# NSRS Modernization

## PLSO Cleveland Chapter

September 2019

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**Appalachian Regional Geodetic Advisor**
**jeff.jalbrzikowski@noaa.gov**
**240-988-5486**

# My Background

- Licensed Surveyor in OH, PA, and WV
- Certified GIS Professional
- University of Akron (Ohio)
  - B.S. in Surveying and Mapping
    - Minor in GIS
- Came to NGS from USACE (Pittsburgh, PA)
  - GIS Technician with MWCD
  - Cadastral Surveyor with BLM Oregon State Office
  - "Intern #2" with Steve Metcalf for a summer ☺

# Have you previously heard that NAD83 and NAVD88 are scheduled to be replaced in the near future?

Who's nervous?

Who's ready?

Who's already working in ITRF?

# Organizational Structure

- Federal Government – Executive Branch

-Department of Commerce (DoC)

(~47,000 employees)

↓

-National Oceanic and Atmospheric Administration (NOAA)

↓

-National Ocean Service (NOS)

↓

-National Geodetic Survey (NGS)

(~175 employees)

# NGS Overview

## Modernizing the NSRS

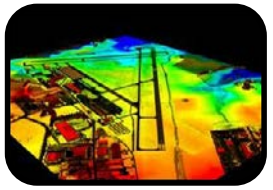

CORS


NHMP


GRAV-D


ECO

## NGS Products and Services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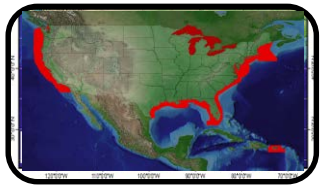
OPUS

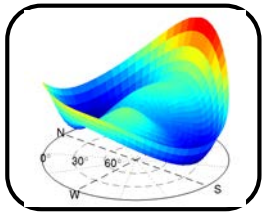

VDatum


Orbit Data


National Shoreline

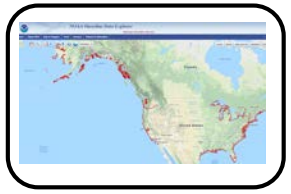

Geodetic Advisors


ERI



Antenna Calibrations


NCAT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CBL

Outreach/COMET

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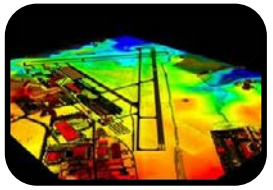
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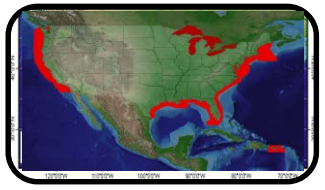
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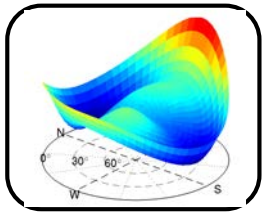

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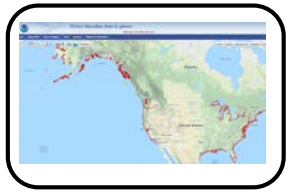
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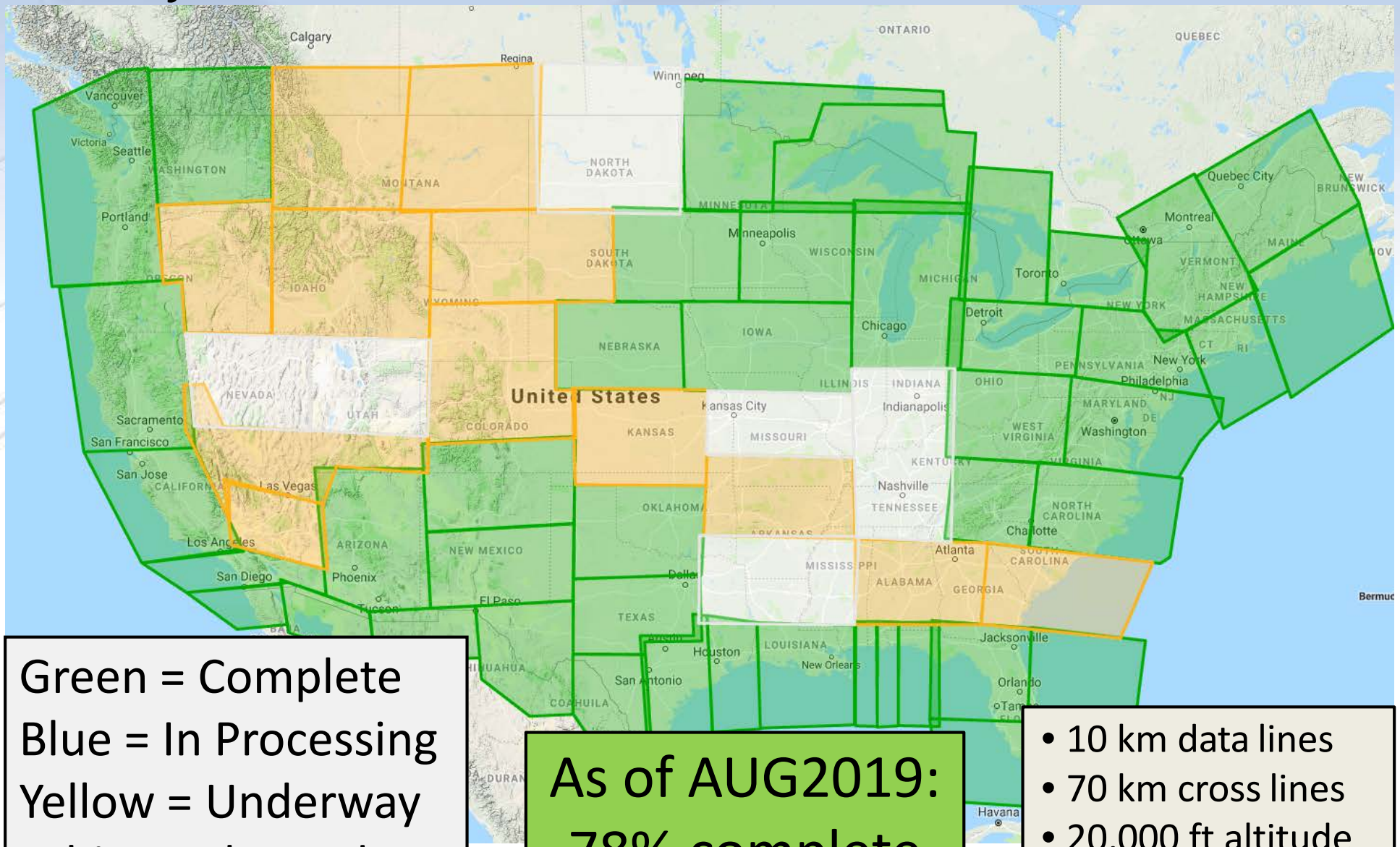
# Gravity for the Redefinition of the American Vertical Datum

- Two major campaigns within GRAV-D

1. High-resolution snapshot of gravity
   - primarily airborne observations, all *relative gravity*, estimated cost of ~$39 million

2. Low-resolution "movie" of gravity changes
   - primarily terrestrial, episodic observations of *absolute gravity* sites

# Gravity for the Redefinition of the American Vertical Datum




Green = Complete
Blue = In Processing
Yellow = Underway
White = Planned

As of AUG2019:
78% complete

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

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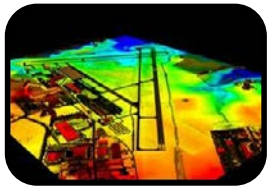
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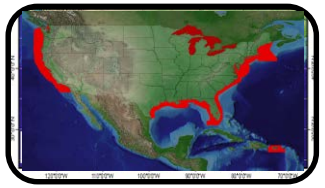
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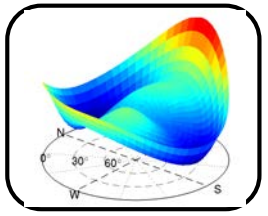

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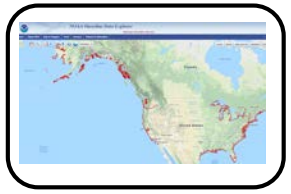
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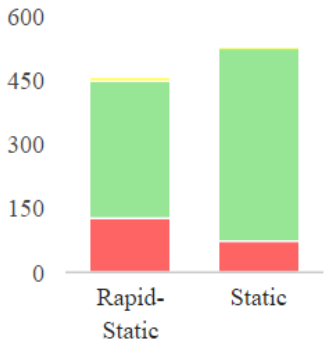
# Online Positioning User Service

- OPUS Rapid Static (OPUS-RS)
  - dual frequency receiver
  - static sessions only
  - 30 seconds epoch rate (aka recording interval)
  - at least 15 minutes of GPS data
- OPUS Static (OPUS-S)
  - same requirements as above
  - 2 to 48 hours of GPS data
- OPUS Projects (OP)
  - same as Static, but allows session processing and adjustment
  - training by NGS required; typically 12 hours
  - files uploaded to OPUS, with a "Project ID" keyed in Options
- Beta OPUS Projects (minor enhancements)

# Note on OPUS "my profile"

projects
shared solutions

support / feedback




**OPUS Today**
as of 2019-02-05T16:00 EST

**antenna** - choosing wrong may degrade your accuracy.

2.000 *meters above your mark.*
**antenna height** of your antenna's reference point.

jeff.jalbrzikowski@noaa.gov
* **email address** - your solution will be sent here. **Privacy Act Statement**

Options to **customize** your solution.

| | | |
|---|---|---|
| **formats** | standard ▼ | **formats explained** |
| **base stations** | **Use:** **Exclude:** | identify any CORS you wish to explicitly include or exclude from your solution by typing in 4-char site IDs separated with line break<br>**-- sample**<br>**-- find site IDs** |
| **state plane** | let OPUS choose ▼ | your **SPCS zone** |
| **project identifier** | | enter the id provided by your project manager |
| **my profile** | ▼ | customize OPUS defaults for future solutions |
| **share my solution** | No, don't share ▼ | **sharing explained** |

be careful!

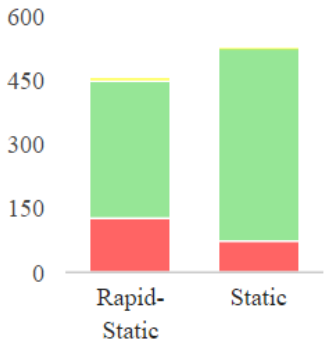
Upload to Rapid-Static
for data 15 min. - 2 hrs.

Upload to Static
for data 2 hrs. - 48 hrs.

# OPUS Projects

projects
shared solutions

support / feedback

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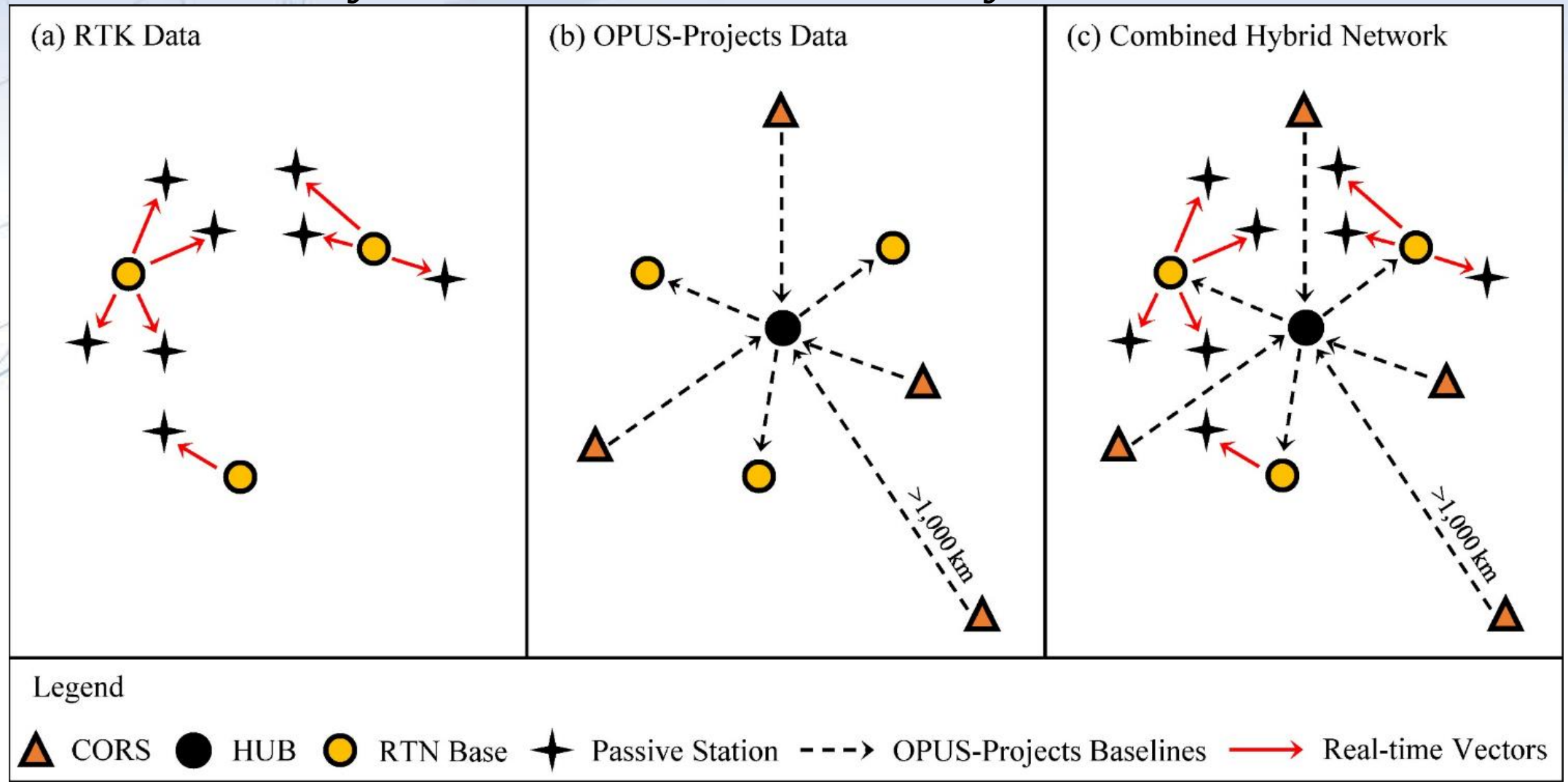
Upload to Rapid-Static
for data 15 min. - 2 hrs.

Upload to Static
for data 2 hrs. - 48 hrs.

# OPUS for Real-Time

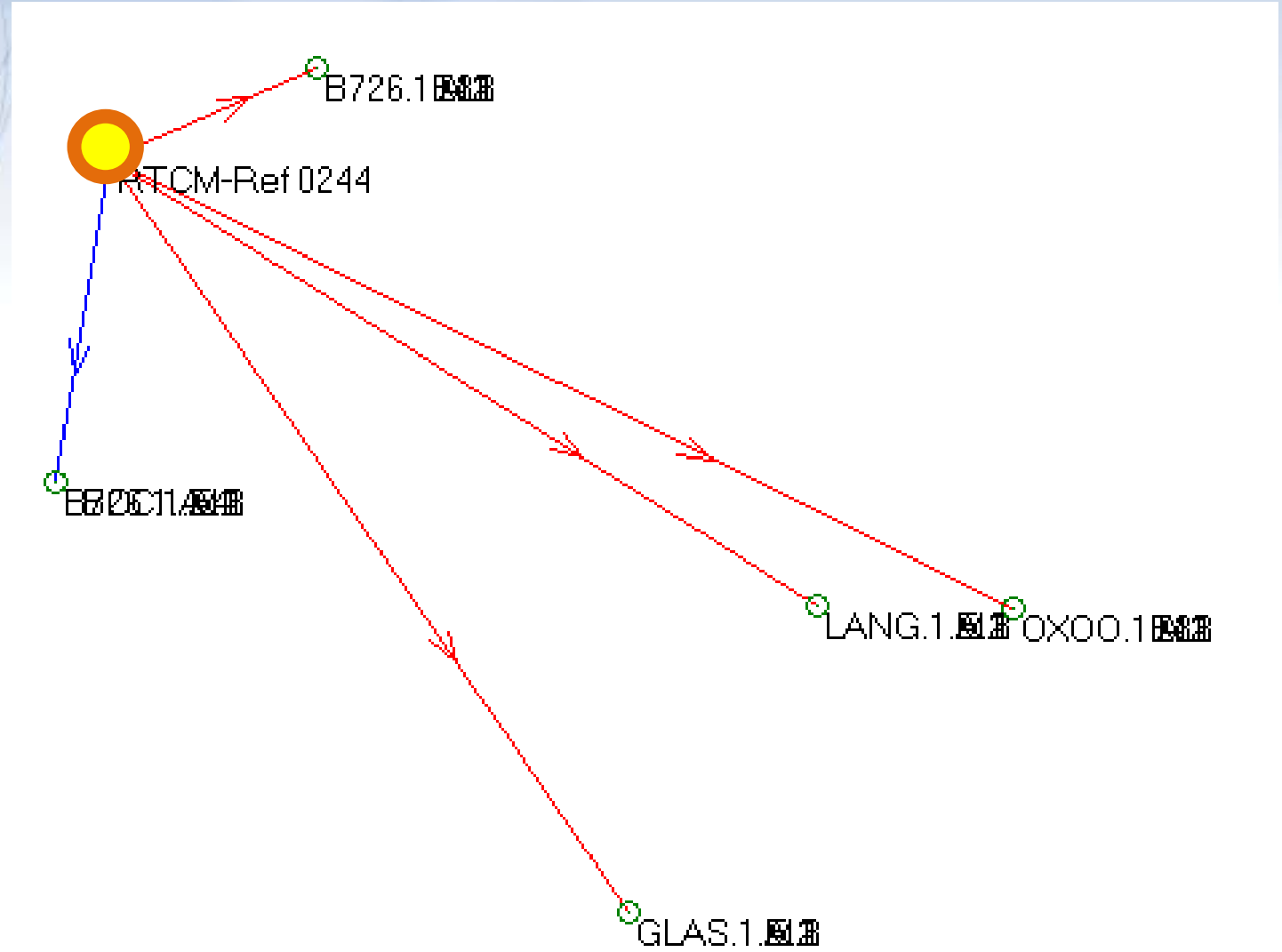
## Hybrid Static + RTN Survey Networks

[Weaver et al. 2018]

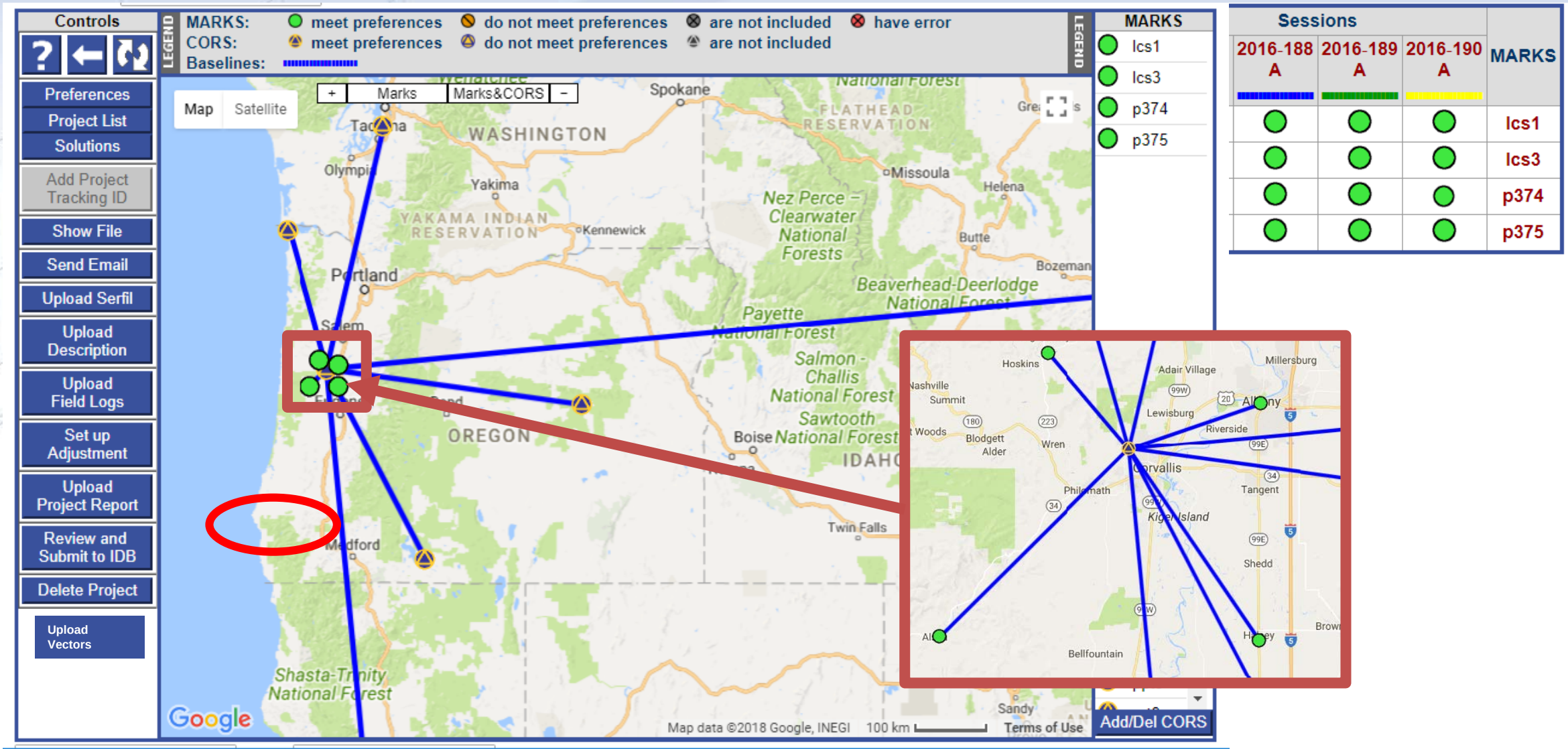


# Example: Download RTN Data

BASE
(LCS1)

