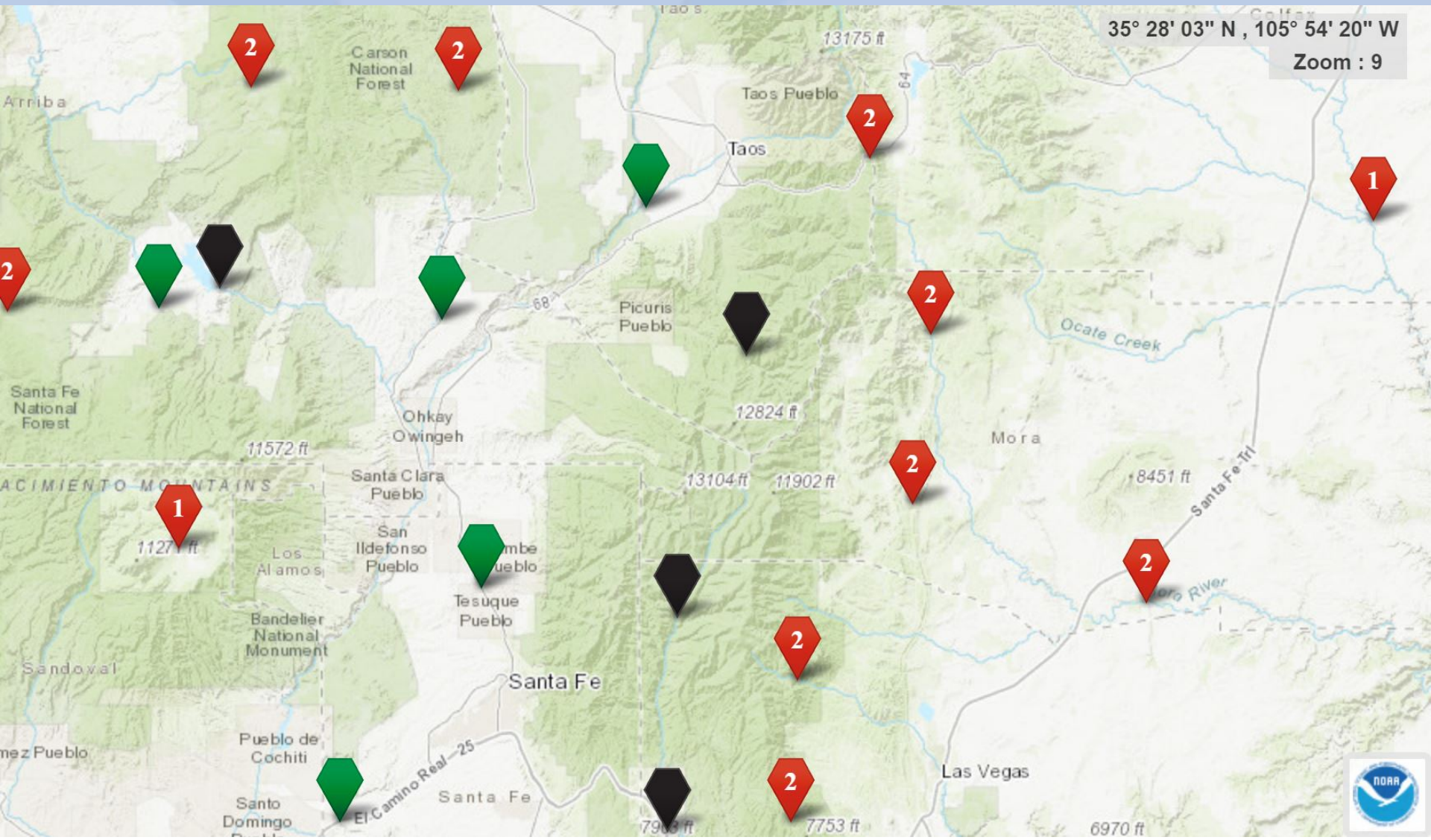
13% **Private sector** (Surveying, Engineering, and Geomatics firms)

7% **City/county agencies** (County surveyors, engineers, public works)