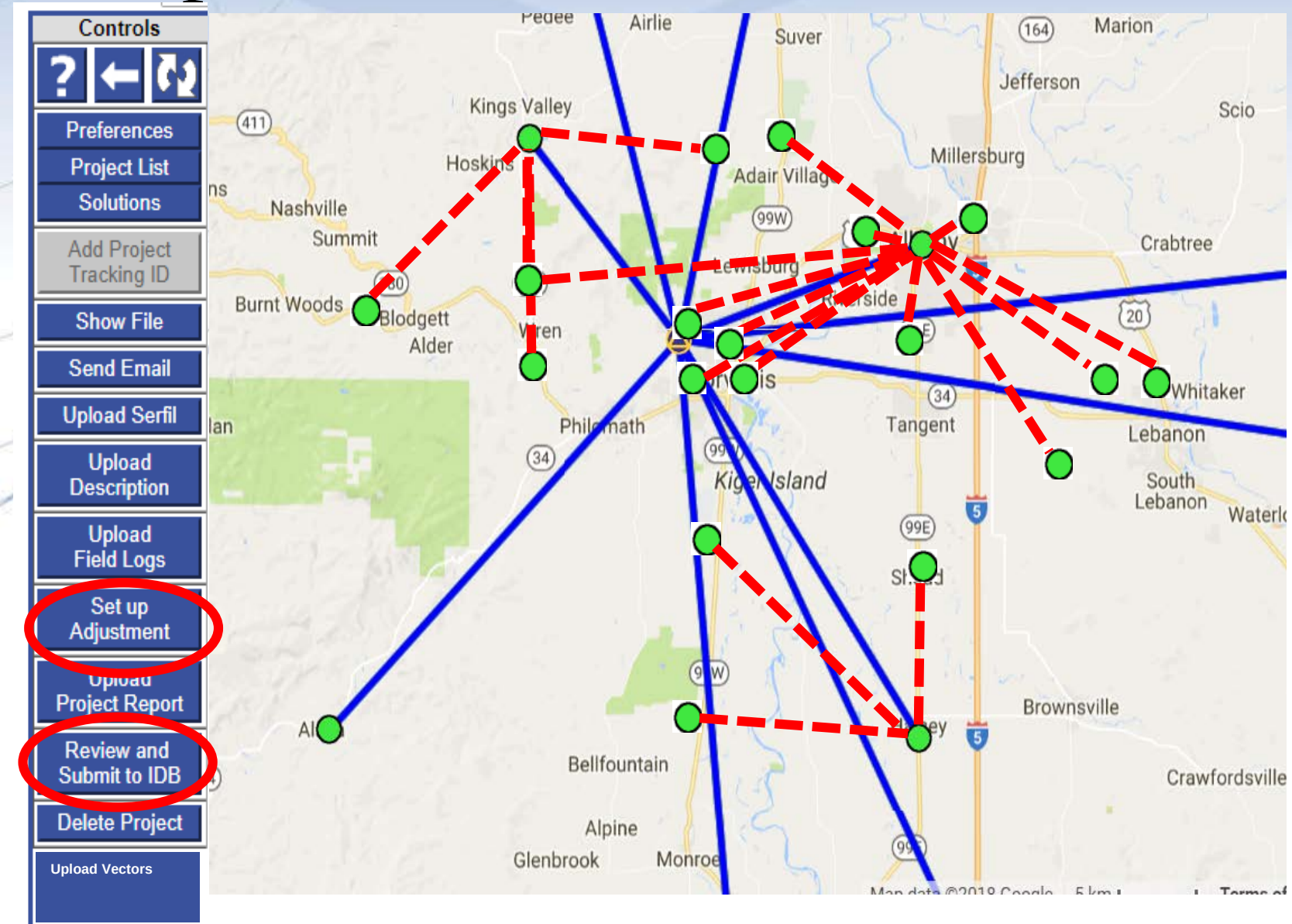


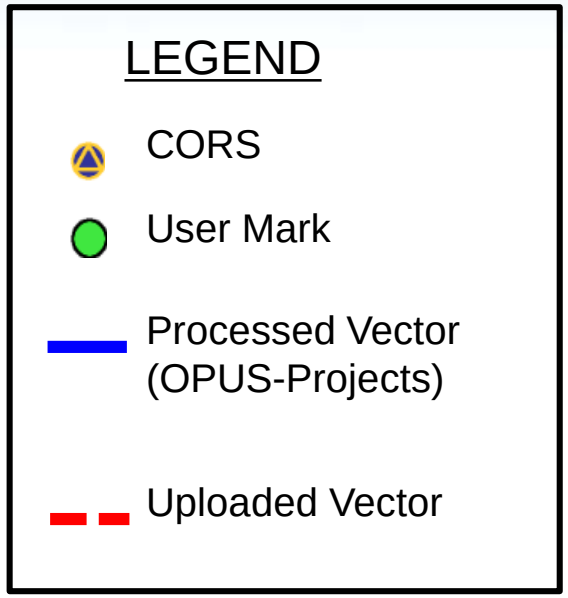
# Process the Static Data in OPUS-Projects




| Sessions | | | MARKS |
|---|---|---|---|
| 2016-188 A | 2016-189 A | 2016-190 A | |
| ● | ● | ● | lcs1 |
| ● | ● | ● | lcs3 |
| ● | ● | ● | p374 |
| ● | ● | ● | p375 |

# Upload the RTN Vectors to OPUS-Projects



# Adjust the Static + RTN Network in OPUS Projects

- Run least squares adjustment(s) of the combined static data and RTN vectors in the survey network
- Hold CORS (and possibly other published coordinates on passive marks) as control in network adjustments
- Check quality of results
- Submit survey project to NGS for review and publication in national database

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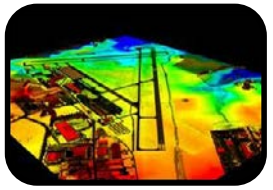
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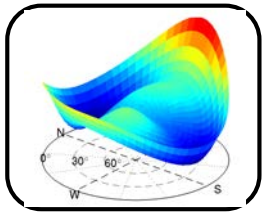

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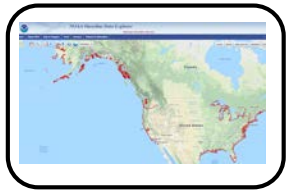
CUSP


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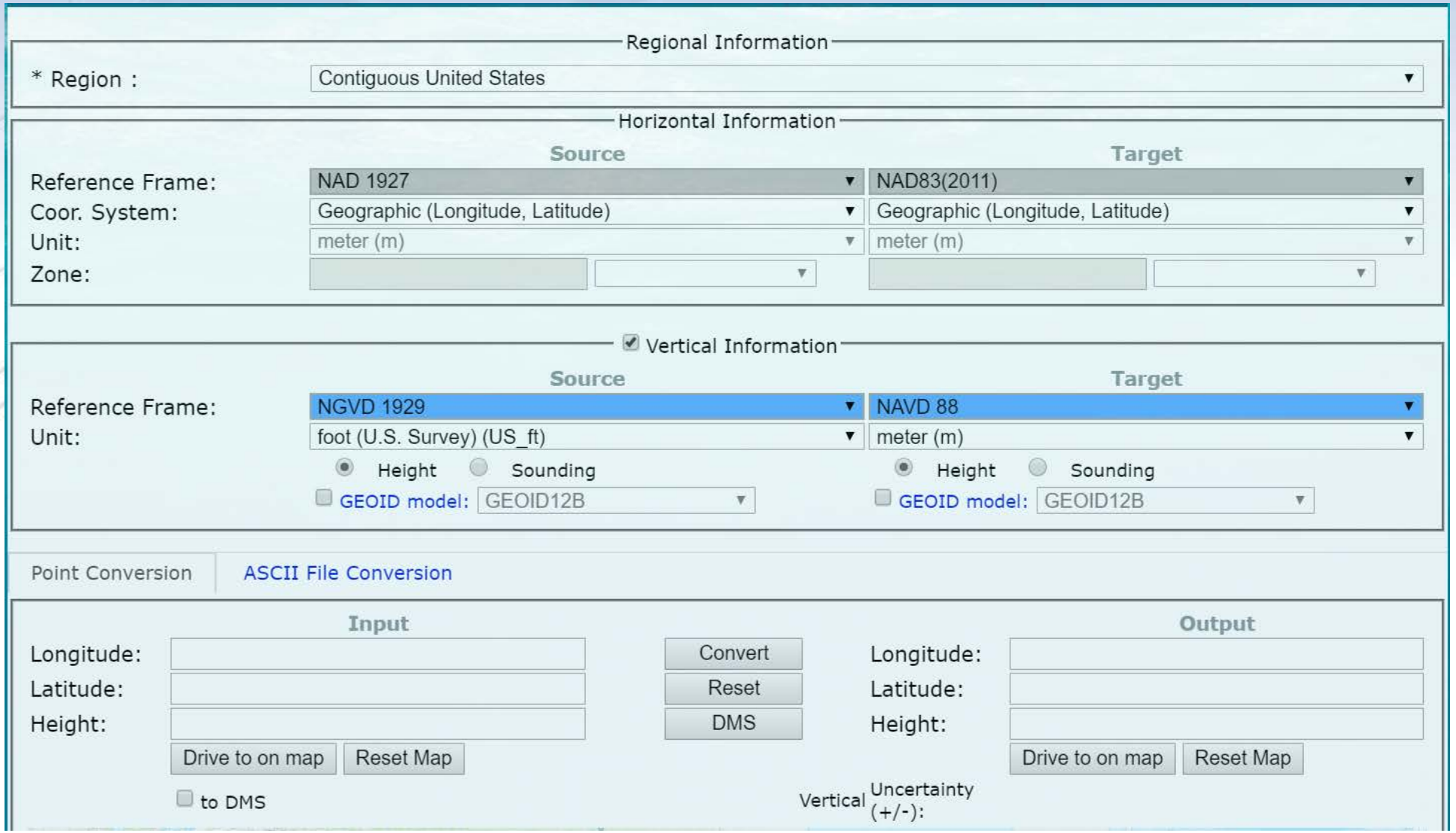
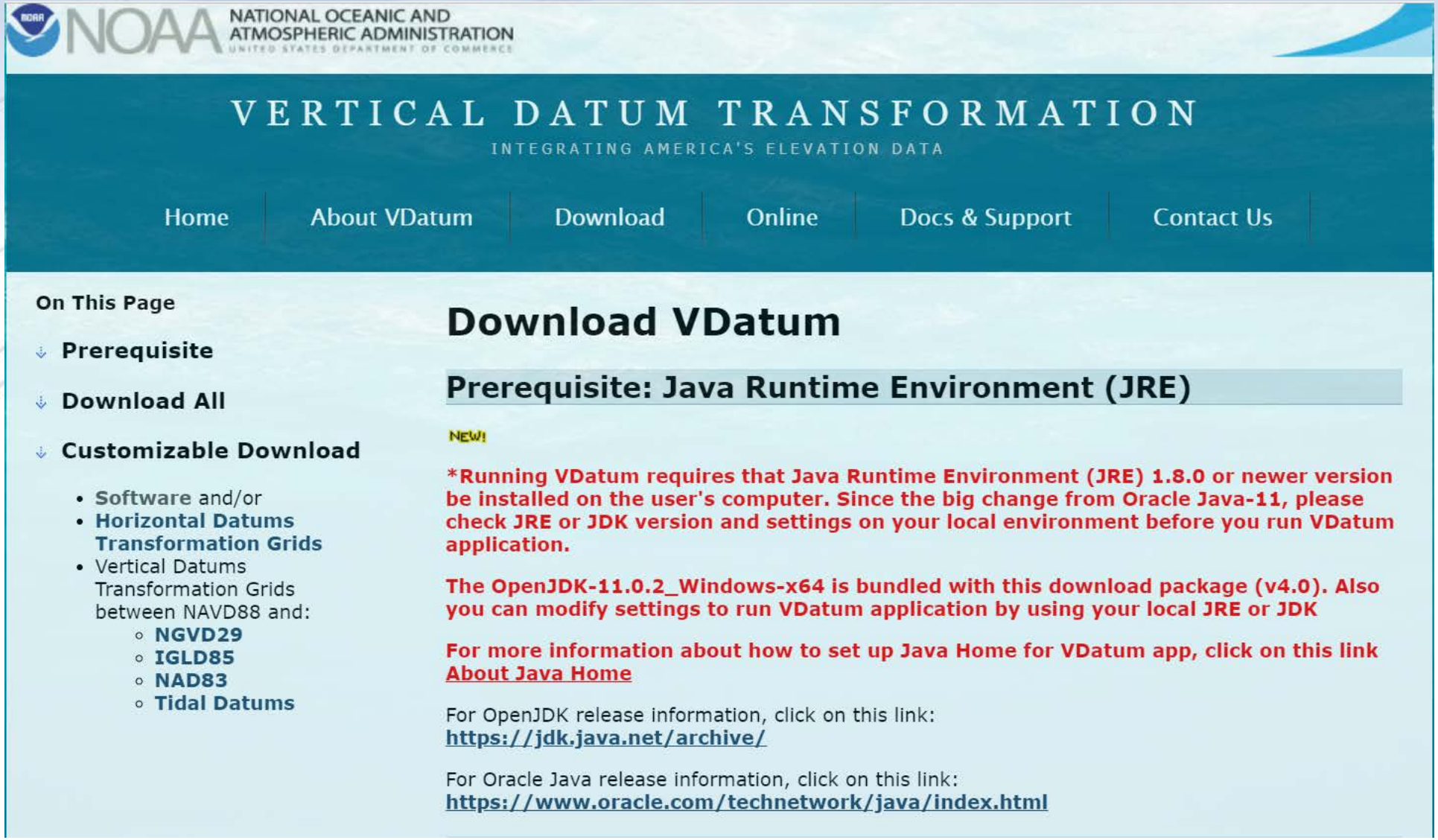
Outreach/COMET

# NOAA VDatum - online



# NOAA VDatum - download



## Ellipsoidal Transformation Epoch Inputs

To provide data transformations with closer agreement to those produced by the NGS HTDP program. VDatum now allows the user to specify the input and output epochs of positions. These epochs will be used to apply a time-dependent, 14 parameter transformation that utilizes HTDP 3.2.5-predicted velocities, where available. If the user does not specify input and output epochs, they will be handled as described below.

Non-User Specified input and output epochs of positions:

If a user does not specify an input or output epoch for positions, the following will be utilized by default as the input epoch and the output will be established based on your computer time and date:

- 2000 for the following frames: IGS08, ITRF2008, IGb08, ITRF2000, ITRF2005, WGS84 (G1674) and WGS84 (G1762)
- 1997 for all NAD83 (2011/CORS96/2007; PA11/PACP00; MA11/MARP00) realizations, ITRF97, WGS84 (transit).
- 1996 for ITRF96
- 1988 for ITRF88, ITRF89, ITRF90, ITRF91, ITRF92, ITRF93

User Specified input and output epochs of positions:

Dates may be entered either in the month-day-year format or in the decimal-year format. For the month-day-year format, the month is a number between 1 and 12 and a four-character year is required. The month, day, and year may be separated by spaces or by commas. Valid examples are: 5,4,1998 for May 4, 1998.

For the decimal-year format, enter yyyy.xxx where yyyy denotes the year and xxx denotes the fraction of the year. Valid examples are:

2010.0 for January 1, 2010
1979.359 for May 12, 1979

○ month-day-year ◉ decimal year

**Specify the reference date of the input position(s):** 2010.000

**Specify the reference date of the output position(s):** 2019.530

OK

Note: Remove output position reference date to proceed with default epoch positions.

# NOAA VDatum Website

vdatum.noaa.gov

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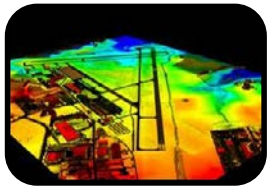
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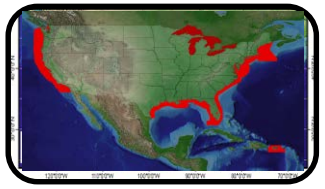
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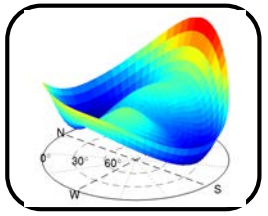

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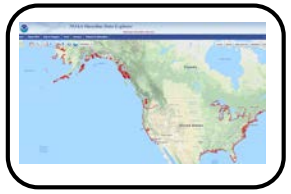
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https://www.ngs.noaa.gov/ADVISORS/

# Regional Geodetic Advisor Program

- www.ngs.noaa.gov/ADVISORS/
- query any major search engine: "ngs advisors"

**Appalachian**
(KY, OH, PA, and WV)
**Jeff Jalbrzikowski, NOAA, P.S., GISP**
NOAA/NOS/National Geodetic Survey
125 South Oval Mall
318 Mendenhall Lab
Columbus, OH 43228
**Mobile:** (240) 988-5486
jeff.jalbrzikowski@noaa.gov

# State Geodetic Coordinators

- not an NGS employee
- a liaison between the State's geospatial community and the NGS

## Ohio

**Raymond W. Foos, P.S.**
Survey Operations Manager
Office of CADD & Mapping Services
Ohio Department of Transportation
Mail Stop 4130 - 1st Floor
1980 W Broad St
Columbus, OH 43223
**Phone:** (614) 466-3075
**Mobile:** (440) 309-7055

Ray.Foos@dot.ohio.gov

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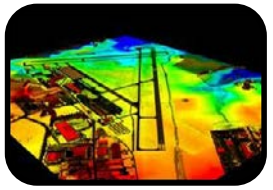
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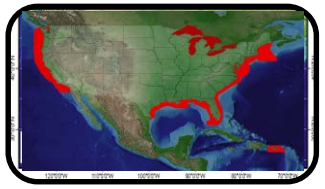
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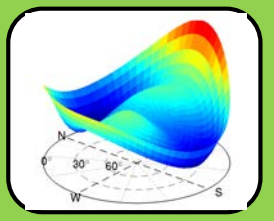

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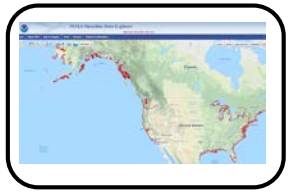
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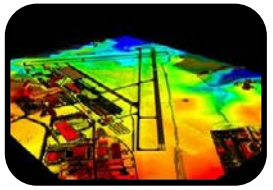
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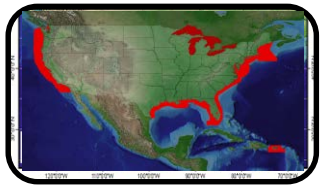
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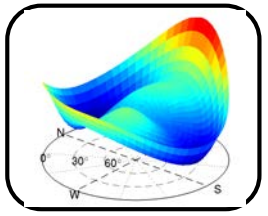

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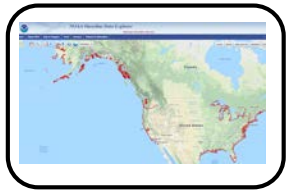
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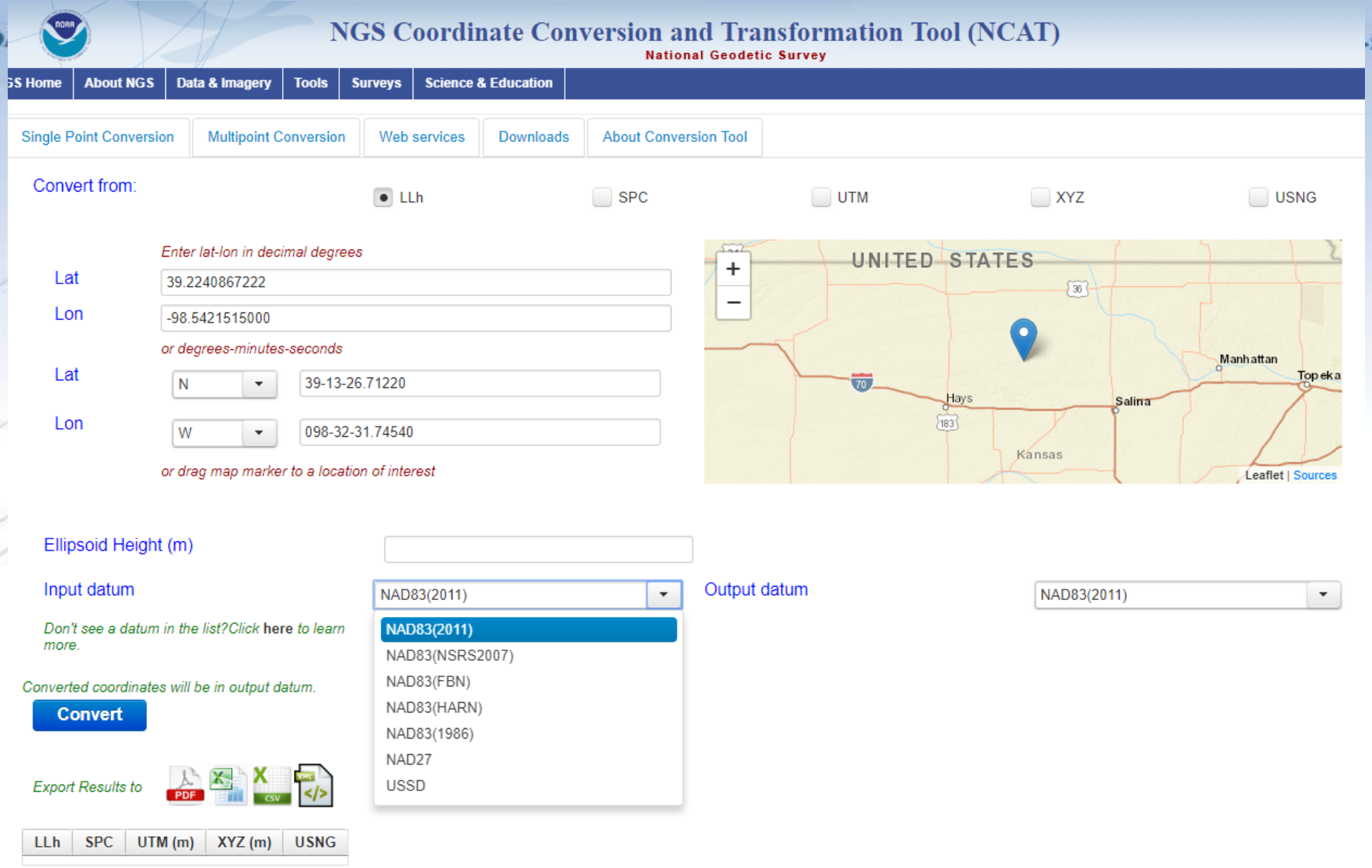


# NGS Coordinate Conversion and Transformation Tool

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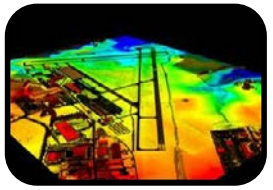
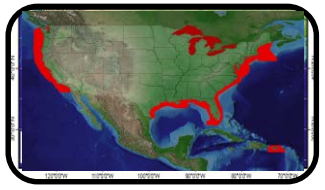
ECO

## NGS Products and Services


ASP


OPUS

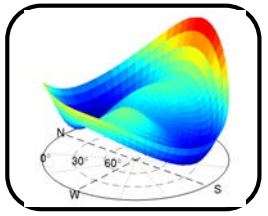

VDatum


Orbit Data


National Shoreline

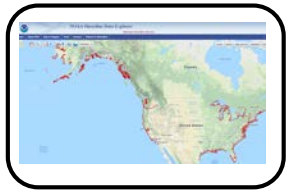

Geodetic Advisors


ERI



Antenna Calibrations


NCAT


CUSP


CBL

Outreach/COMET

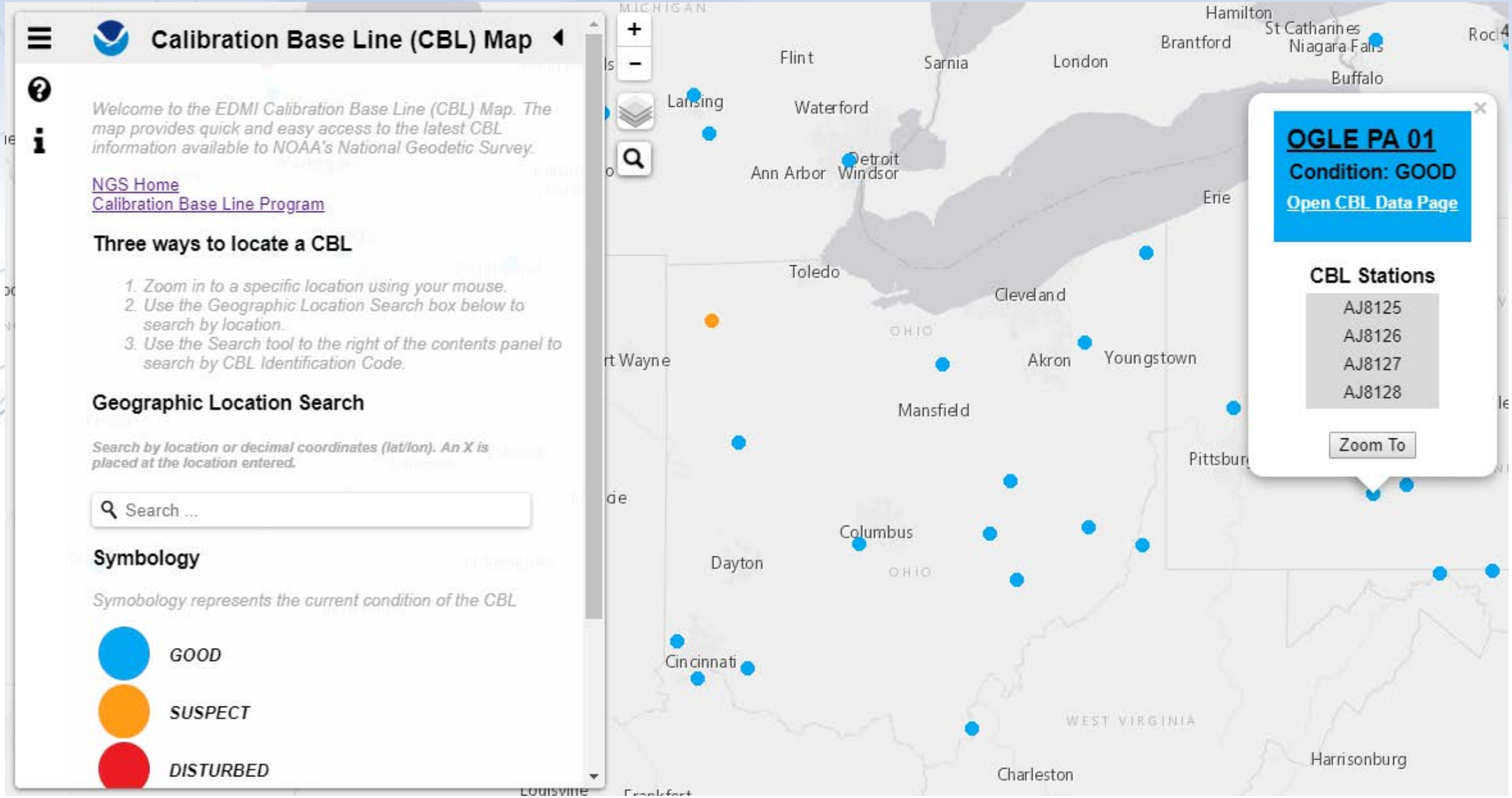
# Calibration Base Lines

- Three types of CBL defined by NGS
  - **Primary** CBL (**PCBL**): in Woodford, VA; it is open for use to Contributing Partners (like KAPS)
  - **Federal** CBL (**FCBL**): est. with EDM checked at the NGS PCBL and IAW NOAA TM NGS-8
  - **Cooperative** CBL (**CCBL**): est. with EDM checked on an FCBL and IAW that same NGS-8 manual

# Calibration Base Lines

- NGS commitment to the CBL Program:
  - A minimum of one FCBL per State
  - Establishment procedures document
  - Public access to the CBL database
  - Software to process your observations
  - Verification and re-measurement data review
  - Technical support (Advisors or other personnel)

# Beta CBL Map Viewer



# NGS Overview

## Modernizing the NSRS

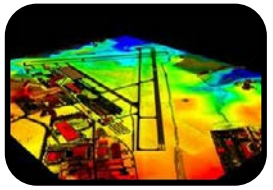

CORS


NHMP


GRAV-D


ECO

## NGS Products and Services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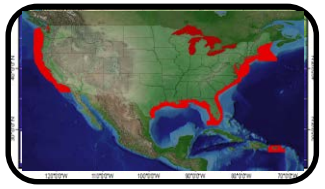
VDatum


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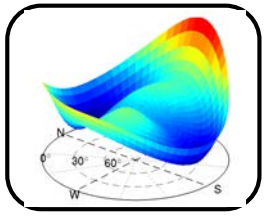
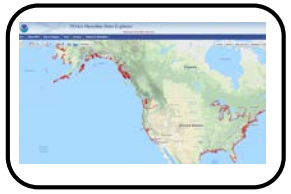


Antenna Calibrations


NCAT


CUSP


CBL

Outreach/COMET

# Cooperative program for Operational Meteorology, Education, and Training

- Meteorology… huh?
- The origin of the program was the National Weather Service, also a NOAA sub-agency.
- It expanded to various NOAA missions.

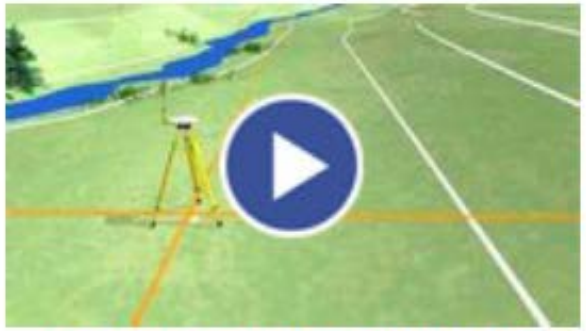
# Outreach and COMET

What are Geodetic Datums?

How Were Geodetic Datums Established?


What Is the Status of Today's Geodetic Datums?

What's Next for Geodetic Datums?



Precision and Accuracy in Geodetic Surveying

Two Right Feet? U.S. Survey Feet vs. International Survey Feet

# 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.

# National Spatial Reference System (NSRS)

A consistent coordinate system that defines

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

throughout the United States.

*…and their time variants*

# 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 | GEOID12A & B | NADCON |
| NAD27 | NGVD29 | IGLD55 | GEOID09 | VERTCON |
| USSD | VIVD09 | | GEOID06 | |
| | GUVD04 | | GEOID03 | SPCS83 |
| | NMVD03 | | GEOID99 | SPCS27 |
| | ASVD02 | | GEOID96 | |
| | PRVD02 | | 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 by IERS) | | EGM2008 | Oregon Coordinate Reference System (ORCS) |
| IGS (Intl. GNSS Service reference frame) | | | The Kansas Regional Coordinate System |

Hyperlink to ITRF station map

# NSRS … do I have to use it?

- Office of Management and Budget: Circular A-16
  1) requires all Federal civilian agencies to utilize geodetic control for their geospatial activities
  2) dictates DoC in responsible charge of that control
  3) NGS has defined that control as the NSRS
  4) FGCS has issued requirements, via FRNs, to reference data to the ***most recent components*** of the NSRS
     - 1989 FRN designated NAD 83
     - 1993 FRN designated NAVD 88

Hyperlink to NAVD88 FRN  Hyperlink to NAD83 FRN

# NSRS … do I have to use it?

- No, not really! But it is a good idea.
- States may mandate use
- State, Local, Regional entities, or the Private Sector have ***no requirement*** to maintain their data in reference to the NSRS
- But if you want to get involved in survey contracting with the Federal Government it's a necessity

# NSRS and New Datums

- The blanket term being used is:

## NSRS Modernization

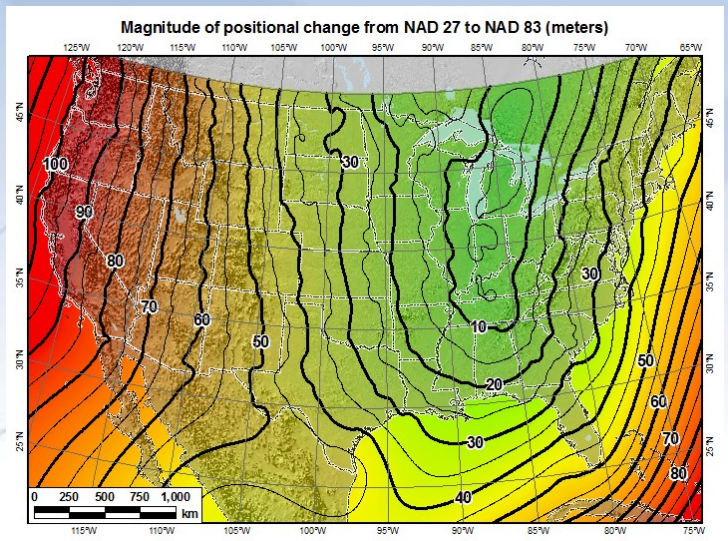
Term includes all things related to the new datums, like updates to OPUS, SPCS, and some programs that have not yet even been finalized.

# NSRS Modernization means…

- Replacing NAD83 — **Blueprint for 2022, Part 1**
- Replacing NAVD88 — **Blueprint for 2022, Part 2**
- Re-inventing Bluebooking
- Improving the Geodetic Toolkit
- Better Surveying Methodologies

(Re-inventing Bluebooking, Improving the Geodetic Toolkit, Better Surveying Methodologies) — **Blueprint for 2022, Part 3**

# A (very) Brief History of U.S. Horizontal / Geometric Datums





U.S. Standard Datum

NAD27

NAD83 (1986)

NAD83 (HARN /199X)

NAD83 (2007)

**NAD83 (2011)**

time

shift: < 10 m | tens of meters | few 0.1m | few 0.01m | few 0.01m

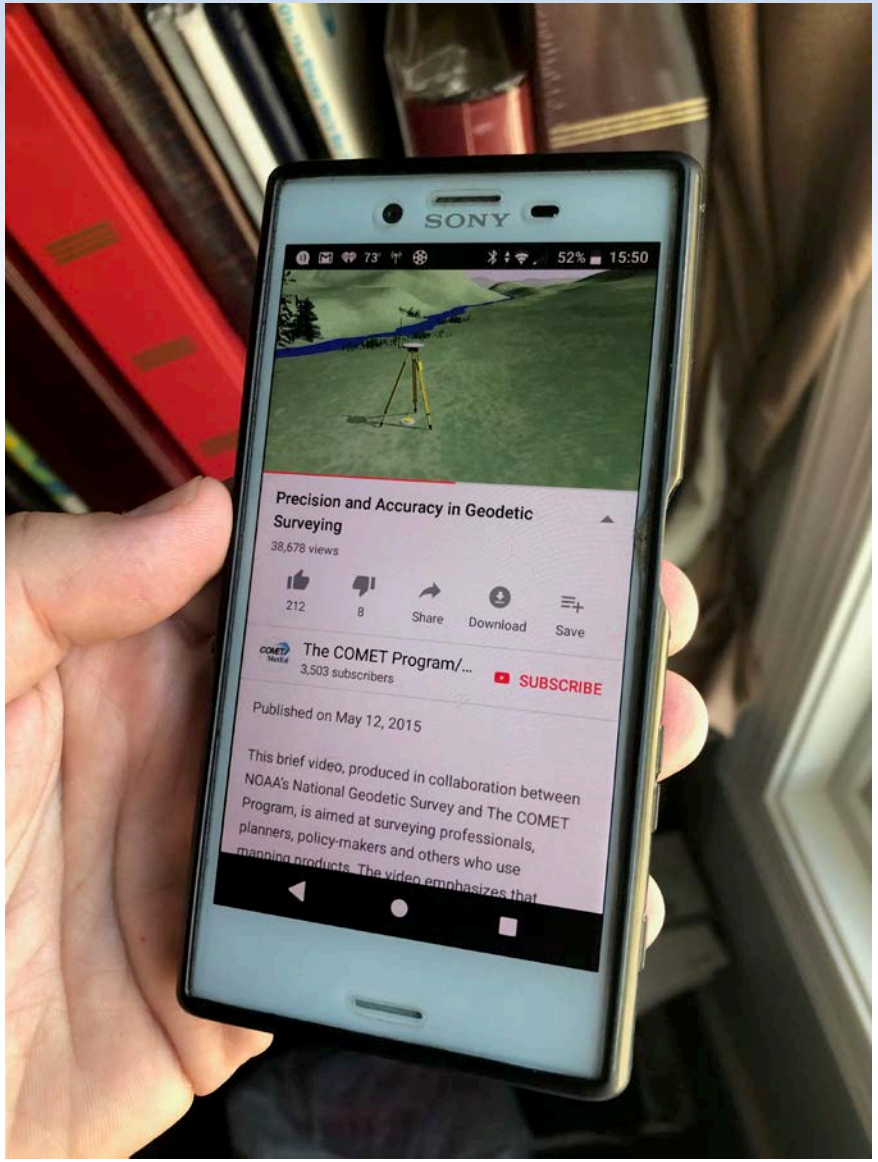
# Evolution of the NSRS

NAD27 → NAD83 (1986) → NAD83 (2007/2011)

# NATRF2022 is our "smartphone"

- You resisted it for a while…
- It was a little cumbersome to get used to
- But now you use it every day!

- Heck, I'll bet you use an app to do site recon and recover your survey control



# North American Terrestrial Reference Frame of 2022

# (NATRF2022)

# Why replace NAD83?

- **Main driver: *Global Navigation Satellite System (GNSS)***
- **ACCESS!**
  - GNSS equipment is fast, inexpensive, reliable
  - Reduces reliance on physical control marks
- **ACCURACY!**
  - Insensitive to distance-dependent errors
  - Immune to monument instability; active control via CORS
- **CONSISTENCY!**
  - Eliminates systematic errors in current datums
  - Aligned with global reference frames (ITRF now "mature")
  - Integrated system for both position and height

# Replacing NAD83

1. NAD83 will be replaced by four "plate-fixed" reference frames
2. remove non-geocentricity of NAD83 by aligning with global reference frame ITRF2014
3. identical to ITRF2014 at 2020.00, then diverges
4. remove most of tectonic plate rotation from ITRF2014 using updated Euler Poles (pronounced "oiler")

*Shift and Drift…*

# Reference Frame ≈ Datum

- Reference Frame is a more *scientifically appropriate* way of saying "datum"
- could be debated that "datum" was misused
- you will continue to see NGS use the phrase "New Datums for 2022"

# Reference Frame Defined

A Reference Frame is a point of view or a 'frame of reference'.

If your reference frame is North America, you are standing somewhere within North America, **seeing how other places move**, from your point of view.

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*Shift and Drift…*

# Four "Plate-Fixed" Reference Frames

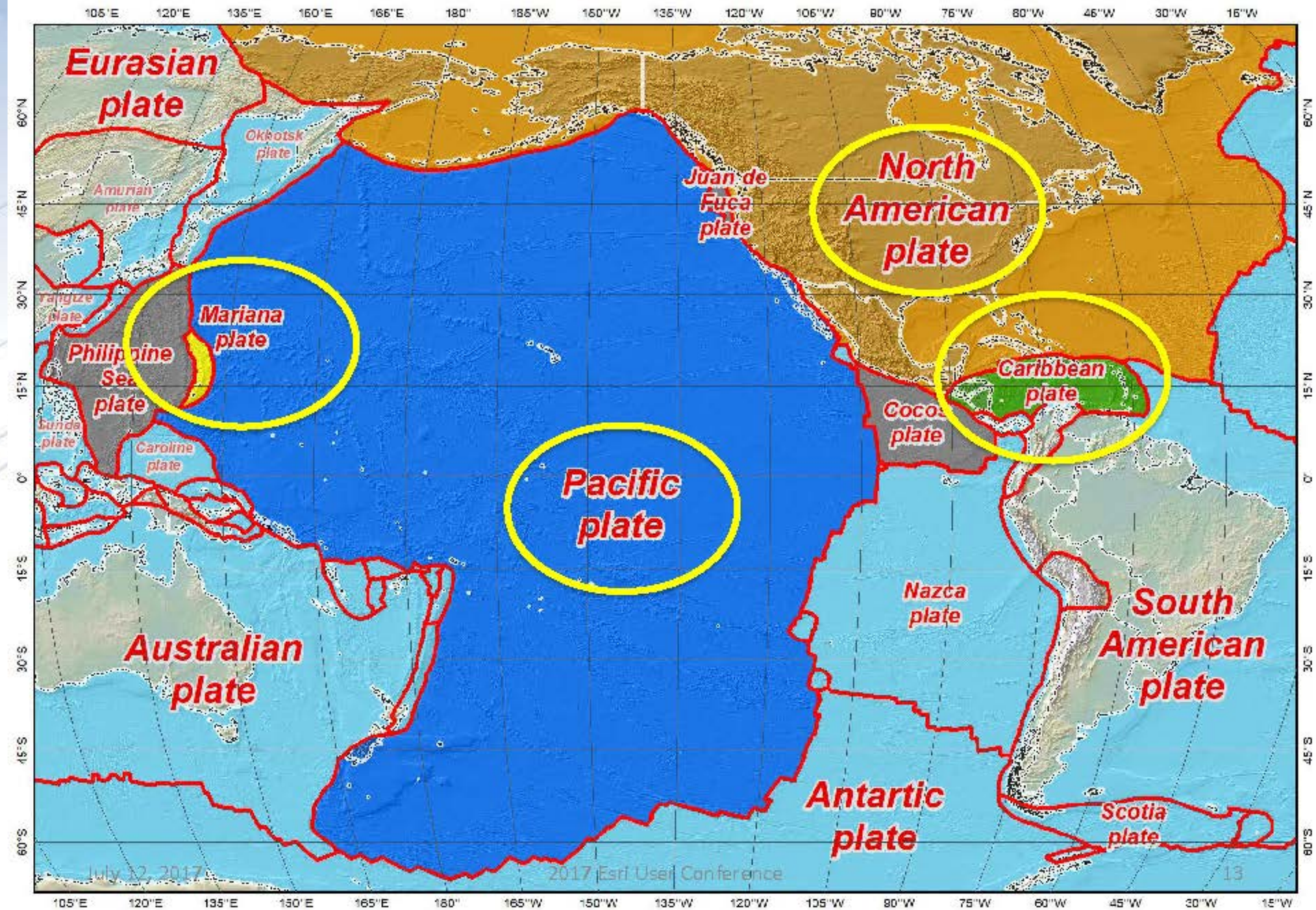
North American Terrestrial Reference Frame of 2022
(NATRF2022)

Pacific Terrestrial Reference Frame of 2022
(PATRF2022)

Caribbean Terrestrial Reference Frame of 2022
(CATRF2022)

Mariana Terrestrial Reference Frame of 2022
(MATRF2022)