4% **Federal partners** (NOAA, USACE, BLM, NGA, NAVO, NPS)

3% **Academics** (Mainly university surveying programs)


Alamogordo
31° 42' 51" N , 107° 33' 12" W
Zoom : 9
9029 ft
6613 ft
Mimbres River
Rio Grande
Highway 180
Silver City Hwy NW
26
SAN ANDRES MO
White Sands National Monument
70
TULAROSA VA
54
Organ Mountains - Desert Peaks National Monument
Dona Ana
Las Cruces
8851 ft
Fort Bliss
Luna
El Paso
7186 ft
UNITED STATES
MEXICO


35° 28' 03" N , 105° 54' 20" W
Zoom : 9
Carson National Forest
Arriba
Taos Pueblo
Taos
13175 ft
Picuris Pueblo
Ocate Creek
Santa Fe National Forest
Ohkay Owingeh
12824 ft
11572 ft
Mora
Santa Clara Pueblo
13104 ft
11902 ft
8451 ft
Santa Fe Trl
ACIMIENTO MOUNTAINS
San Ildefonso Pueblo
Los Alamos
Tesuque Pueblo
Bandelier National Monument
Sandoval
Santa Fe
Pueblo de Cochiti
Santo Domingo
El Camino Real
Las Vegas
7753 ft
6970 ft

GPS on Bench Marks (GPSBM)

National Geodetic Survey

Positioning America for the Future

GPS on BM Links
Home
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Report
2019 Temporary Web Map
Prioritized Marks
Training Resources
GPS on BM FAQ

Related Links
Beta GEOID18
Archived 2018 Campaign
NGS Data Explorer
DSWorld
OPUS Upload
Mark Recovery Form

GPS on Bench Marks

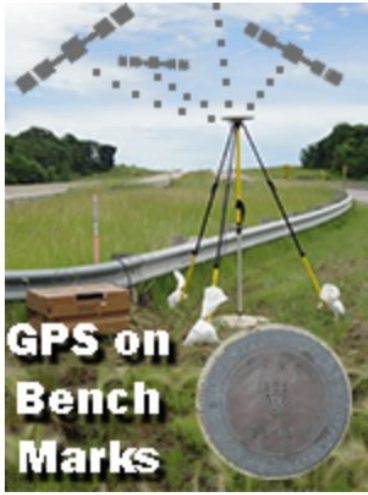
Help improve the National Spatial Reference System (NSRS) by participating in the GPS on Bench Marks (GPS on BM) campaign. Your efforts will support the following objectives:

- Improve the **2022 Transformation Tool** , which will enable conversions to the new vertical datum in 2022 and be integrated into the NGS Coordinate Conversion and Transformation Tool (NCAT).
- Update Passive Control Status: shared solutions provide NGS and other users insight into the health of the passive control network and updated information for project planning.
- Automatic Reprocessing in 2022: Shared data will be automatically reprocessed and given new coordinates after the new datums are released in 2022.

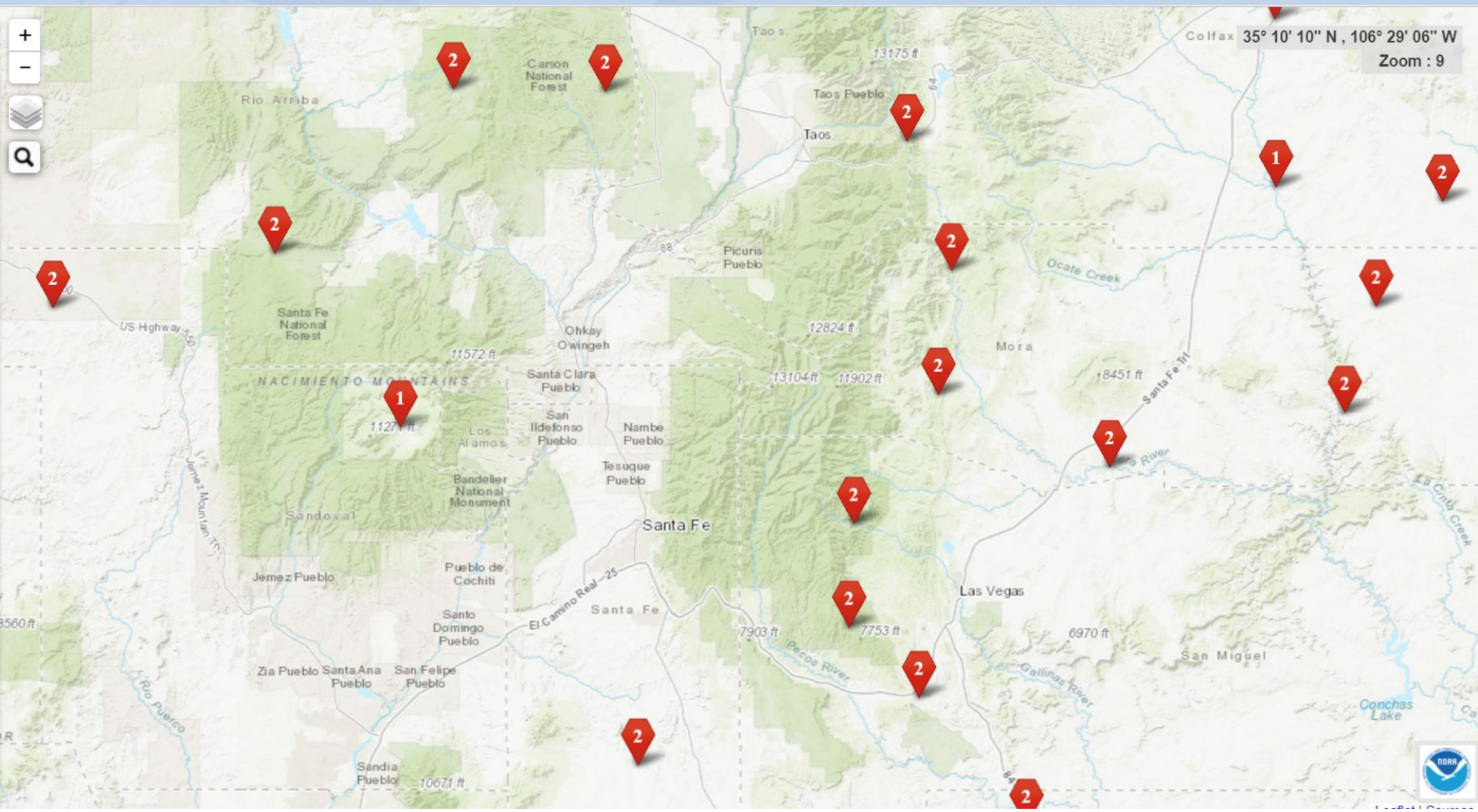
Recover, Observe, Report

Regardless of your objective, GPS on BM will always include three important steps: recover, observe, and report.