# The four tectonic plates "fixed" for the 2022 terrestrial reference frames



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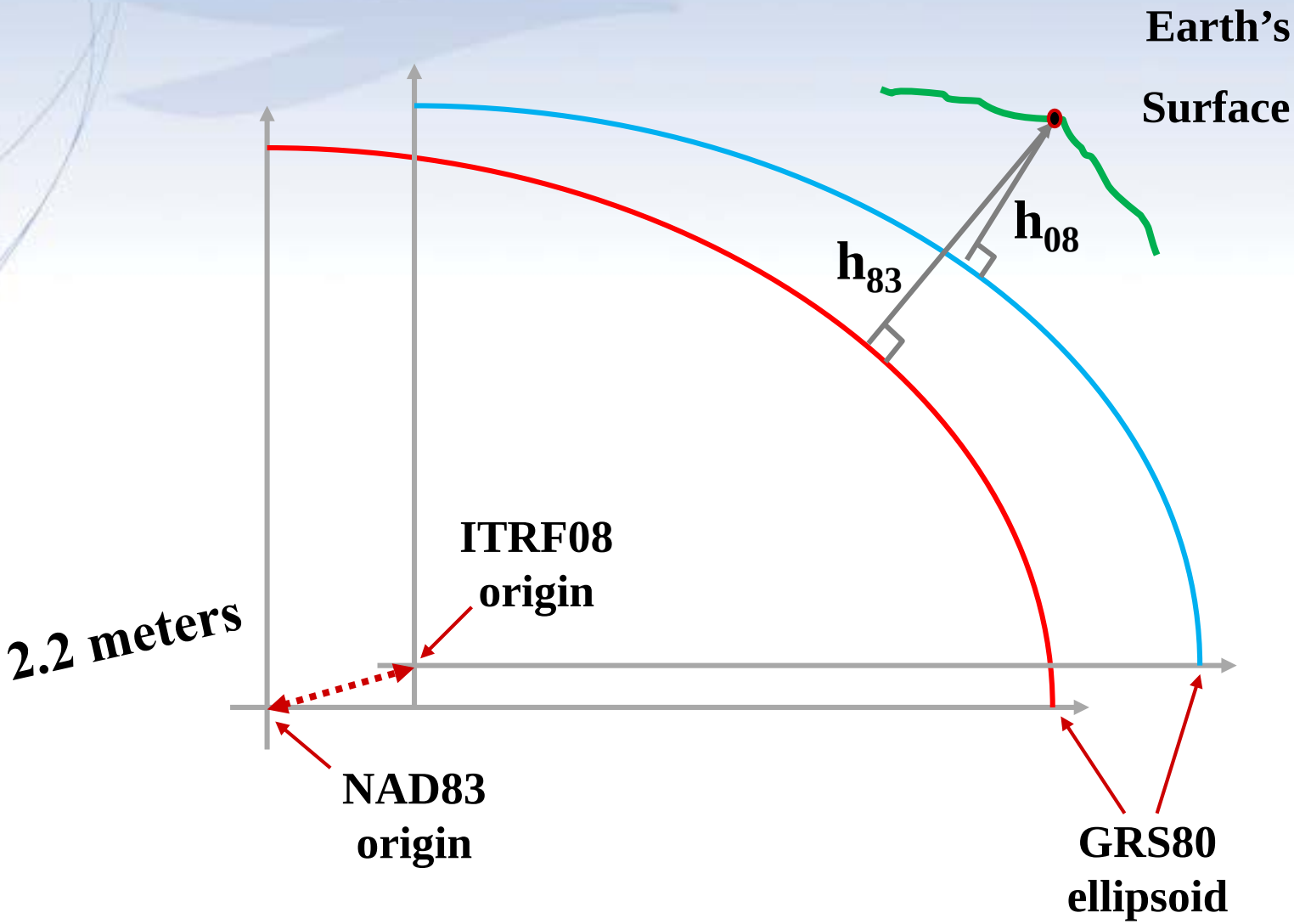
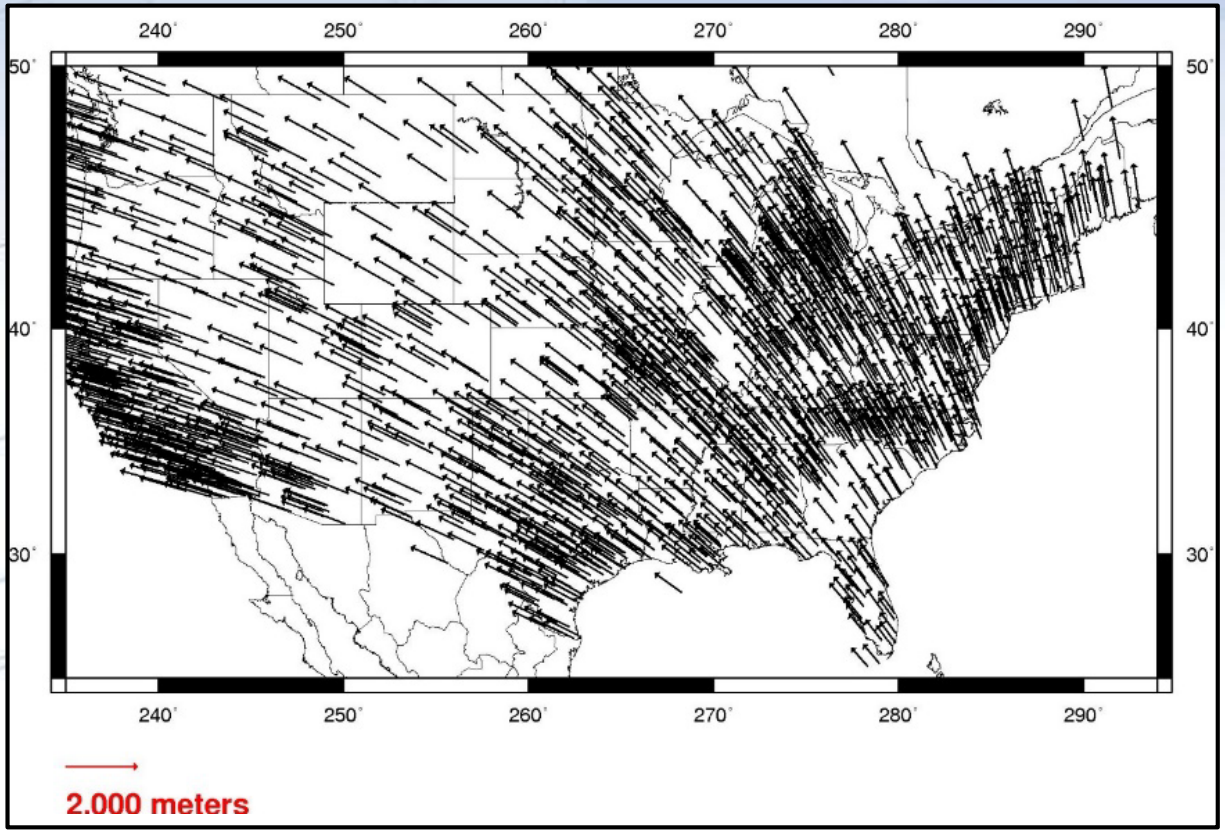
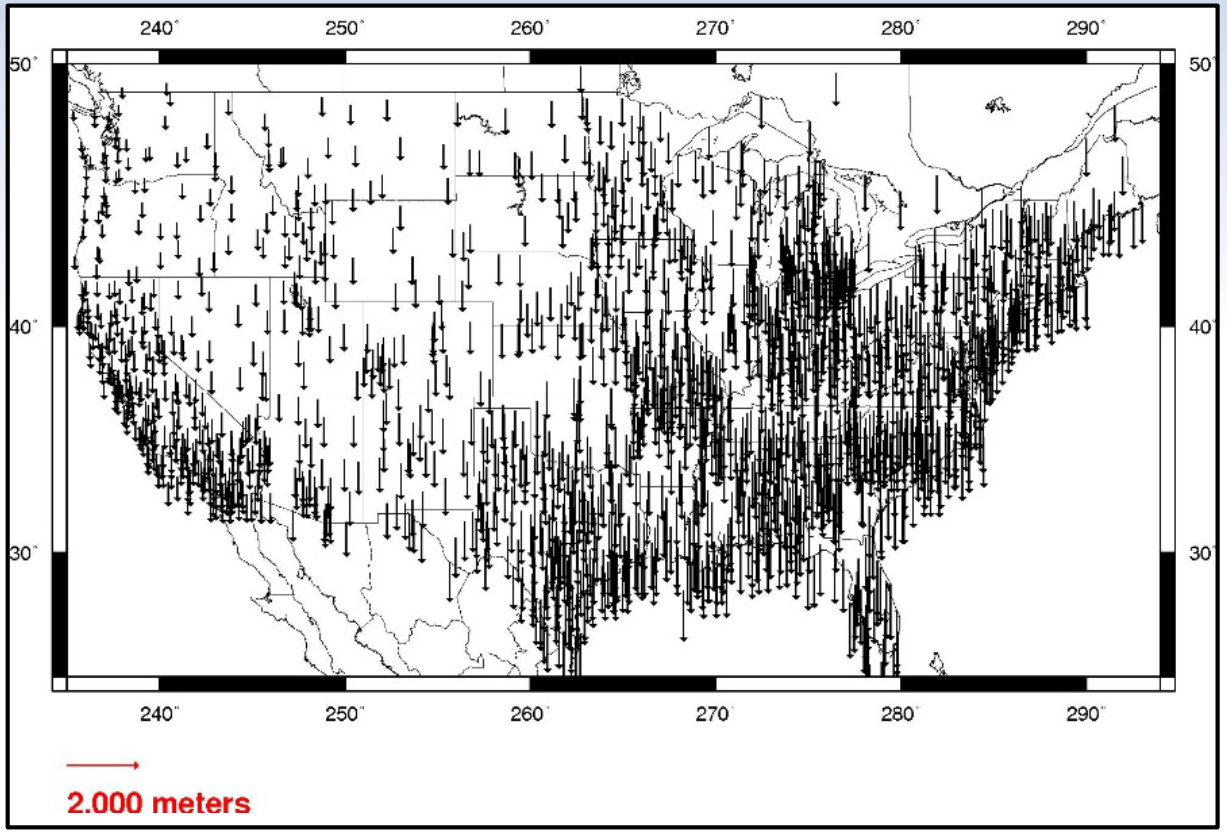
*Shift and Drift…*

# Non-geocentricity of NAD83



# Geometric Change due to ellipsoid non-geocentricity




Horizontal (Lat,Lon) Component

Ellipsoidal (h) Component

*Shift…*

# Replacing NAD83

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*Shift and Drift…*

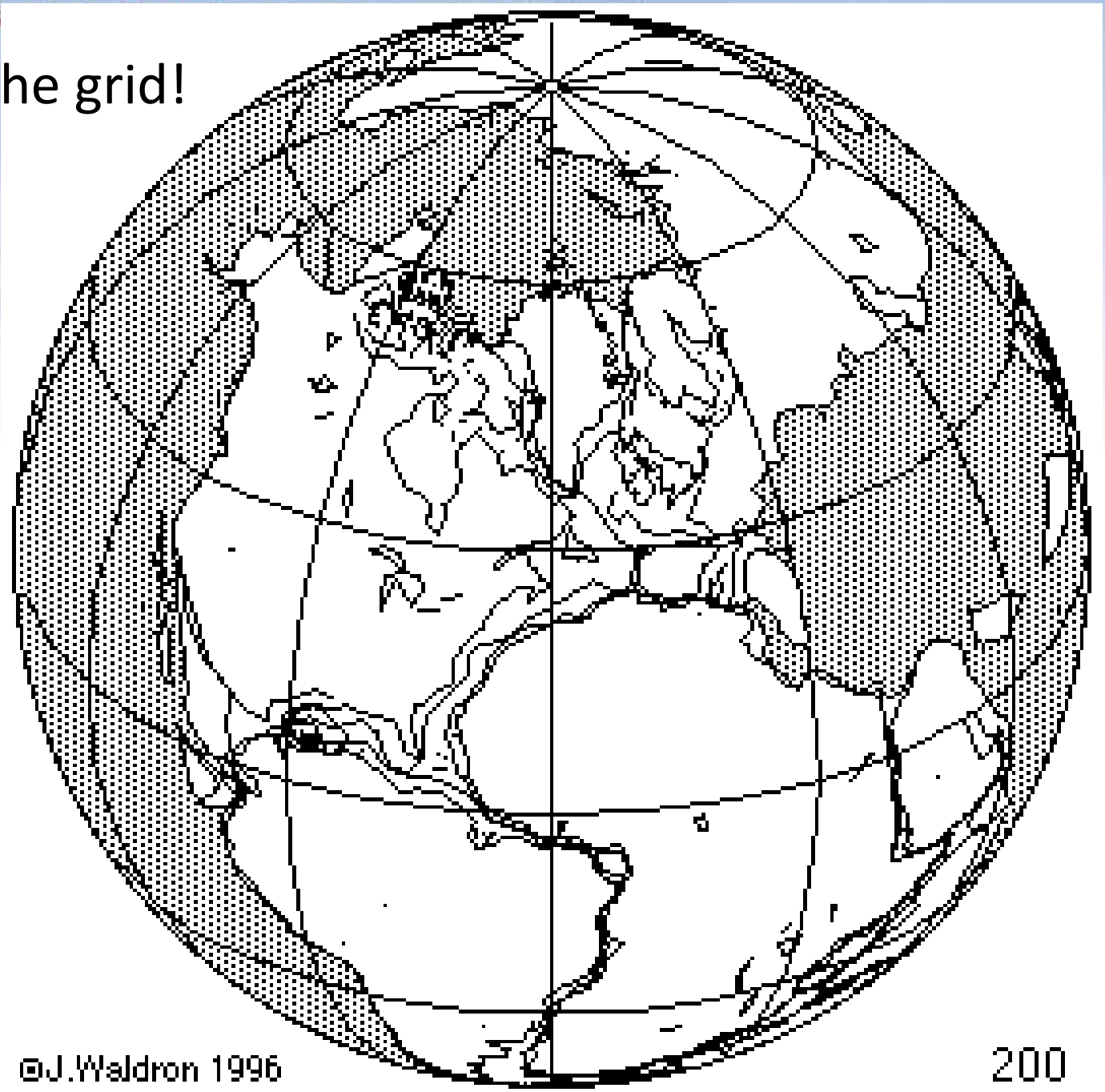
# International Terrestrial Reference Frame

# ITRF

# International Terrestrial Reference Frame

- The stable coordinate system that allows us to measure change over space, time and evolving technologies.
- An accurate, stable set of station positions and velocities.
- Network measurements interconnected by co-location of different space geodetic techniques.
- ITRF ≈ IGS Reference Frame (thus IGS08 ≈ ITRF08)
- Approximately represents the motions of the tectonic plates with respect to the Earth's deep interior… huh?

# Watch the grid!



# Replacing NAD83

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4. **removes most of tectonic plate rotation from ITRF2014 using updated Euler Poles (pronounced "oiler")**

*Shift and Drift…*

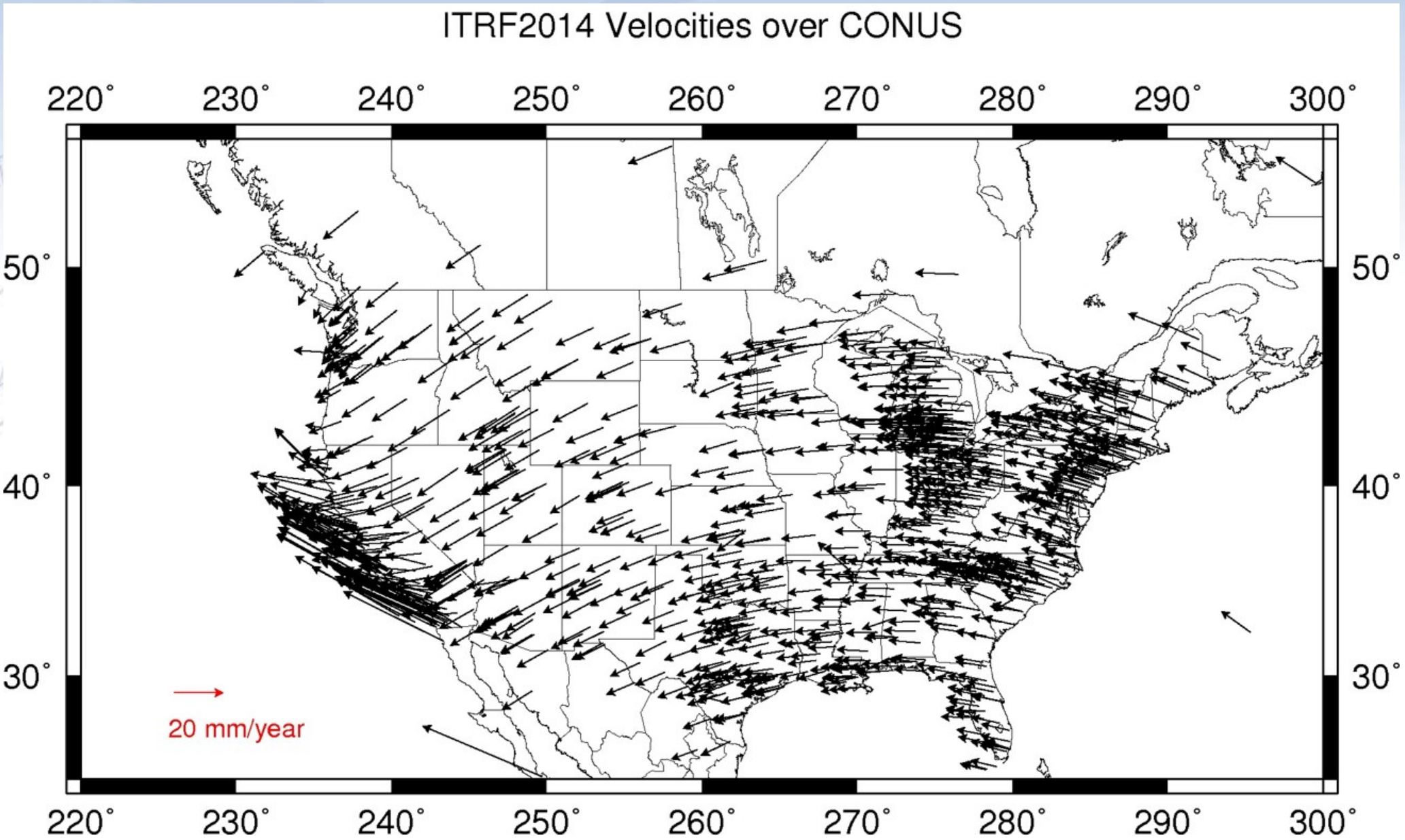
# The wrong question, circa 2022:

"What is the position of that point?"

# The right question, circa 2022:

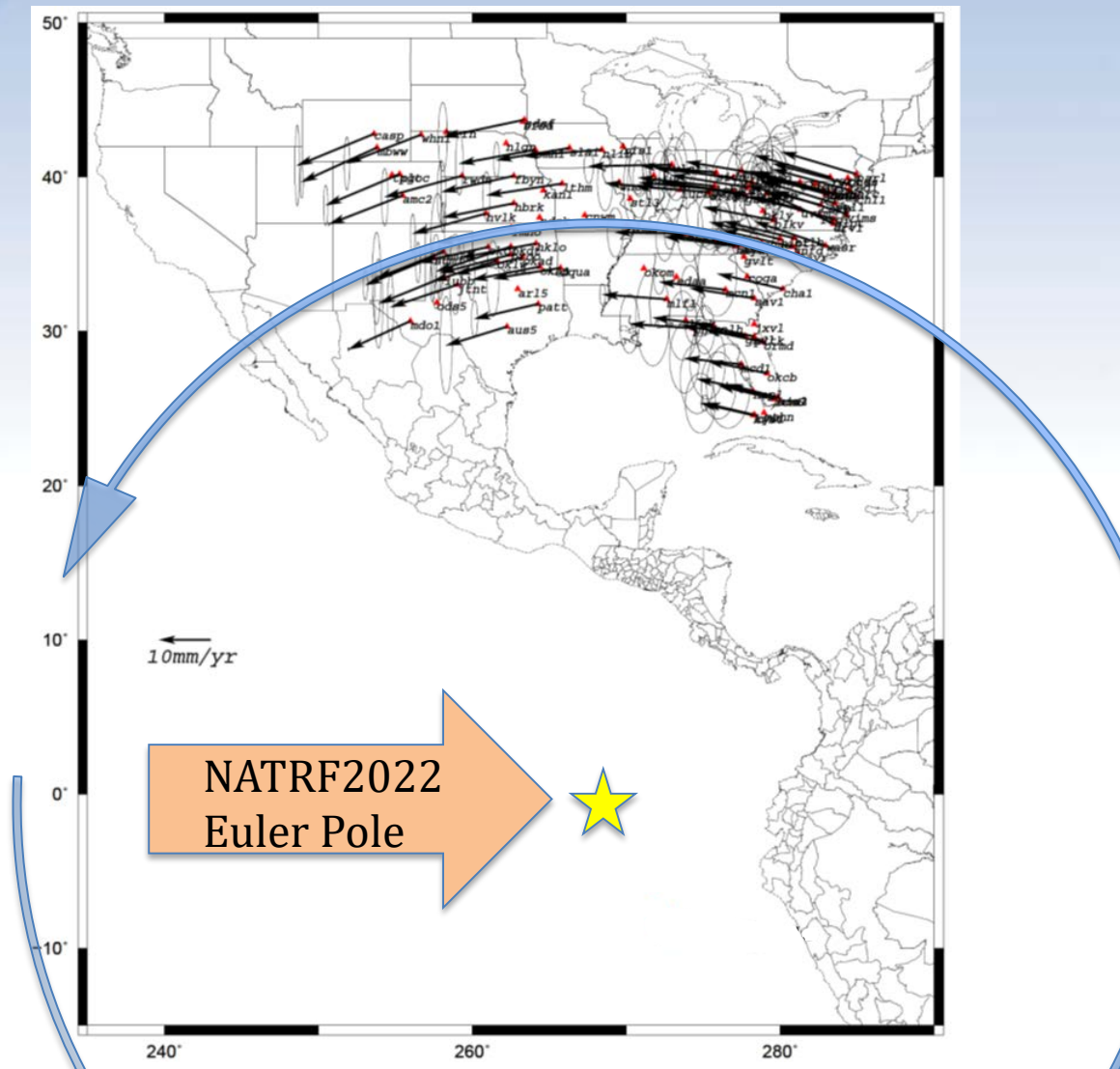
"What is the position of that point, **on some specific date**?"