Recover
Observe
Report

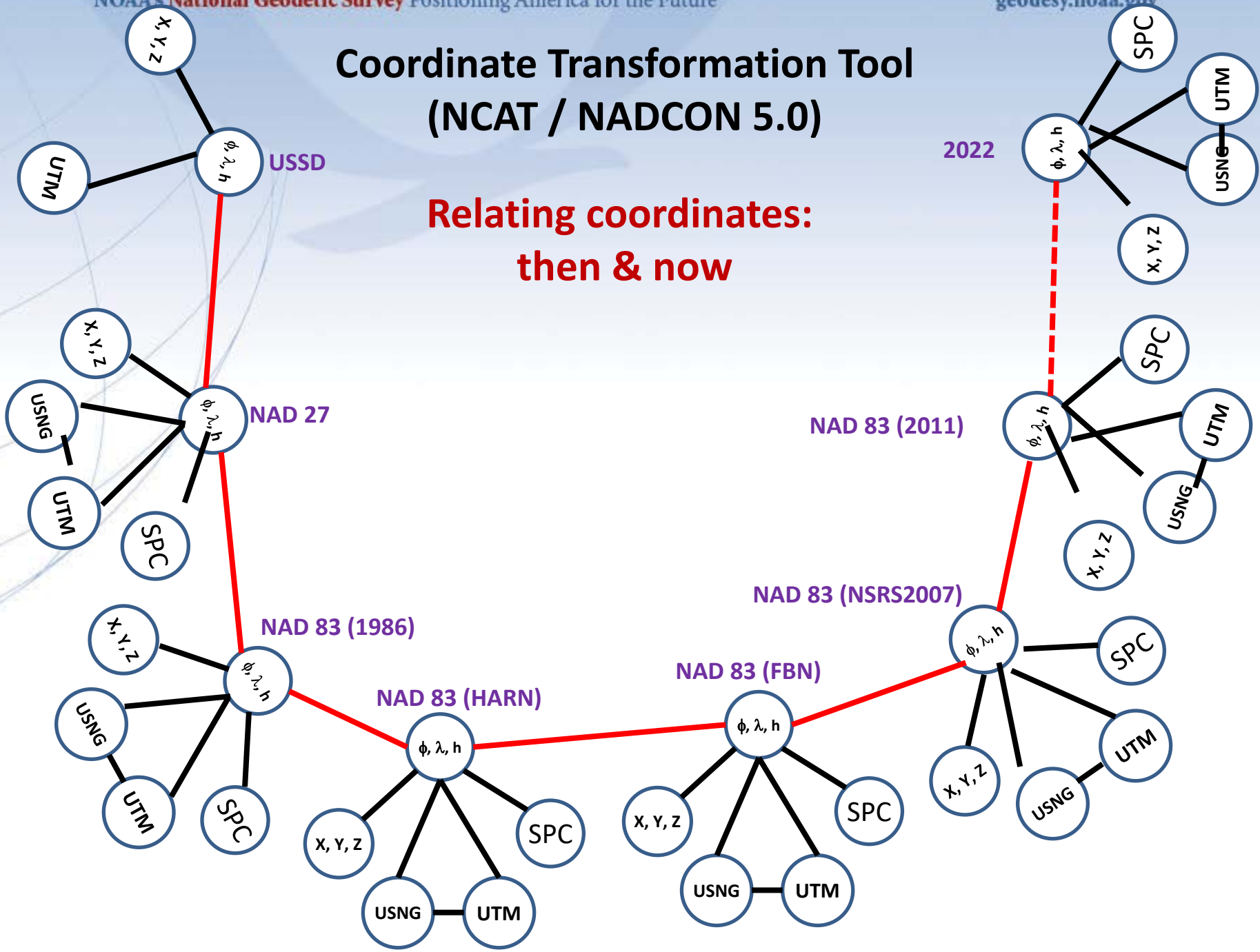


GPS on Bench Marks (GPSBM)

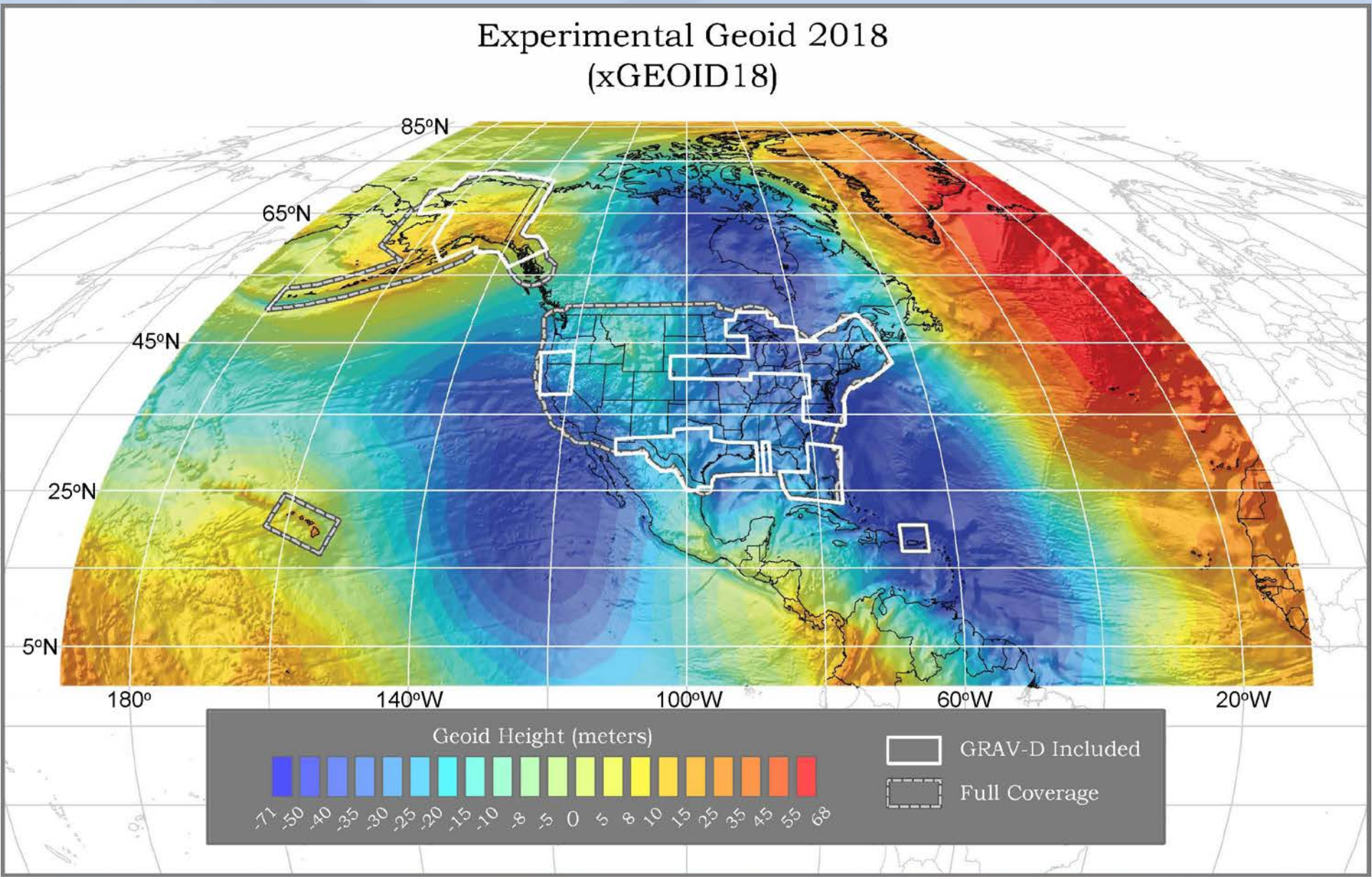


Coordinate Transformation Tool (NCAT / NADCON 5.0)

Relating coordinates: then & now



Annual Experimental Geoids



Preparing for Tomorrow:
Online Positioning User Service (OPUS) NAPGD2022 Preview

********** New Reference Frame Preview **********

We are replacing the nation's NAD 83 and NAVD 88 datums, to improve access and accuracy of the National Spatial Reference System. More at https://geodesy.noaa.gov/datums/newdatums/

Below are approximate coordinates for this solution in the new frames:

APPROX ORTHO HGT: 1480.951 (m)

[PROTOTYPE (Computed using xGeoid18B,GRS80,IGS08)]

(NAVD88: 1481.549 m)

(Extracted from OPUS Extended Output)

geodesy.noaa.gov

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National Geodetic Survey

Positioning America for the Future

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Coming in 2022: New Datums! Learn more...

NOAA's National Geodetic Survey (NGS) provides the framework for all positioning activities in the Nation. The foundational elements of latitude, longitude, elevation, shoreline information impact a wide range of important activities.

Learn more about:

- Data and tools we provide
- Activities in your area
- Applications of geodesy

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Get coordinate information and the tools you need to work independently.

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Download data and critical information into nautical charts.

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NGS works closely with the global researchers advancing geodetic science.

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Looking for Bench Marks?