# Euler Pole




*Drift…*

- Euler Poles and "Plate-Fixed"
  - In the ITRF, many tectonic plates have one *dominant* motion: **rotation**
    - (plus plenty of other motions)
  - Euler Pole - point about which a plate rotates




ITRF

Frame = constant

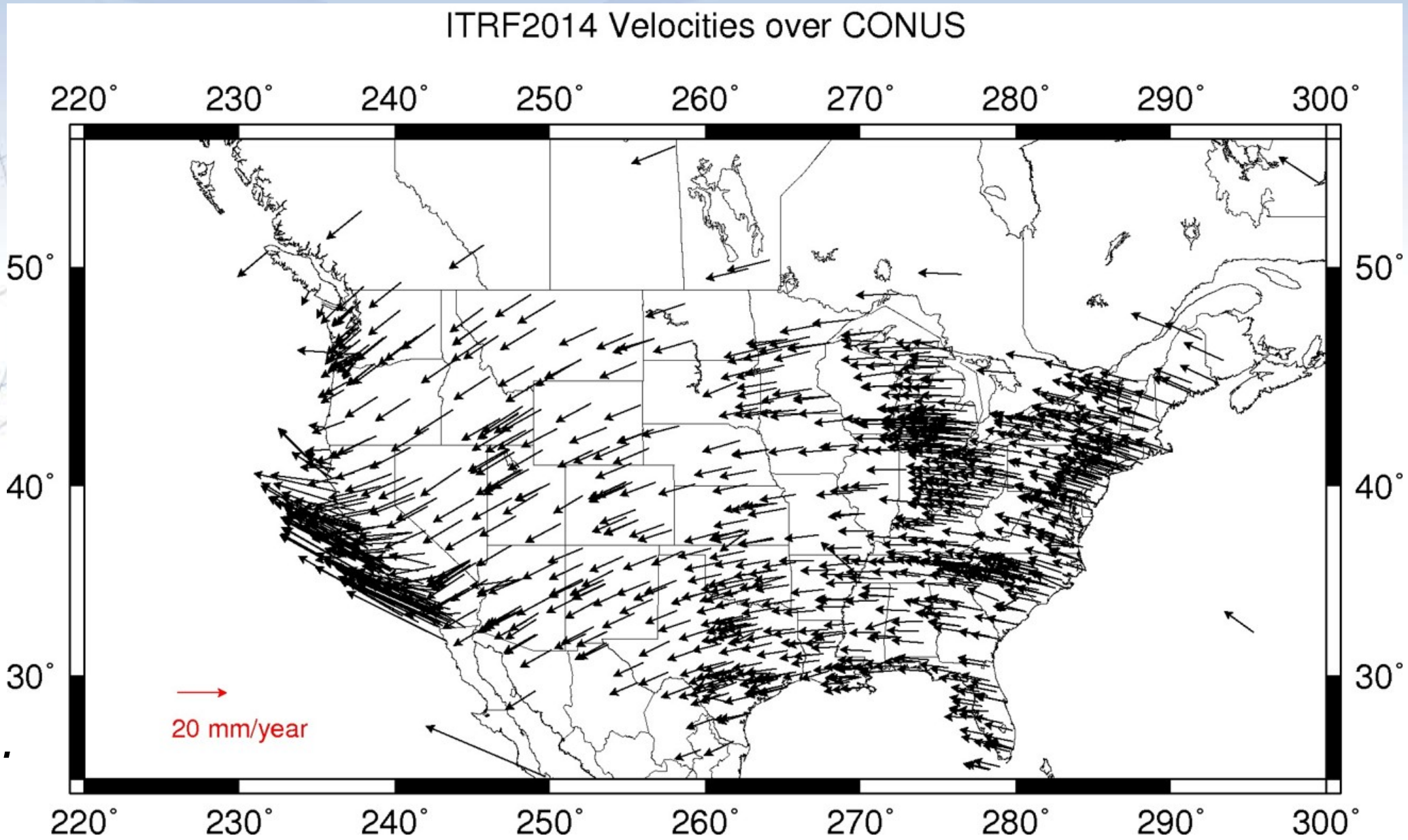
NA Plate = rotating

NATRF

Frame = rotating
(relative to ITRF)

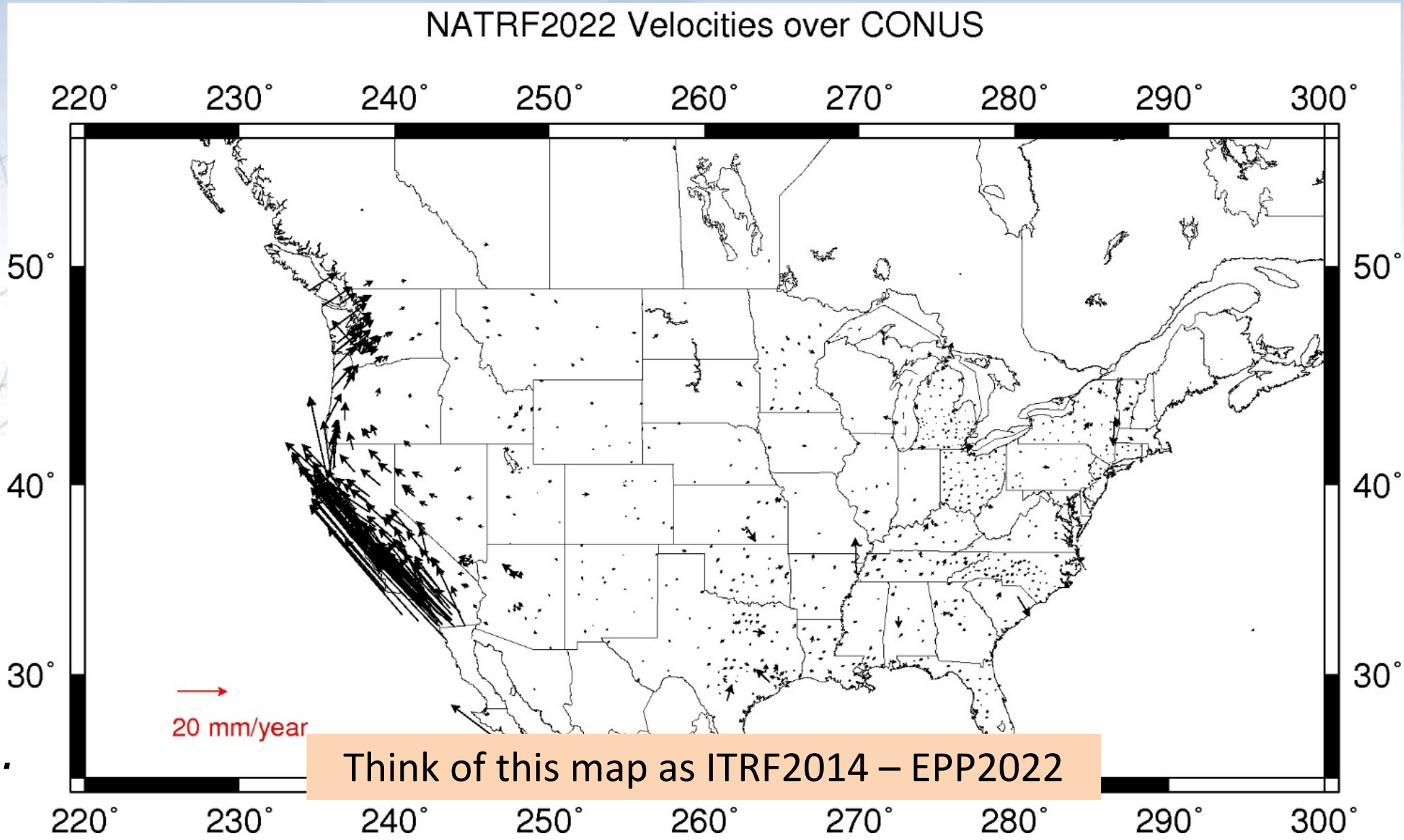
NA Plate = constant
(relative to NATRF2022)

# CORS Velocities in ITRF2014




*Drift…*

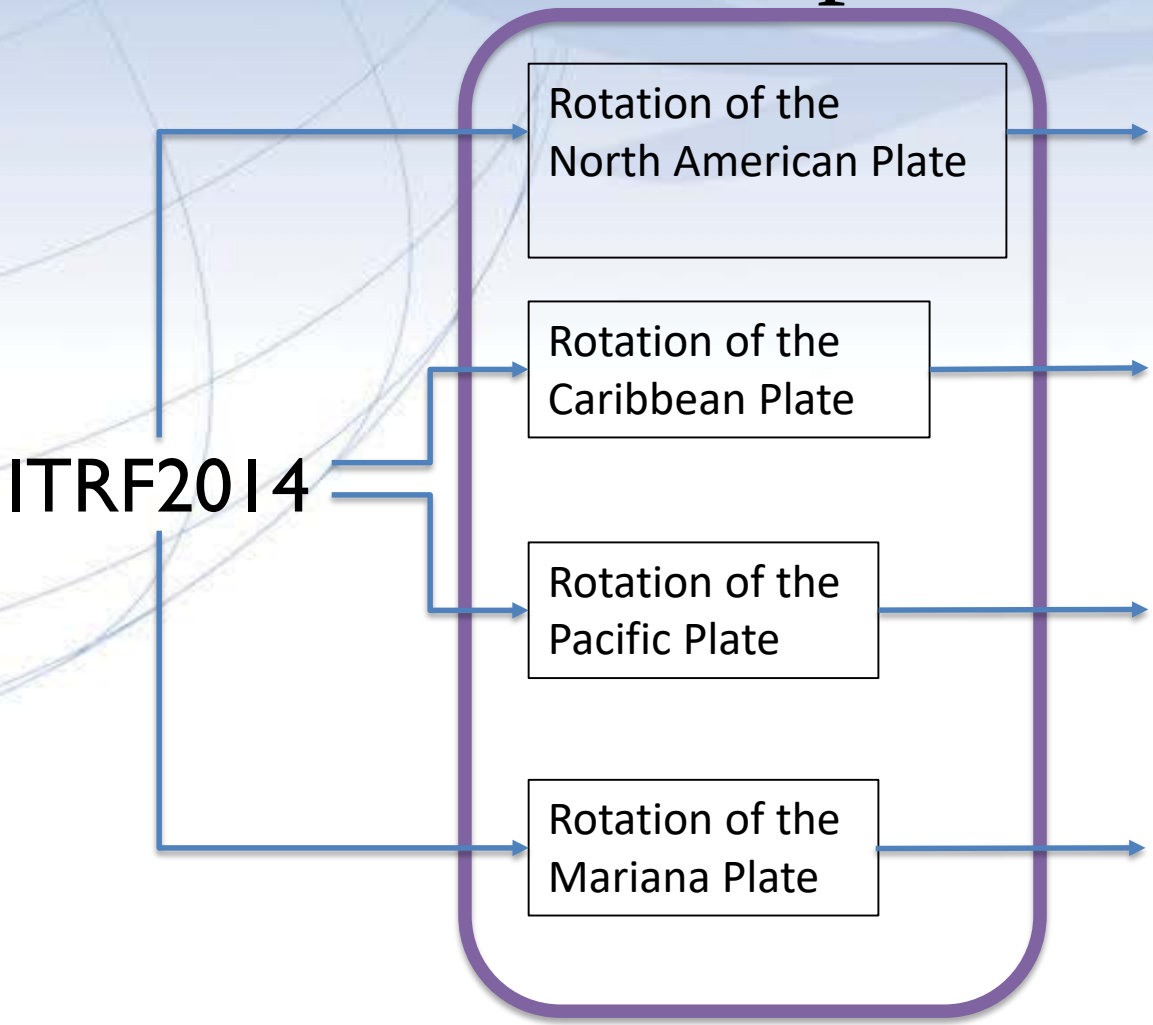
# CORS Velocities in NATRF2022




*Still Some Drift…*

Think of this map as ITRF2014 – EPP2022

# The preeminence of ITRF




The North American Terrestrial Reference Frame of 2022 (NATRF2022)

The Caribbean Terrestrial Reference Frame of 2022 (CATRF2022)

The Pacific Terrestrial Reference Frame of 2022 (PATRF2022)

The Mariana Terrestrial Reference Frame of 2022 (MATRF2022)

**EPP - Euler Pole Parameters**
**(a way of describing a plate's rotation)**

# *Drift…*

- Everything in the world moves
- Coordinates will be associated with the actual date when the data was taken!
- Velocities at all marks can be estimated
  - Using a new tool, called the **Intra-Frame Velocity Model (IFVM2022)**
- Two things will mitigate the pain of time-dependent coordinates:
  - the "Plate Fixed" frames we've discussed
  - and "Reference Epoch" coordinates

# EPP2022 – Euler Pole Parameters
# IFVM2022 – Intra-Frame Velocity Model

## The two new tools that make time dependent geodetic control practical!

*They work together to account for the Drift…*

# You likely noticed there's *two* sources of Drift

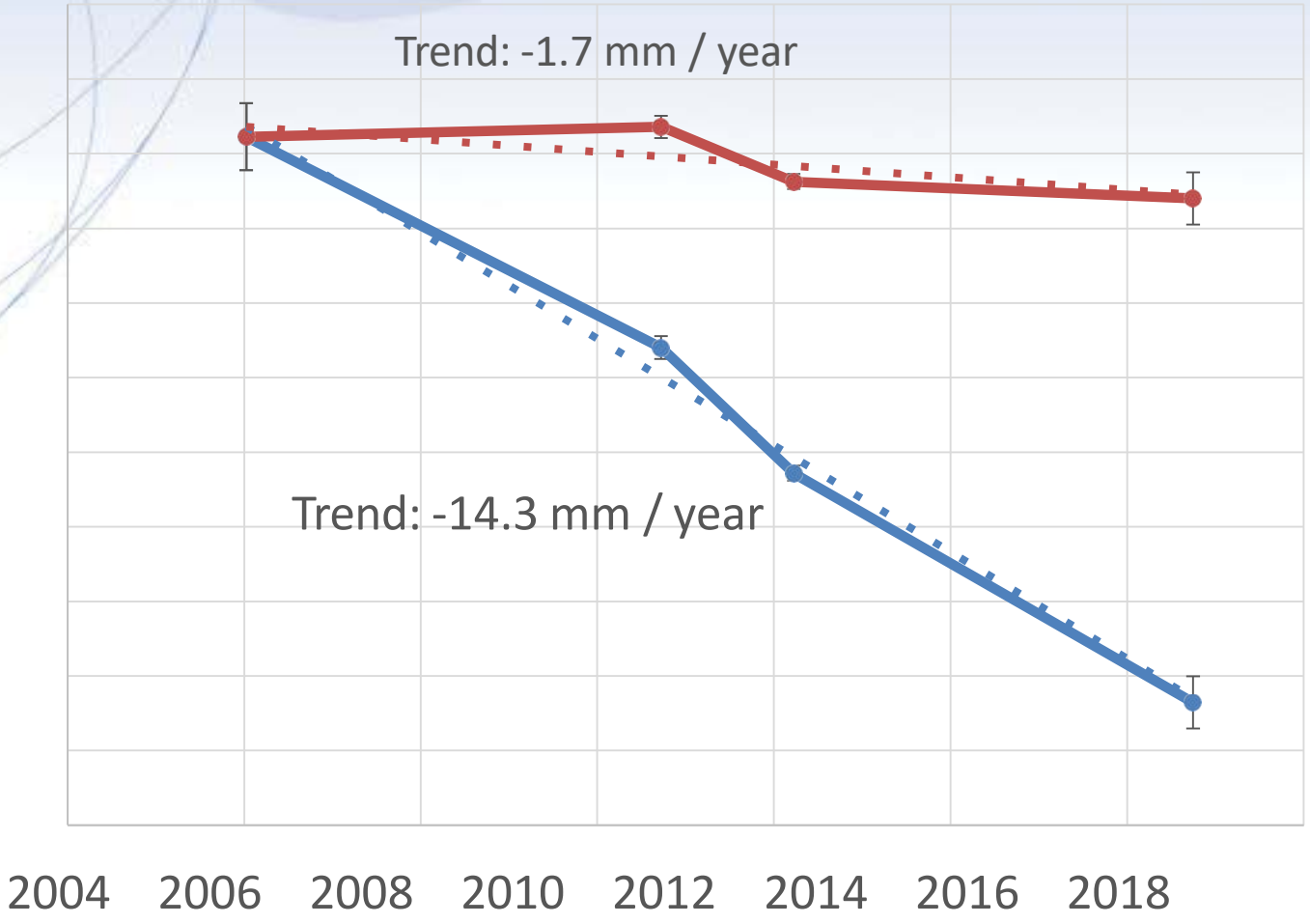
- The plate rotation is a *simple* application of 3 parameters
  - Captured in EPP2022 – latitude, longitude, rotation speed
  - Horizontal *only* – just latitude and longitude
  - Changes the *frame* – ITRF2014 + EPP2022 = NATRF2022 (or PATRF2022, or CATRF2022, or MATRF2022)
  - Does **not** change the *epoch*
- The residual motions, after removing plate rotation, are *complex*
  - Captured in IFVM2022 – complex set of parameters
  - *Residual* horizontal motion – this is all the motion leftover after Euler Pole rotation
  - *All* vertical motion – localized subsidence or uplift
  - Changes the *epoch*
  - Does **not** change the *frame* – "intra" = on the inside; within

# Intra-Frame Velocity Model

- A model of all residual velocities, after removal of tectonic rotation (via EPP):
  - Horizontal residual motion
  - Total vertical motion (ellipsoid heights)
  - Replaces / Improves upon HTDP
- Given $t_1$ and $t_2$, compute $\Delta\phi$, $\Delta\lambda$, $\Delta h$ at any point, accounting for all motions (drifts, earthquakes, GIA, etc.)
- Likely be built upon CORS data, geodynamic models and InSAR

# Intra-Frame Velocity Model

## Longitude (Easting) History of DI4044



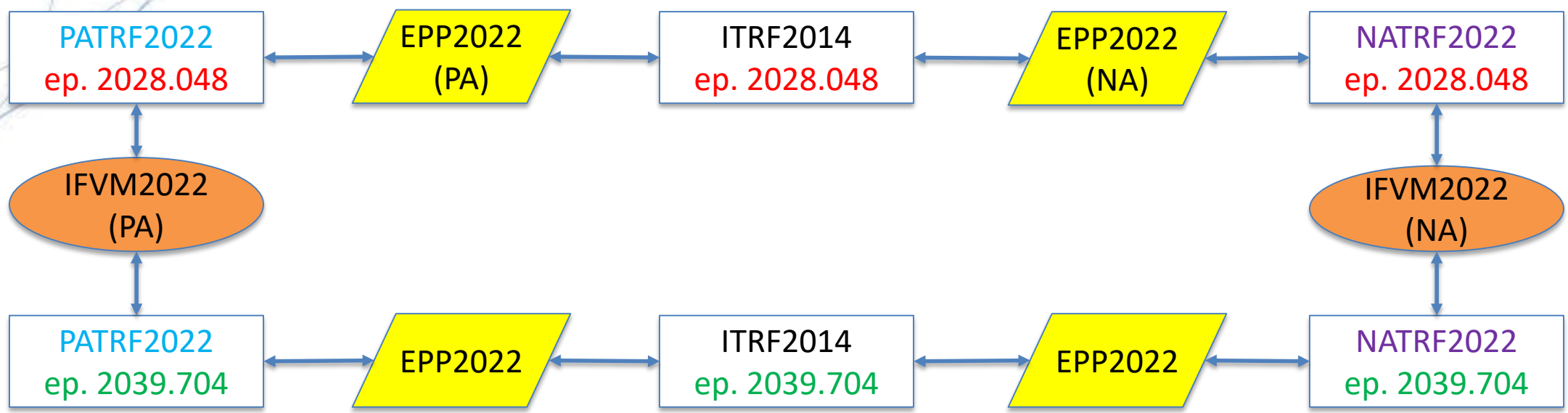

**RED IS NATRF2022 COORDINATE**

**BLUE IS ITRF COORDINATE**

# Example of application of EPP and IFVM

- It's 2039 and you are working in San Diego using NATRF2022
- You need to compare your work against a competitor's survey
  - Done in 2028, using PATRF2022

Important: This slide only covers *geometric* coordinates.



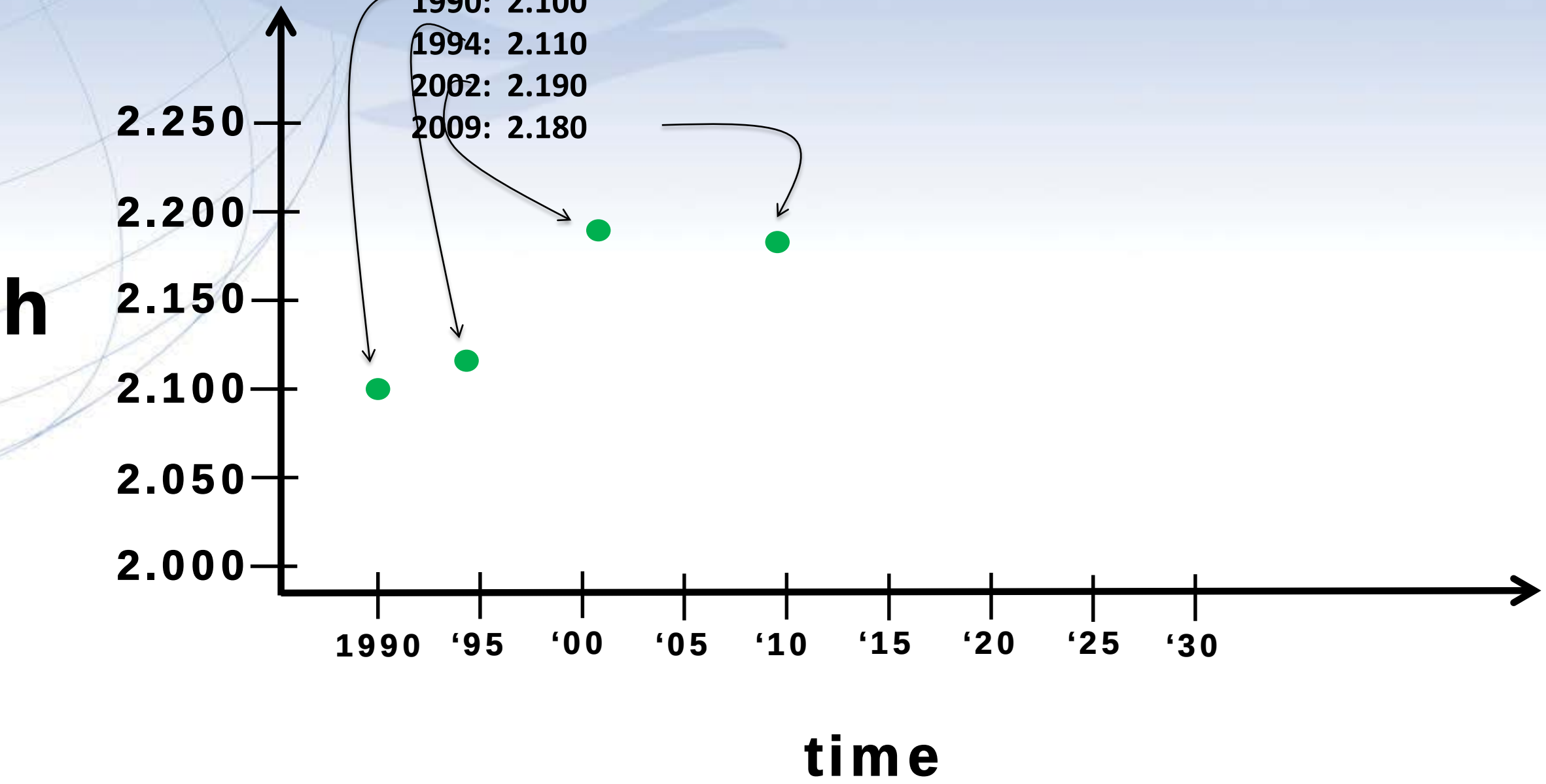
# Daily Epochs Jeff?! Really?!?

- It seems unlikely that the majority of surveyors will embrace coordinates with such diversity of epochs (e.g. 2028.048, 2039.074 from last slide)
- To mitigate that, NGS will issue "snapshots" of the NSRS - every five years
  - We're calling these **Reference Epochs**
  - *Huh?* These will be **estimates of coordinates at specific 5 year intervals** - based on historic time-dependent coordinates and the IFVM2022
    - above items are geometric only, the Geoid Monitoring Service (GeMS) will address geopotential
- Beginning with 2020.00
  - Each "snapshot" will be published 2-3 years after the reference epoch
    - Thus the 2020.00 Reference Epoch Coordinates get published by the end of calendar year 2022

# Reference Epoch Coordinates from Time-Dependent Coordinates

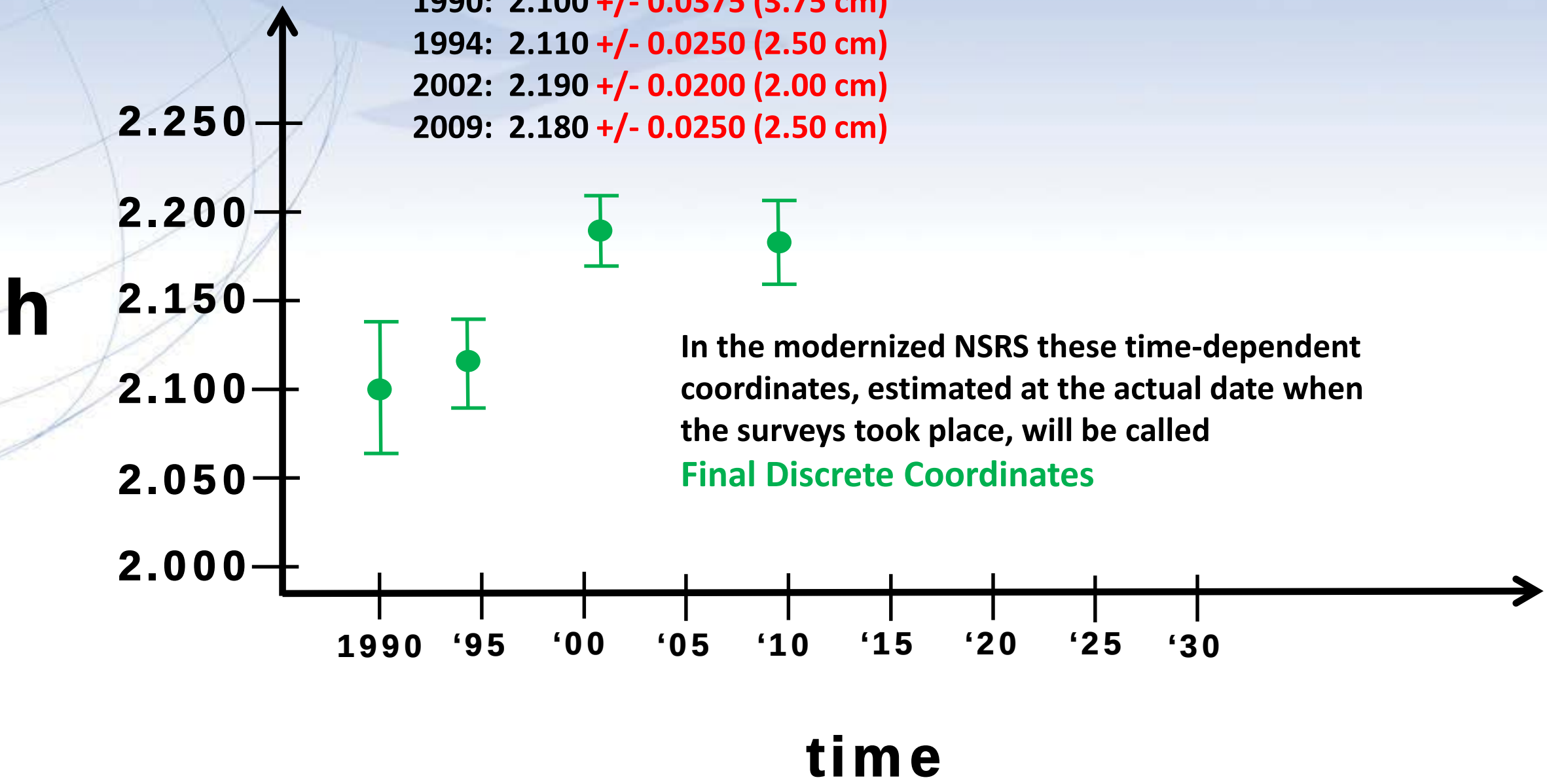
Assume "h" was determined four different times:

1990: 2.100
1994: 2.110
2002: 2.190
2009: 2.180



All measurements have error. Shown here are the same Values of "h", but with their error estimates.

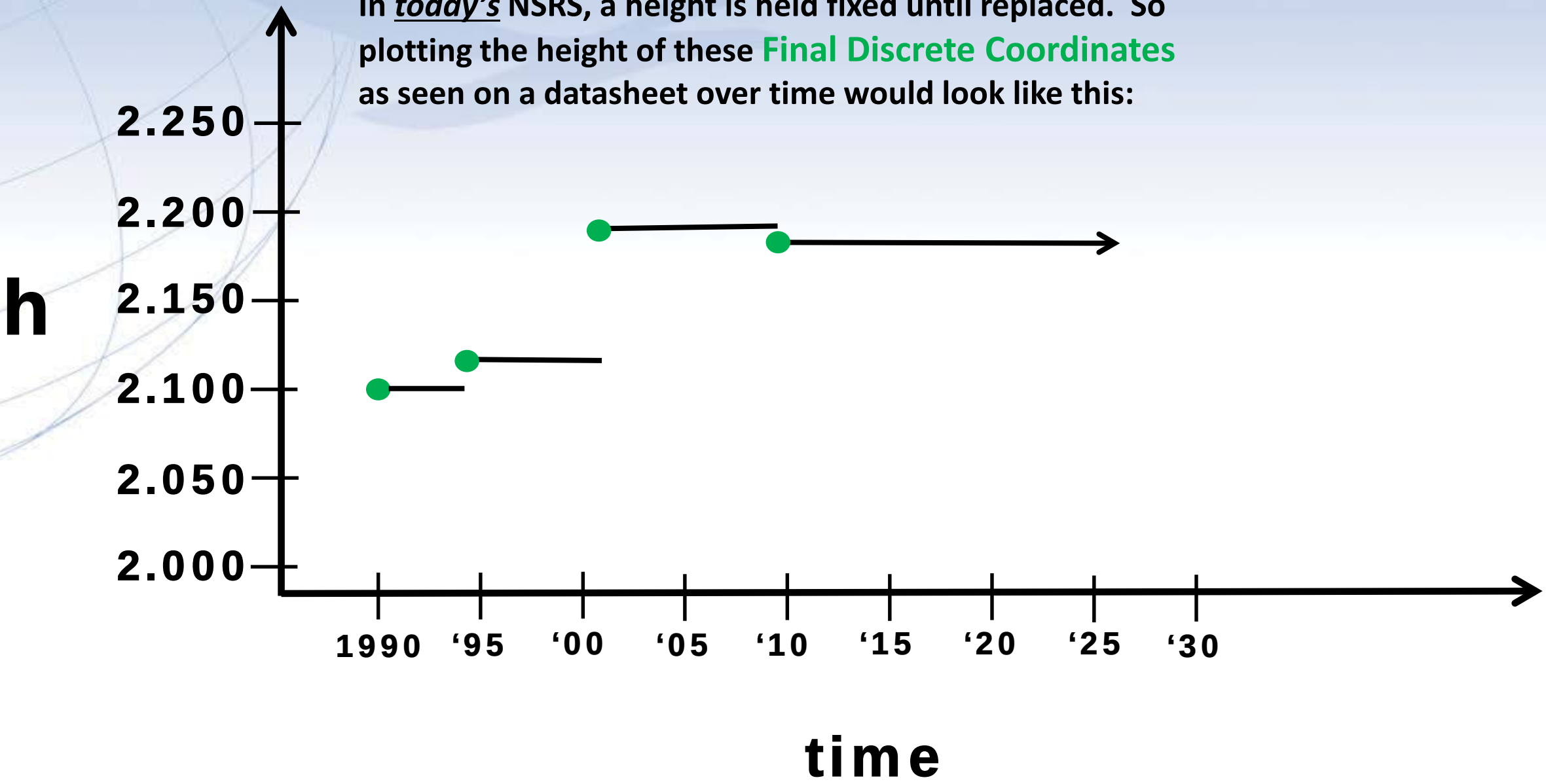
1990: 2.100 +/- 0.0375 (3.75 cm)
1994: 2.110 +/- 0.0250 (2.50 cm)
2002: 2.190 +/- 0.0200 (2.00 cm)
2009: 2.180 +/- 0.0250 (2.50 cm)



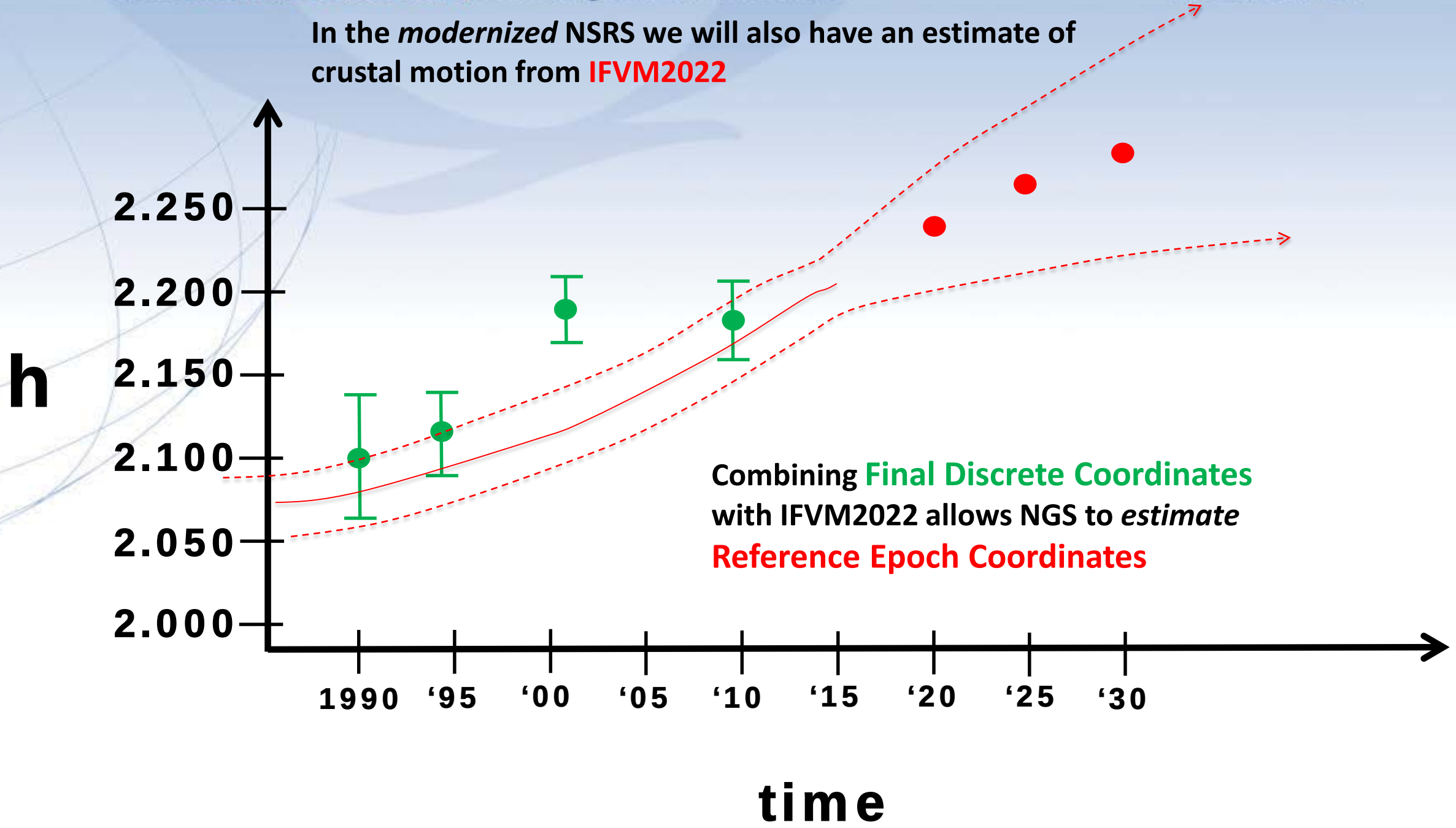

In the modernized NSRS these time-dependent coordinates, estimated at the actual date when the surveys took place, will be called

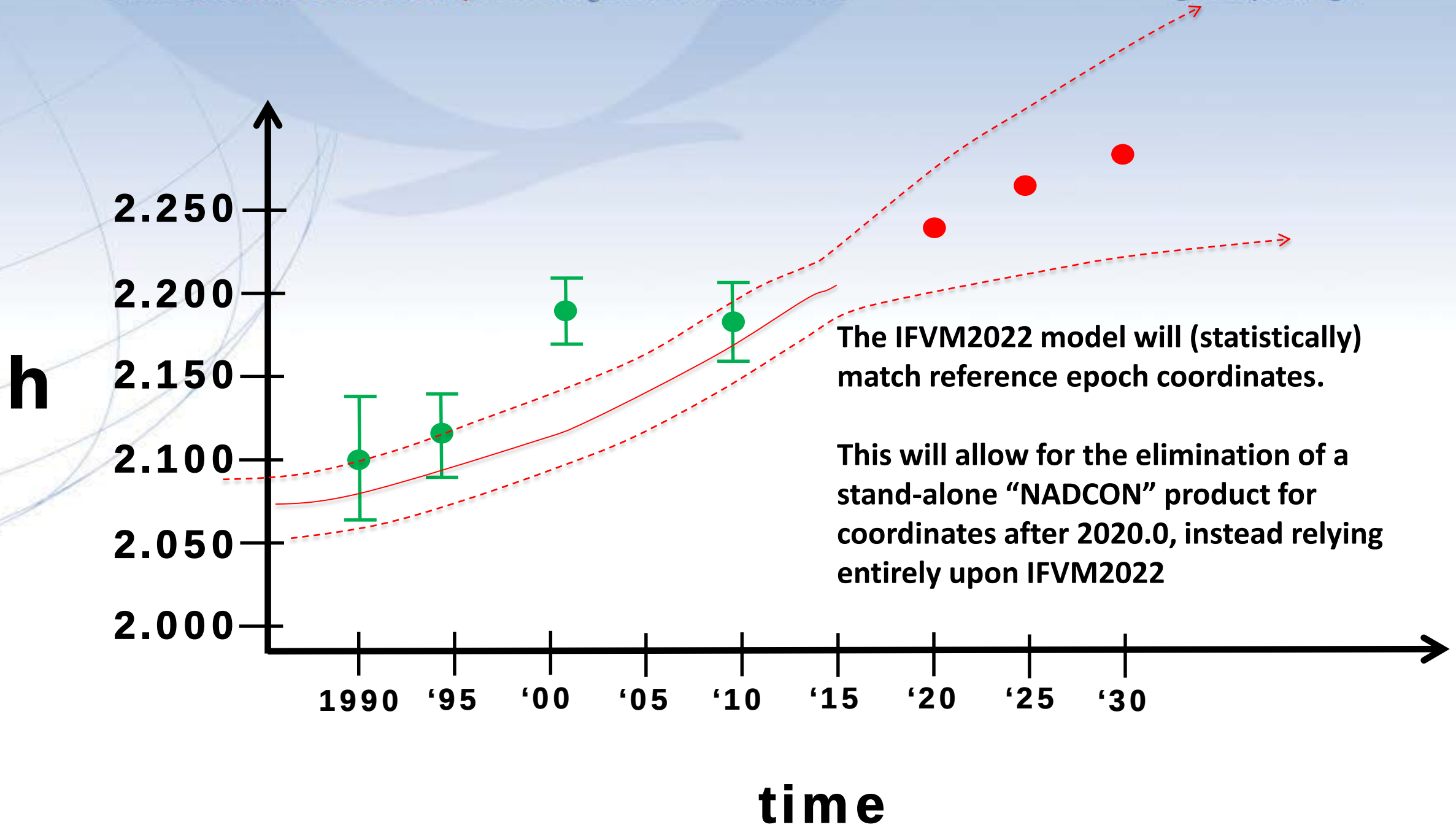
Final Discrete Coordinates

In *today's* NSRS, a height is held fixed until replaced. So plotting the height of these Final Discrete Coordinates as seen on a datasheet over time would look like this:



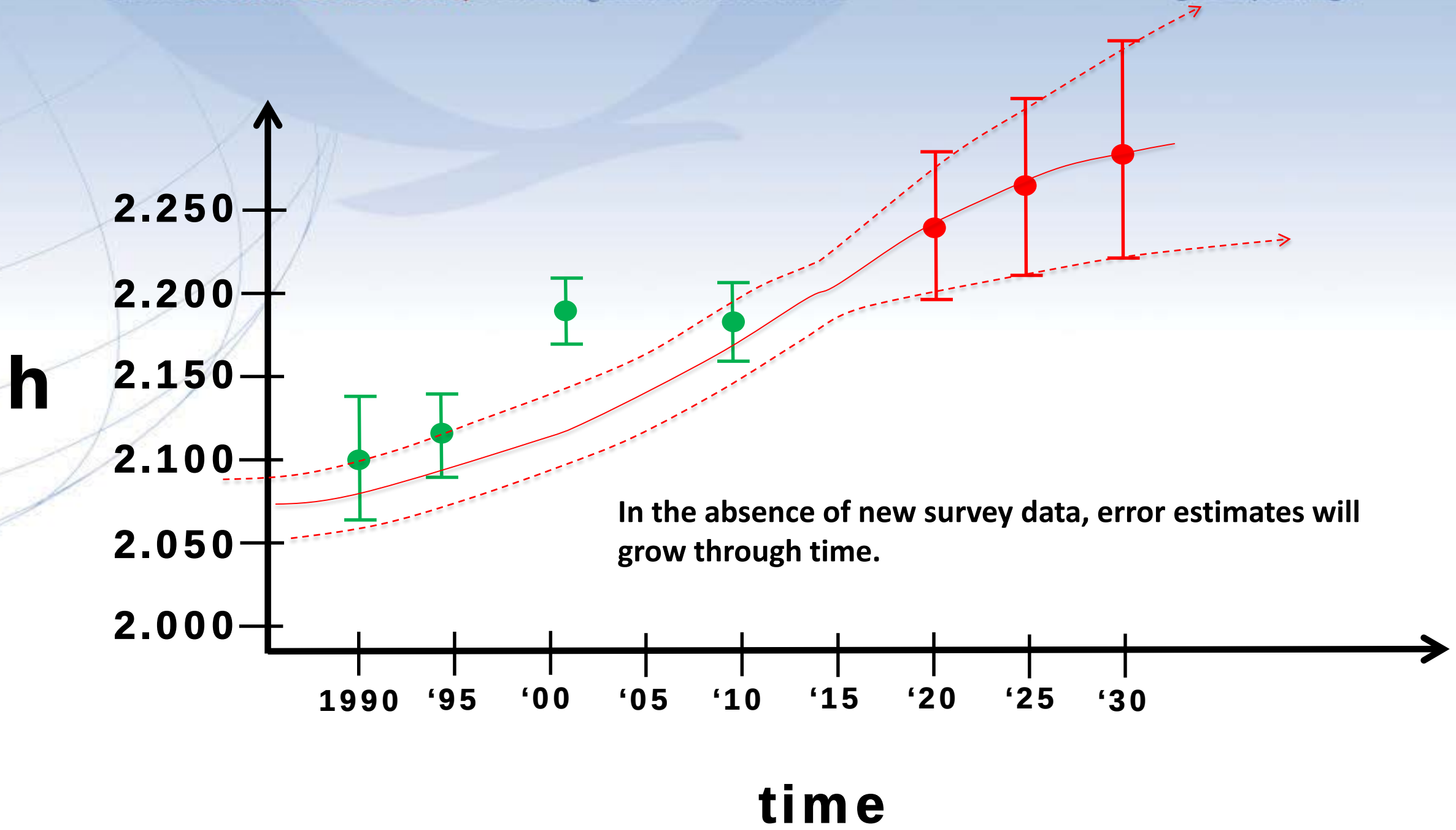
In the *modernized* NSRS we will also have an estimate of crustal motion from IFVM2022