Notices

Register: Geospatial Summit on May 6-7, 2019

BETA Releases: BETA GEOID18

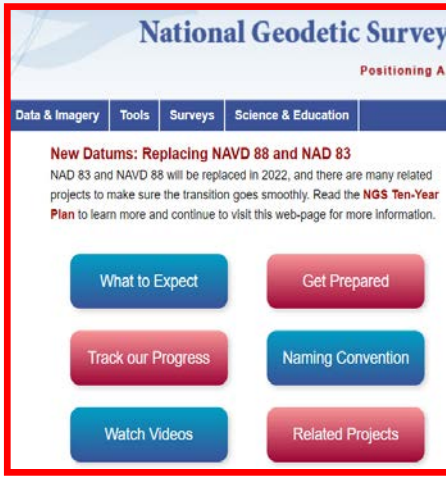
BETA CORS ITRF14 Coordinates

In the News

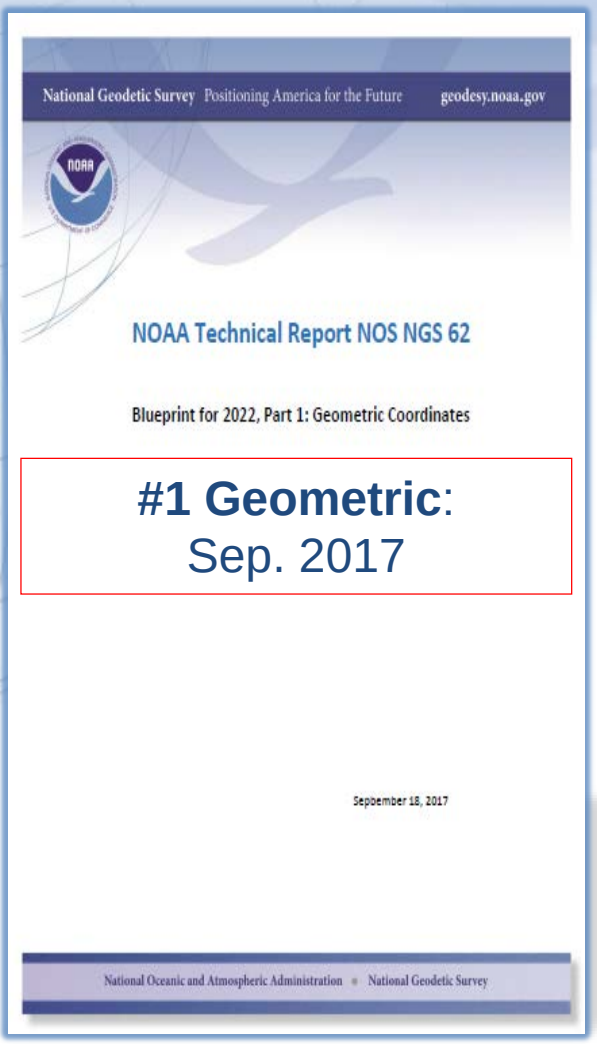
4/5/2019 - Participation in Monthly Geodesy Webinar Series Continues to Grow

03/29/2019 - Site Survey Contributes to Global Coordinate System

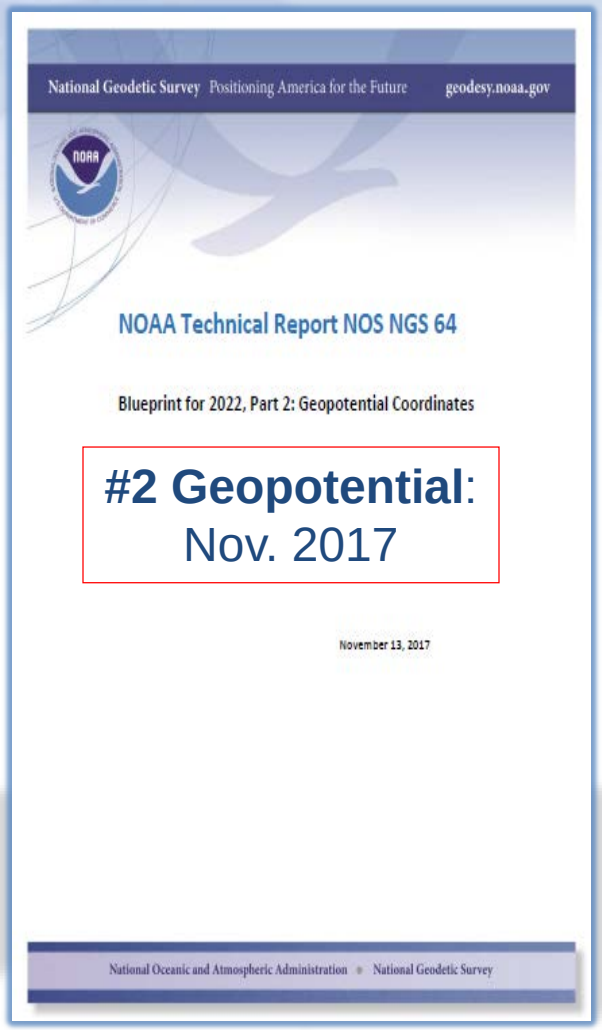
03/22/2019 - GPS on Bench Marks' Campaign Successes Presented at Conference