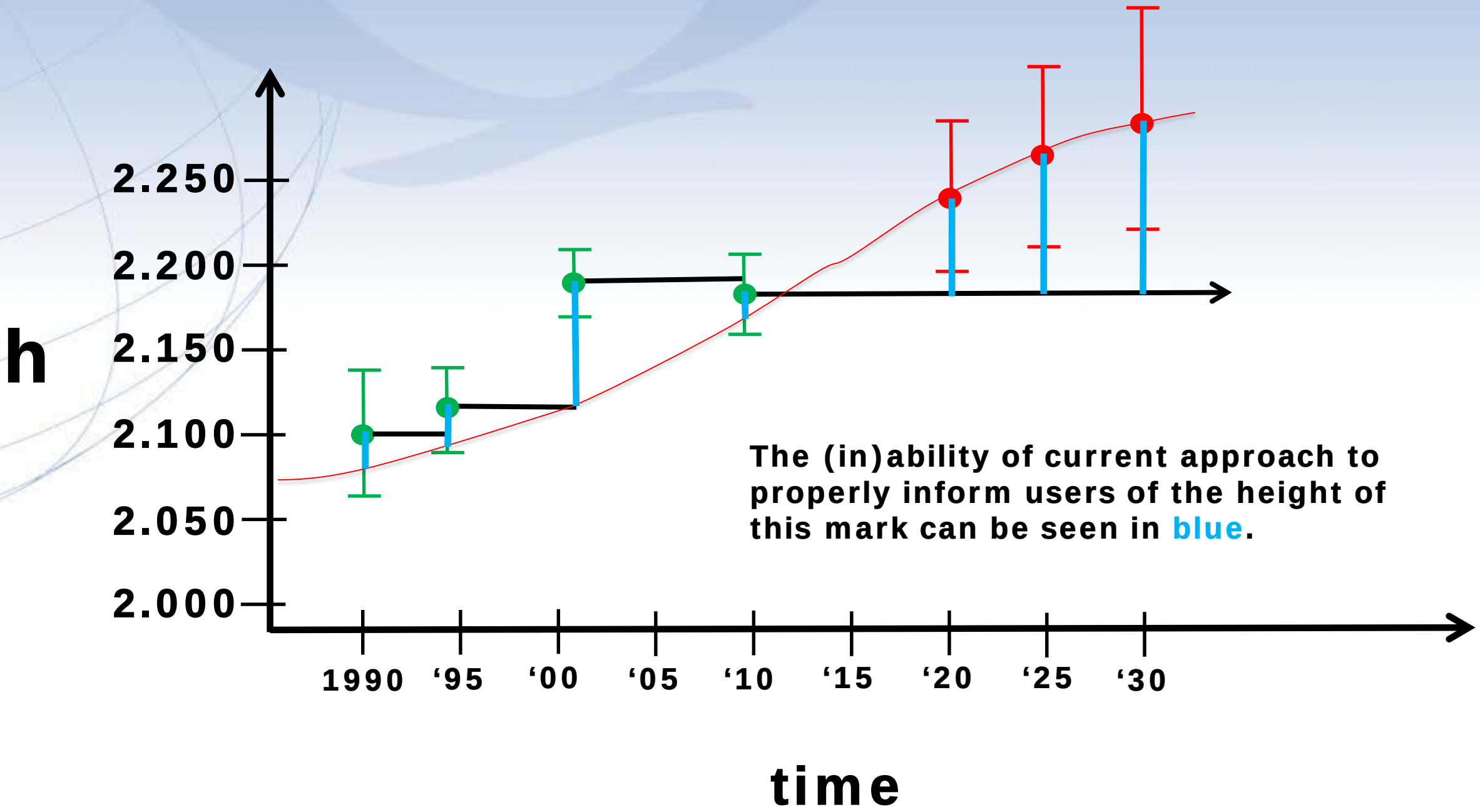





**The IFVM2022 model will (statistically) match reference epoch coordinates.**

**This will allow for the elimination of a stand-alone "NADCON" product for coordinates after 2020.0, instead relying entirely upon IFVM2022**

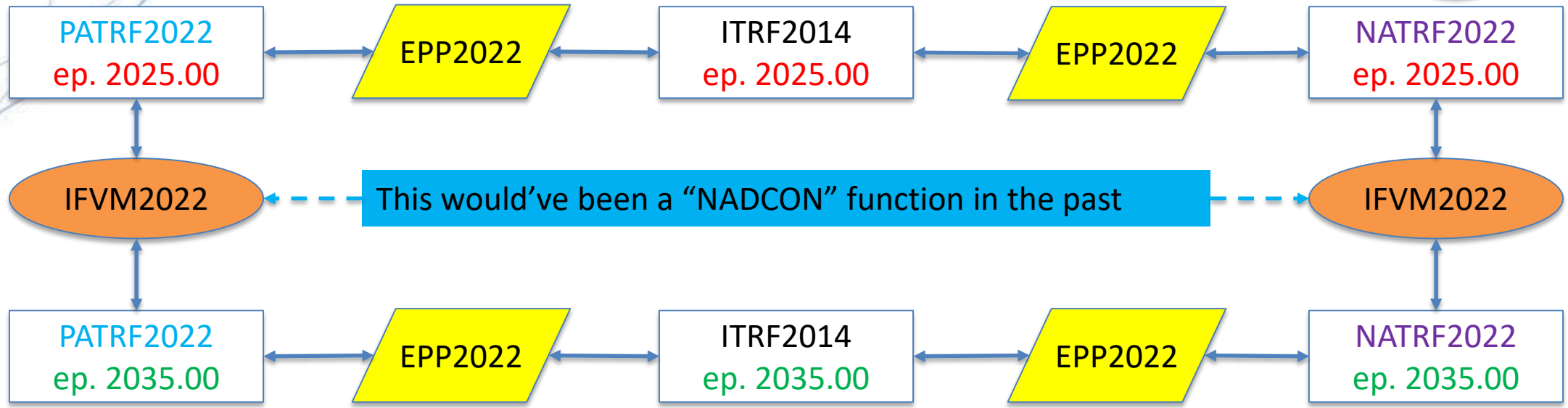

h
2.250
2.200
2.150
2.100
2.050
2.000
1990
'95
'00
'05
'10
'15
'20
'25
'30
time
In the absence of new survey data, error estimates will grow through time.


h
2.250
2.200
2.150
2.100
2.050
2.000
1990
'95
'00
'05
'10
'15
'20
'25
'30
time
The (in)ability of current approach to properly inform users of the height of this mark can be seen in blue.

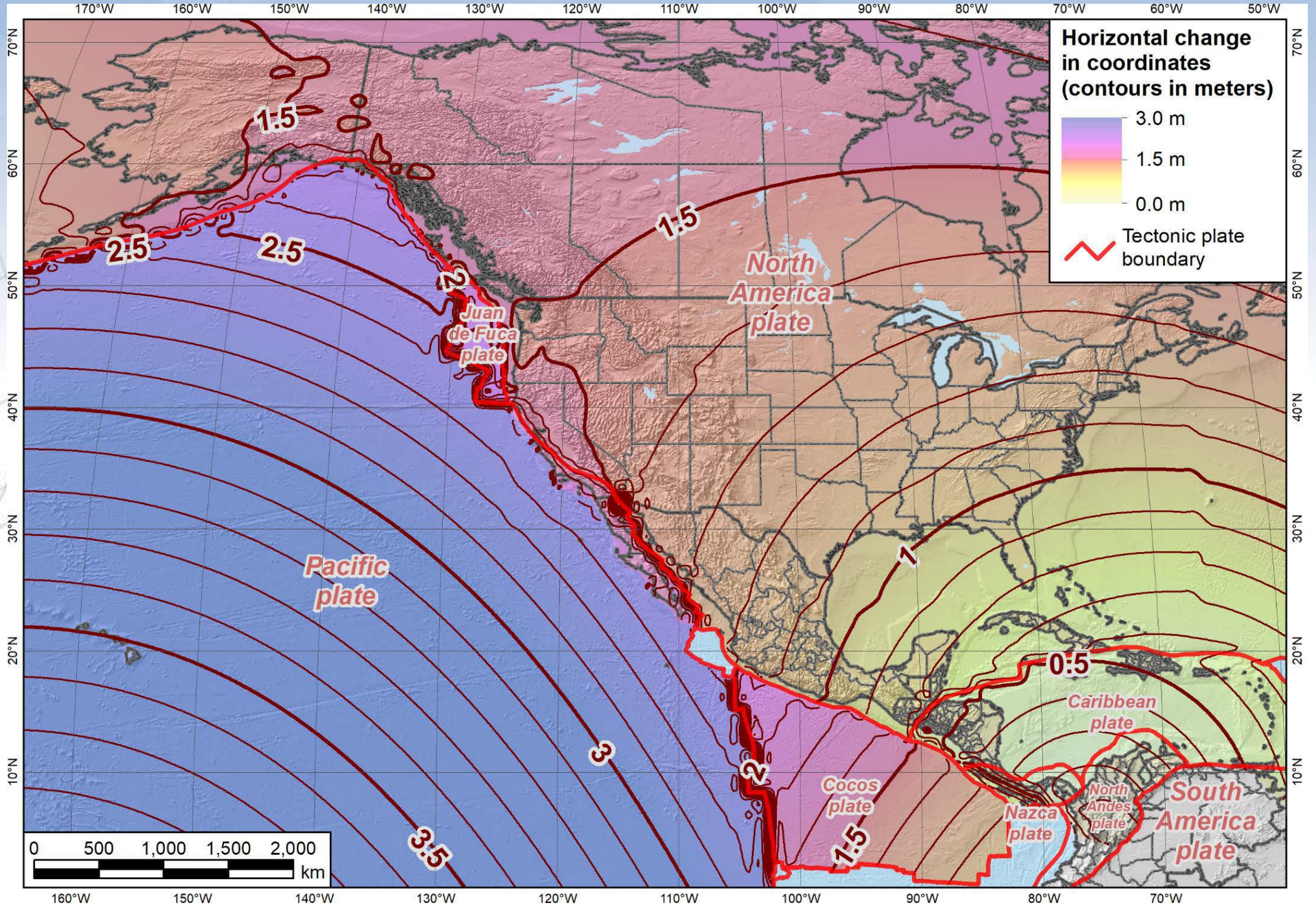
# Example of EPP & IFVM with Reference Epochs

- It's 2039 and you are working in San Diego using NATRF2022 (**epoch 2035.00**)
- You need to compare your work against a competitor's survey
  - Done in 2028, using PATRF2022 (**epoch 2025.00**)

Important: This slide only covers *geometric* coordinates.



# Alright Dude... enough jibba-jabba, what's the impact?

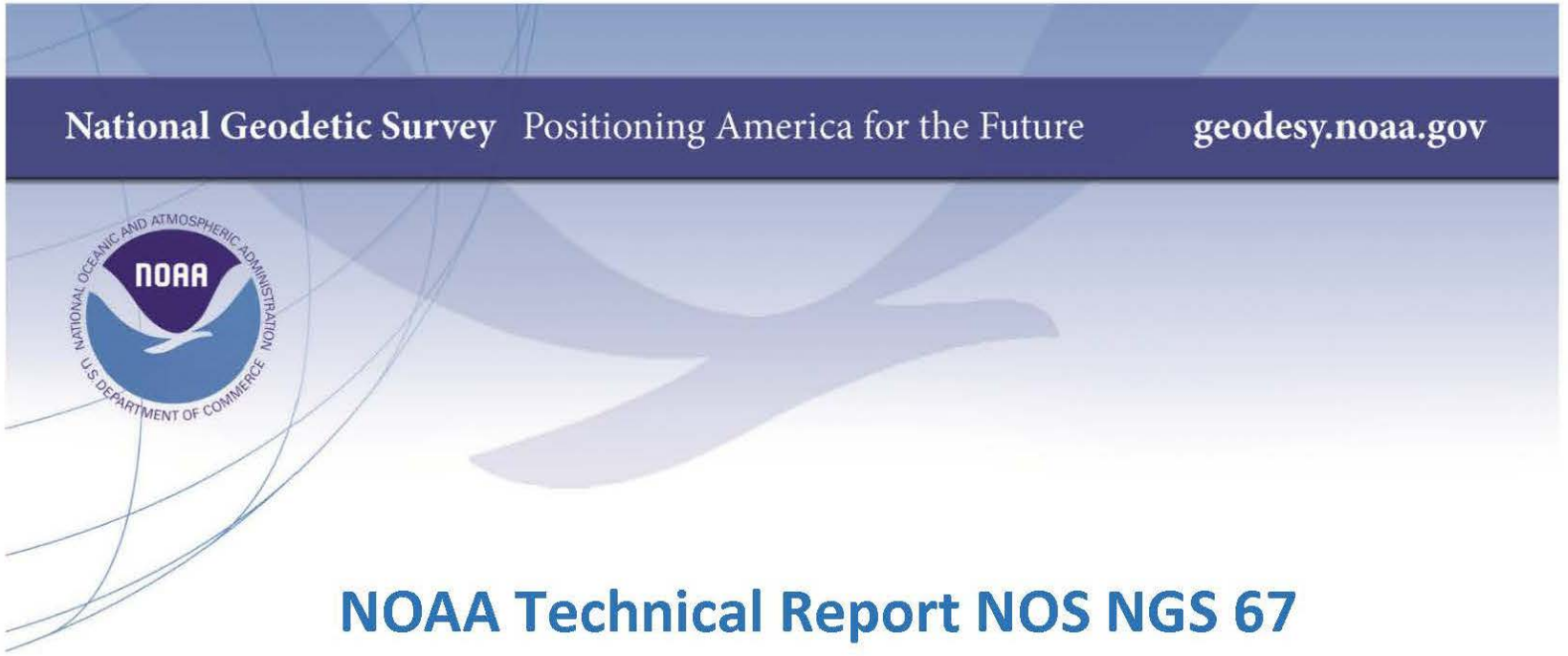

Horizontal change in coordinates (contours in meters)
3.0 m
1.5 m
0.0 m
Tectonic plate boundary
North America plate
Pacific plate
Juan de Fuca plate
Cocos plate
Nazca plate
Caribbean plate
North Andes plate
South America plate
0 500 1,000 1,500 2,000 km
170°W 160°W 150°W 140°W 130°W 120°W 110°W 100°W 90°W 80°W 70°W 60°W 50°W
70°N 60°N 50°N 40°N 30°N 20°N 10°N

# What's that going to look like?

PHOTO = NAD83
RED = NAD83 shoreline data
GREEN = shoreline transformed to NATRF2022

# If you're only working in this region…

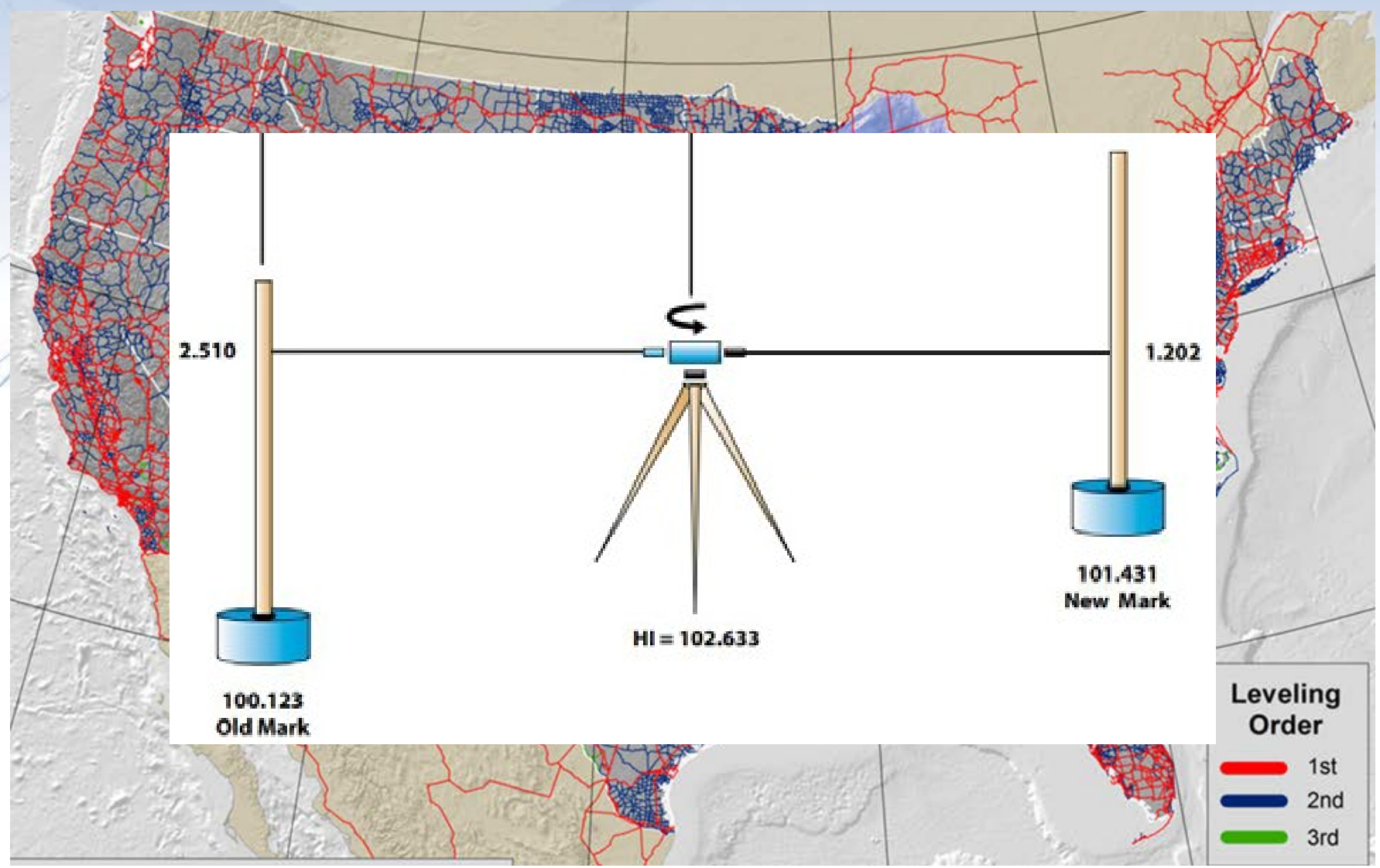
# Blueprint for 2022, Part 3



# North American-Pacific Geopotential Datum of 2022

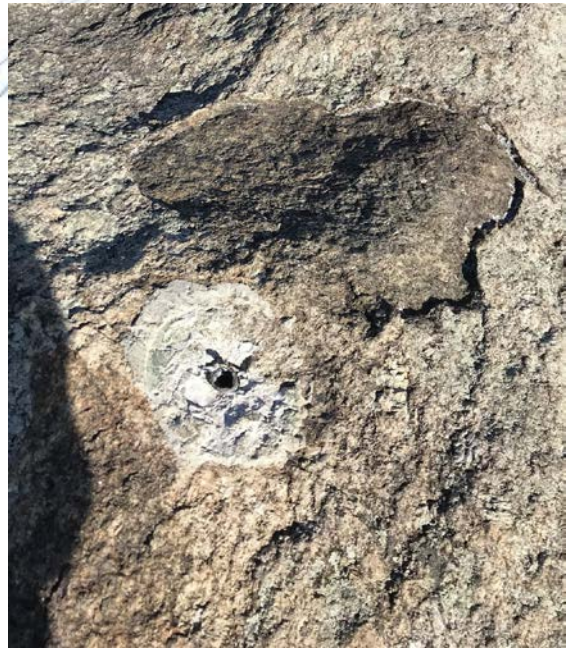
# (NAPGD2022)

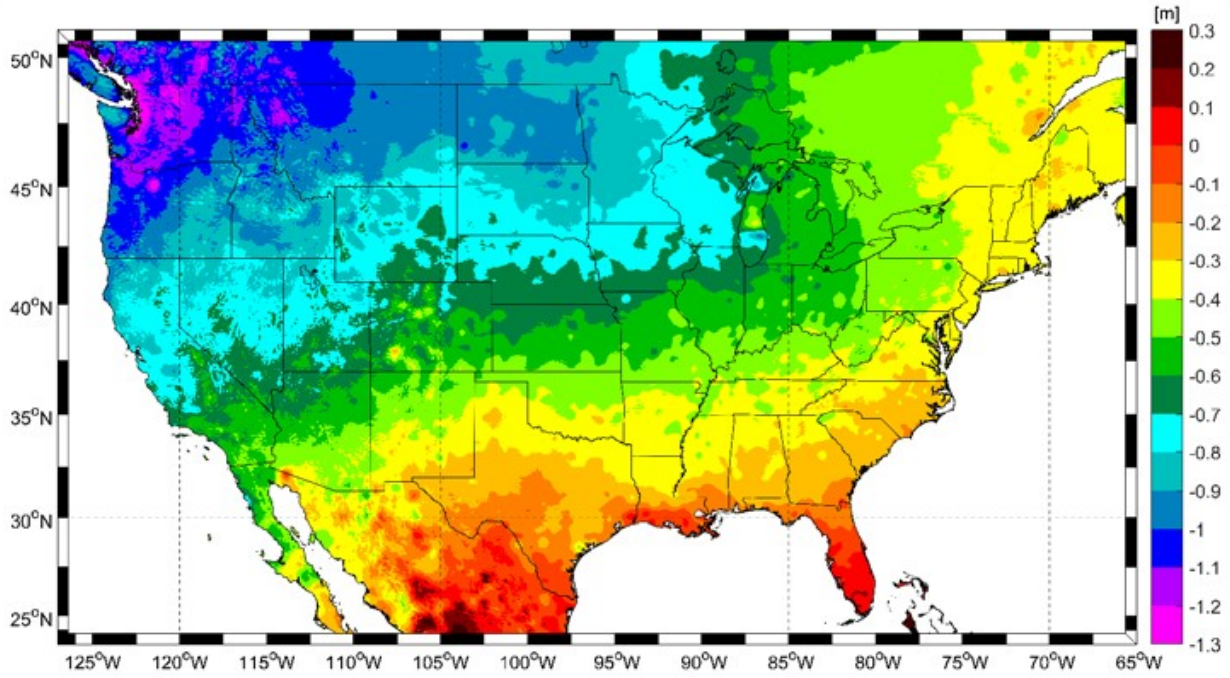
# Why replace NAVD88?