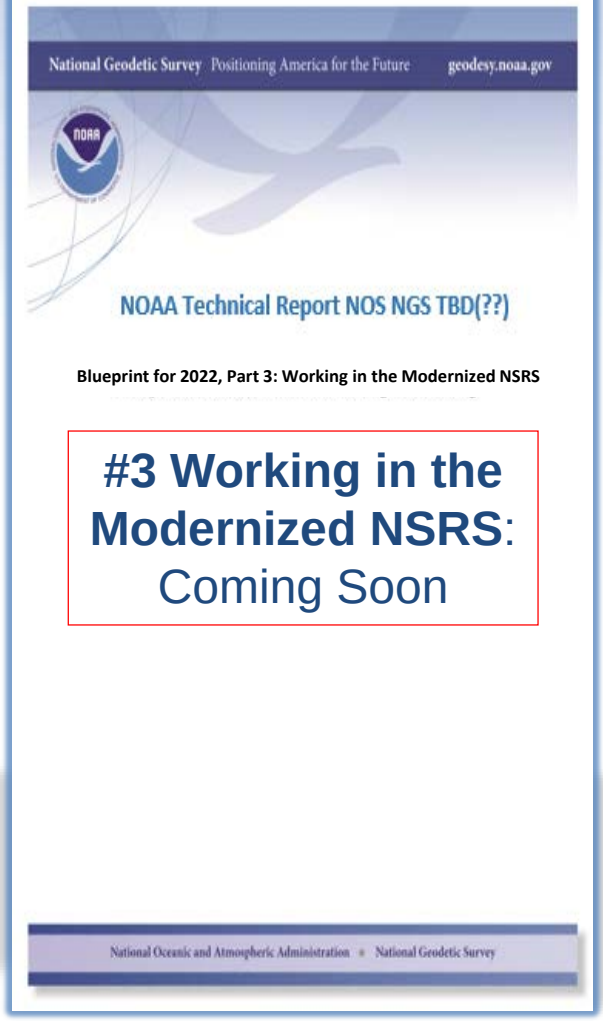
NSRS Modernization: the "Blueprints"



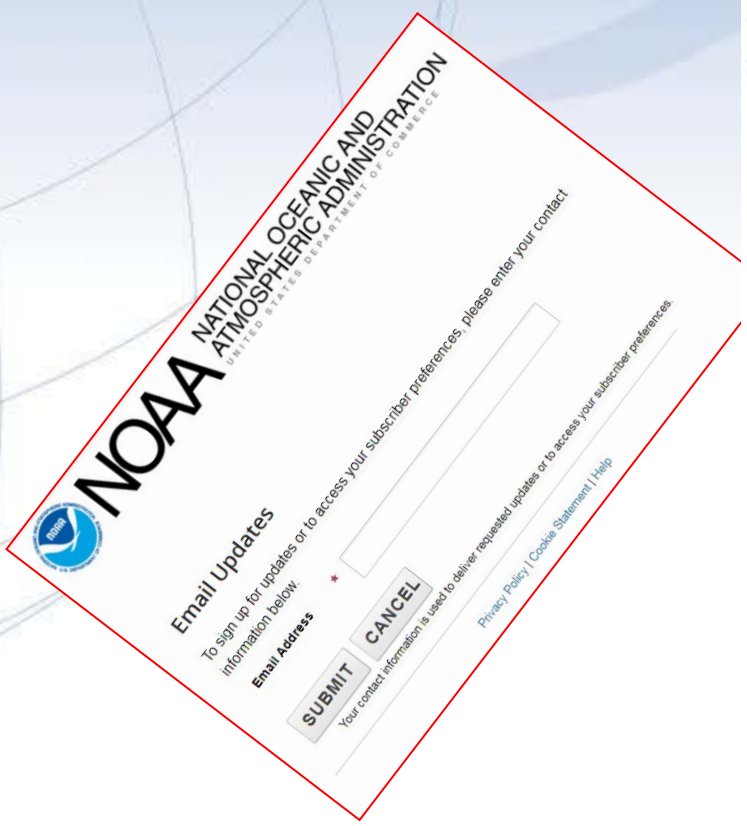
#1 Geometric: Sep. 2017



#2 Geopotential: Nov. 2017



#3 Working in the Modernized NSRS: Coming Soon



National Geodetic Survey *Positioning America for the Future* geodesy.noaa.gov

Issue 14, February 2019

NSRS Modernization News

For all issues of **NSRS Modernization News**, visit:
geodesy.noaa.gov/datums/newdatums/TrackOurProgress.shtml

Geospatial Summit 2019

The next Geospatial Summit about NSRS Modernization will take place May 6-7, 2019 in Silver Spring, MD. Mark your calendars and check the 2019 NGS Geospatial Summit page for more information when it becomes available.

Shutdown Impacts

The 35 day partial shutdown of the government included the Department of Commerce and subsequently the National Geodetic Survey. The potential damage caused to the already tight schedule of the NSRS Modernization effort is not yet fully known. However, some immediate impacts can be stated definitively:

1. The long-awaited GRAV-D airborne gravity survey of the Pacific Islands (Hawaii, Guam, CNMI and American Samoa) was scheduled to begin in early January, and run through March. Existing commitments of the aircraft mean that the entirety of that survey cannot be completed before March. The survey is now scheduled to begin in Hawaii in early February, then move to American Samoa, barring weather, maintenance or further shutdowns. The Guam and CNMI portions of the survey will be put off for a future date.
2. The significance of this delay should not be underestimated. The GRAV-D schedule is effectively the "long pole in the tent". Getting the modernized NSRS out, even in late 2022, depends upon mitigating any significant or unforeseen delays in GRAV-D. 2022 remains the official completion and rollout date, although the schedule is now questionable.
3. *The Blueprint for 2022, Part 3: Working in the modernized NSRS* document is now tentatively scheduled for release prior to the Geospatial Summit in May, despite the disruption to the writing and editing process. Still, the importance of this document to the NGS communications plan puts its release as a top priority under the modernization efforts.

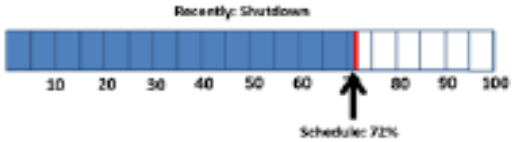
Progress in Ongoing Projects

There are currently 18 ongoing projects directly related to NSRS modernization around NGS. Here are highlights from a select few:

- **Comprehensive Toolkit Improvements**
  Project Manager: Dr. Dru Smith (*Acting*)

  It is NGS's intention that NCAT and VDatum eventually be able to perform all transformation and conversion functions that currently reside as separate tools in the NGS Toolkit. A complete diagram of that functionality has been completed and provided to both the NCAT and VDatum teams in order to assist in this effort. Look for updates to NGS Toolkit over the coming months.

GRAV-D progress last quarter: up 0.9% to 72.8%
Ahead of Schedule (despite the shutdown)!



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May 6-7, 2019 --- Silver Spring, MD

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On May 6-7, 2019 NGS will host the 2019 Geospatial Summit at the Silver Spring Civic Building at 1 Veterans Pl, Silver Spring, MD 20910.

Accurate positioning begins with *accurate* coordinates

Source: Zurich-American Insurance Group