# Known Issues with NAVD88

- tilt/bias in zero reference surface
- subsidence, uplift, freeze/thaw of BMs
- limited access, availability of undisturbed marks






**Approximate Error in NAVD88 "zero elevation"**

# Passive marks may lie still… but they still may lie!
## small instability x long time = large inaccuracy

# Replacing NAVD88

- primary access via GNSS and geoid (OPUS, etc.)
- accurate continental **gravimetric** geoid (1-2 cm)
- aligned with:
  1) NATRF2022 (or CATRF, PATRF, MATRF)
  2) global mean sea level (GMSL)
- monitor time-varying nature of gravity (NGS Geoid Monitoring Service **GeMS**) – anyone watch the webinar today?

# Replacing NAVD88

- Two types of geoid models
  1. Gravimetric
  2. Hybrid

# Replacing NAVD88

- The gravimetric geoid is created from "scratch" with various types of gravity data.
  - USGG2003, USGG2009, USGG2012, xGEOID19

- The hybrid geoid is simply a gravimetric geoid warped to fit some vertical datum… like NAVD88.
  - GEOID03, GEOID09, GEOID12B, GEOID18

# Replacing NAVD88

- USGG2003, USGG2009, USGG2012, xGEOID19

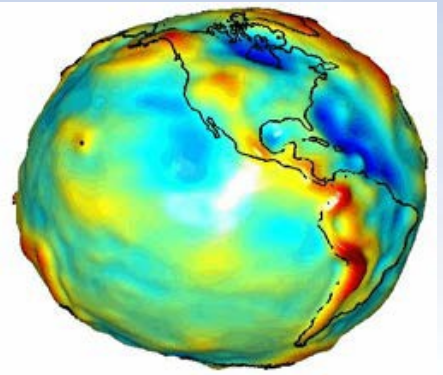
- GEOID03, GEOID09, GEOID12B, GEOID18

# Building a Geopotential Field Model

GRACE/GOCE/Satellite Altimetry

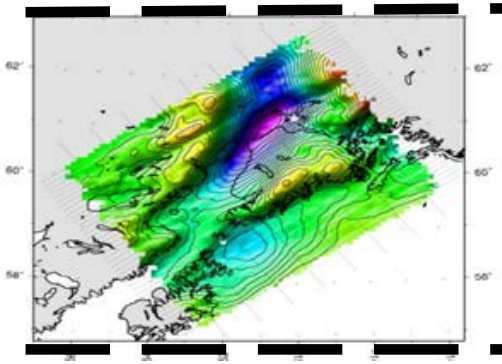
Long Wavelengths
(> 250 km)

+



Airborne Observations
(GRAV-D)

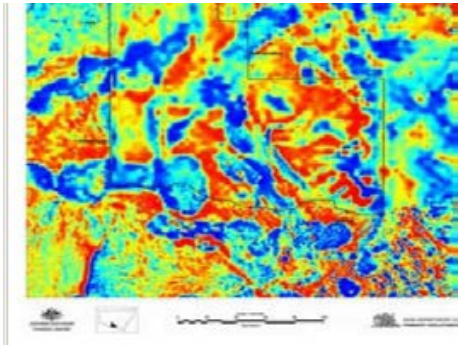
Intermediate Wavelengths
(20km to 300 km)



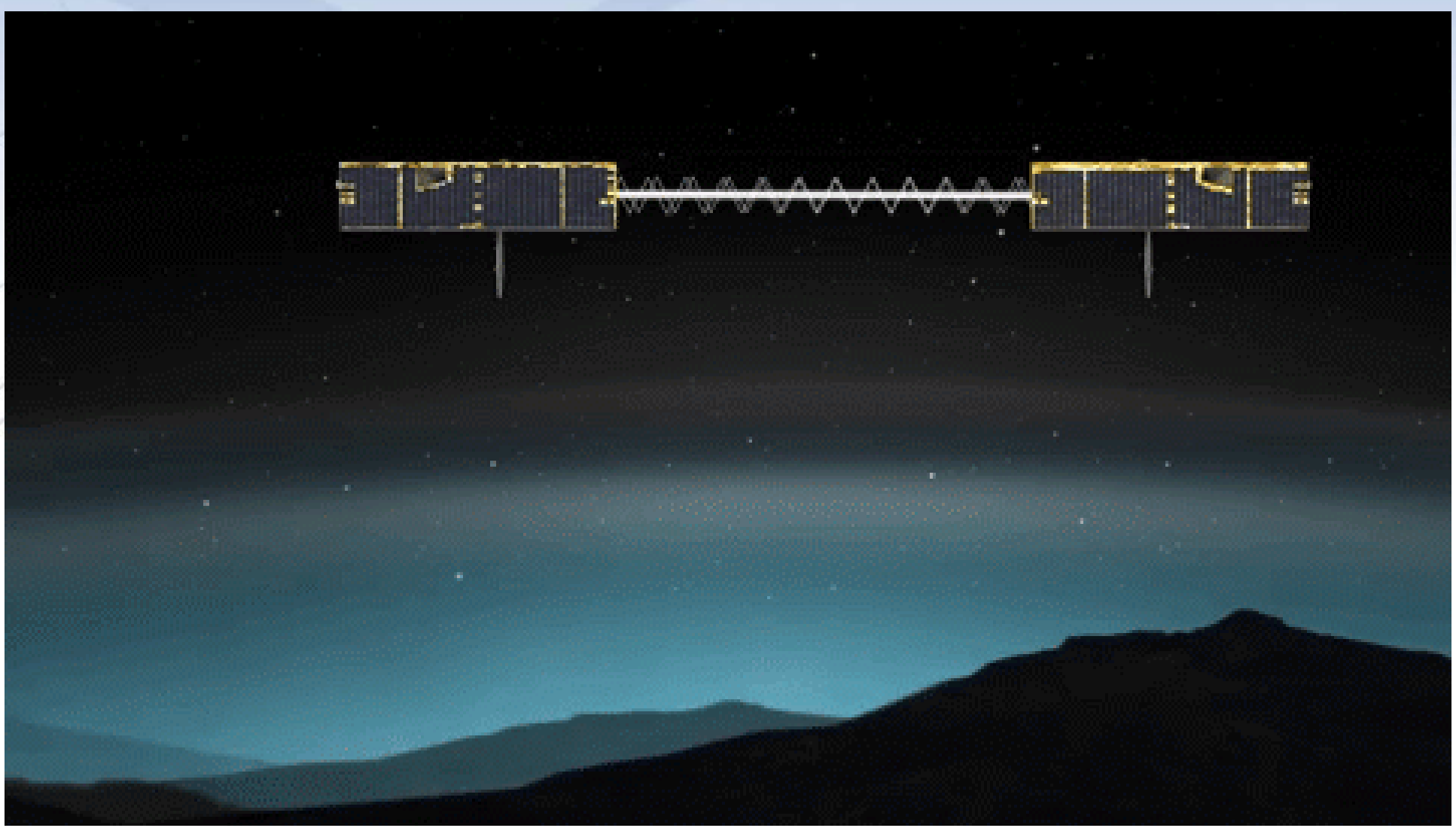
+

Terrestrial/Surface Measurement and
Predicted Gravity from Topography

Short Wavelengths
(< 100 km)



# GRACE - 2 Satellites measuring separation



# GRAV-D – airborne relative gravimeters

# Terrestrial Gravimeter - Relative

# Terrestrial Gravimeter - Relative

# Terrestrial Gravimeter - Absolute

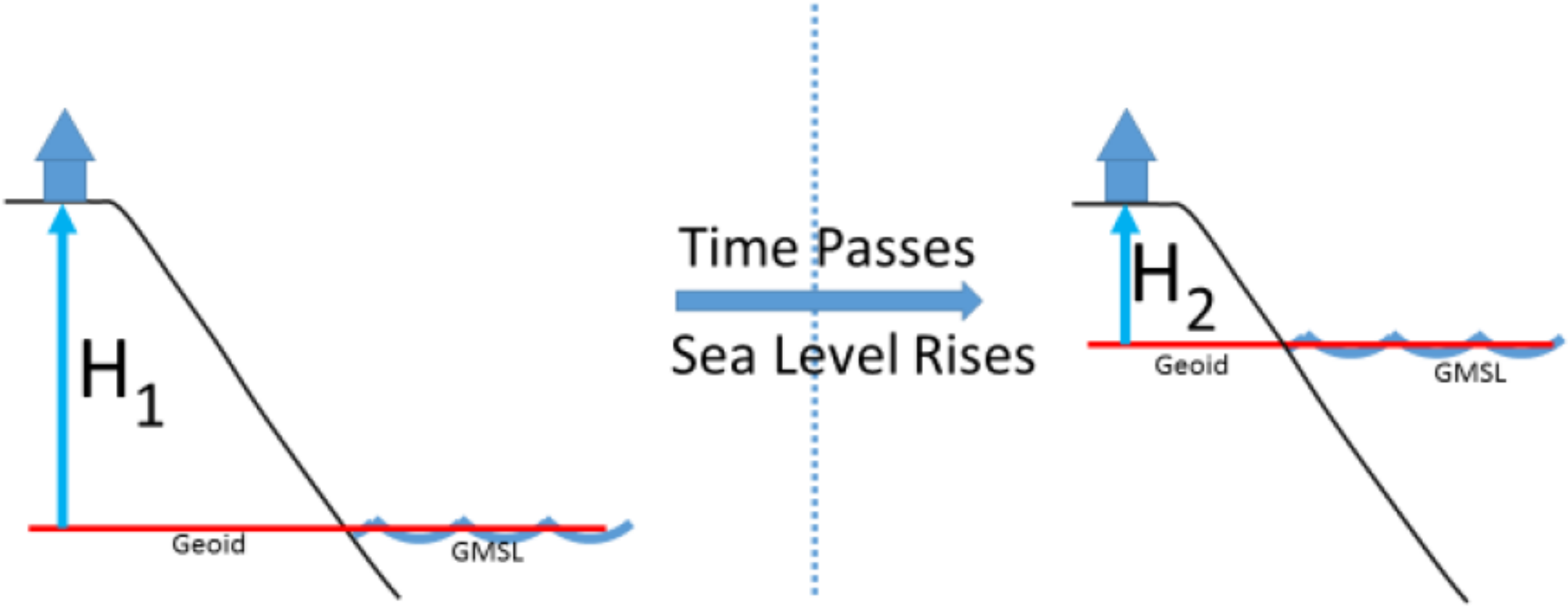
# Terrestrial Gravimeter - Absolute

# Individual Components of NAPGD2022

- global model of the geopotential field
  - **GM2022**
- geoid undulation models by region
  - **GEOID2022** aka "0 elevation"
- deflection of the vertical (DoV) models by region
  - **DEFLEC2022**
- surface gravity models by region
  - **GRAV2022**
    - static – SGRAV2022
    - dynamic – DGRAV2022

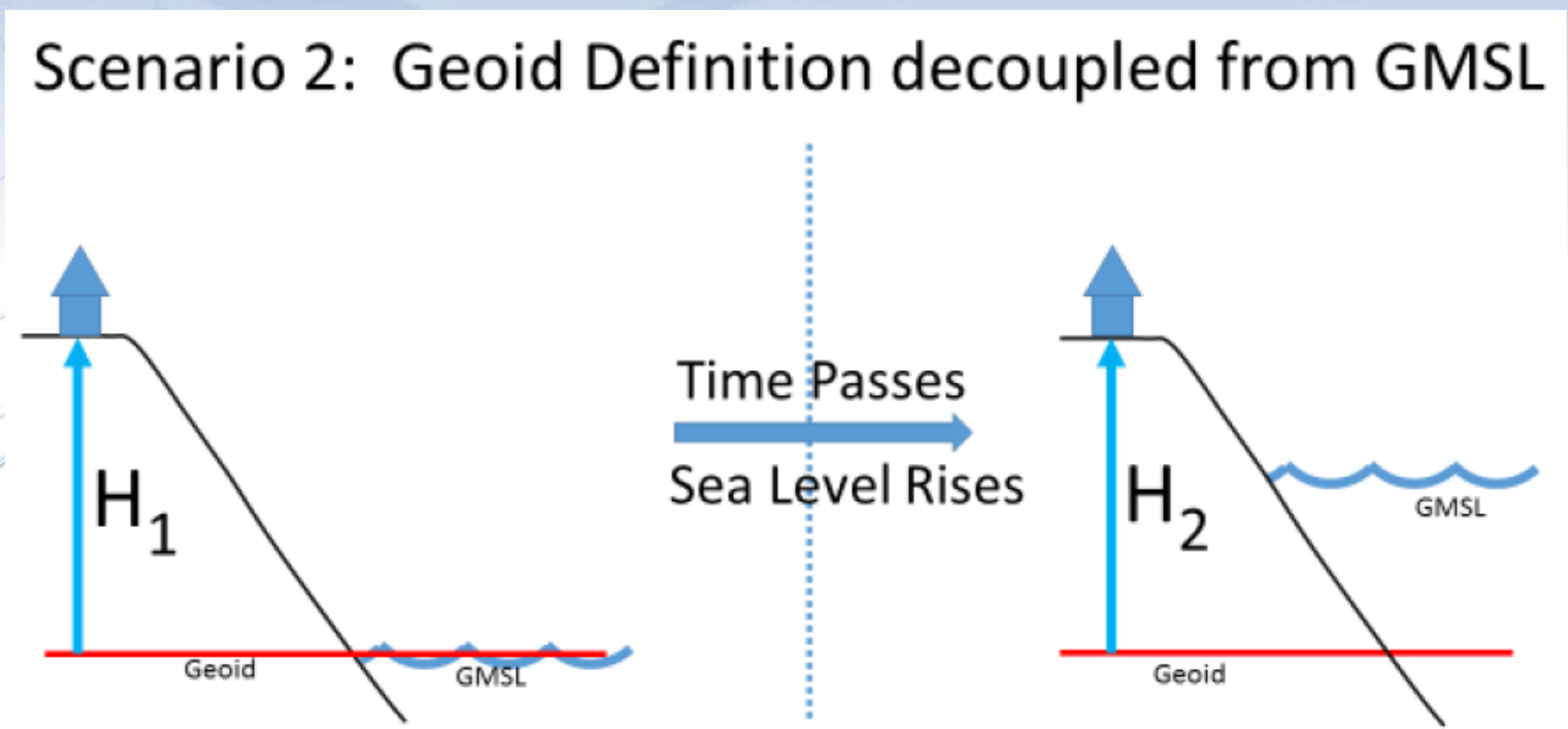
# Sea Level Change and the Geoid

## Scenario 1: Geoid Definition remains tied to GMSL



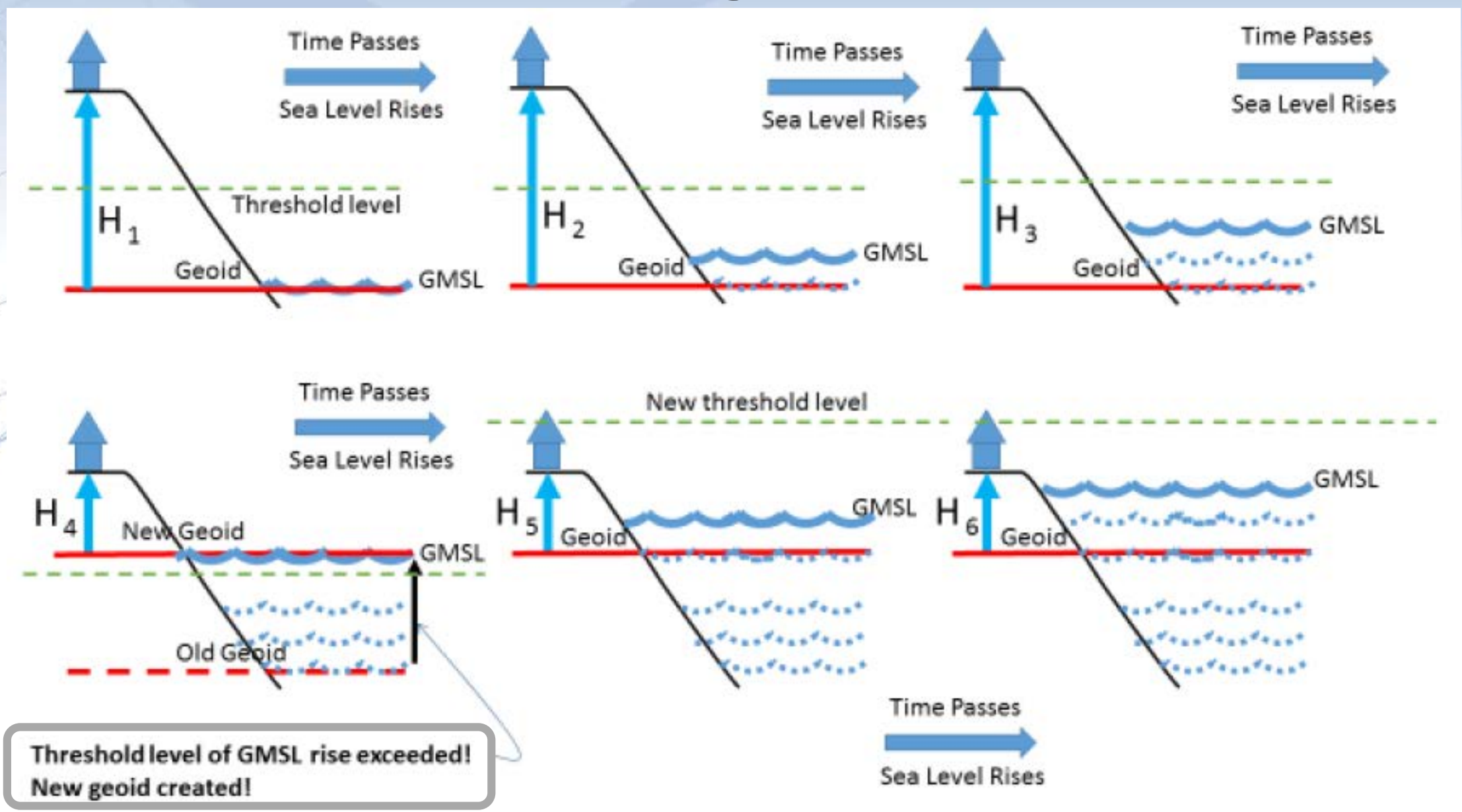

As Global Mean Sea Level rises, orthometric height gets smaller

# Sea Level Change and the Geoid




As Global Mean Sea Level rises, orthometric height remains constant

# Sea Level Change and the Geoid

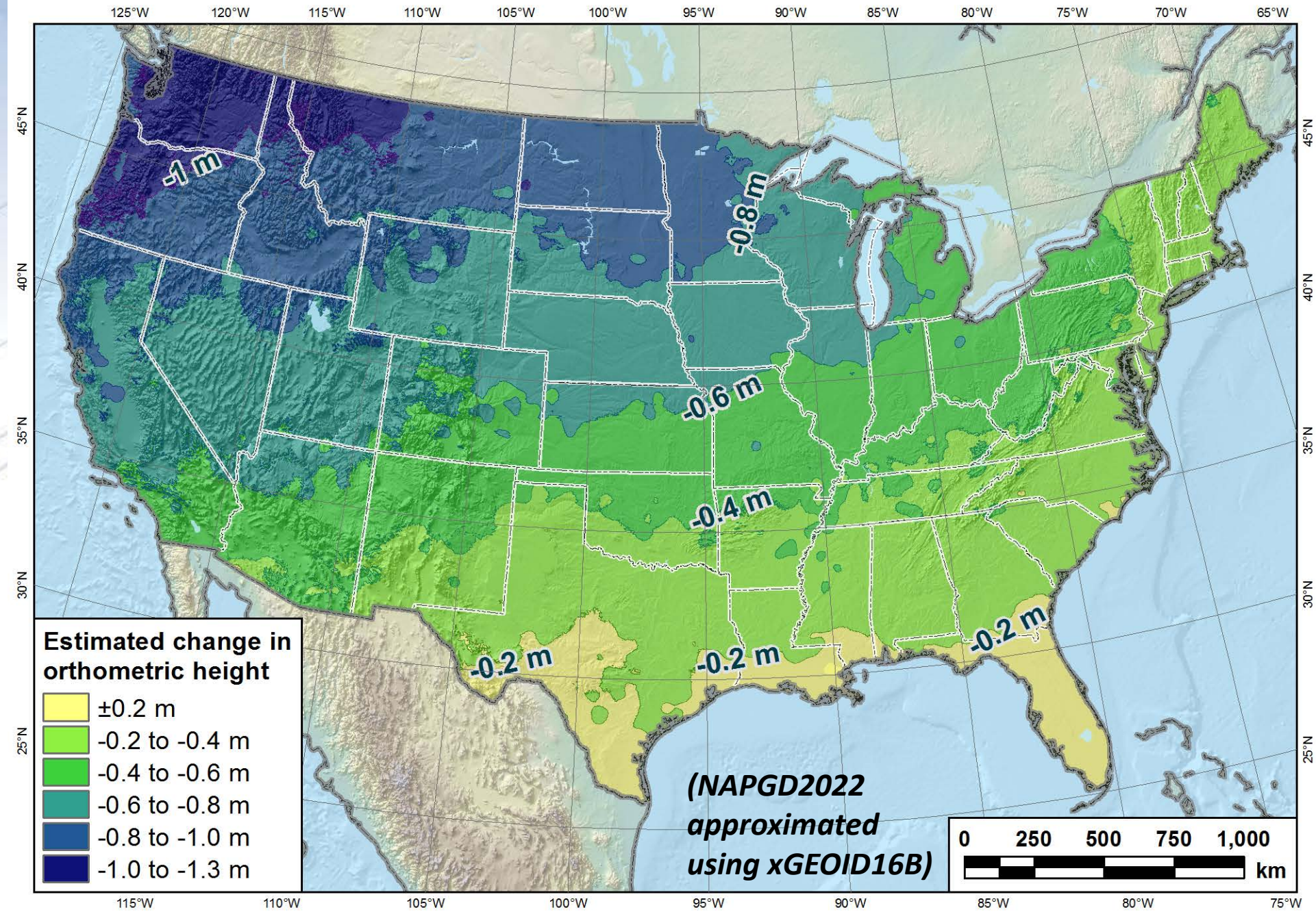


National Geodetic Survey Positioning America for the Future geodesy.noaa.gov

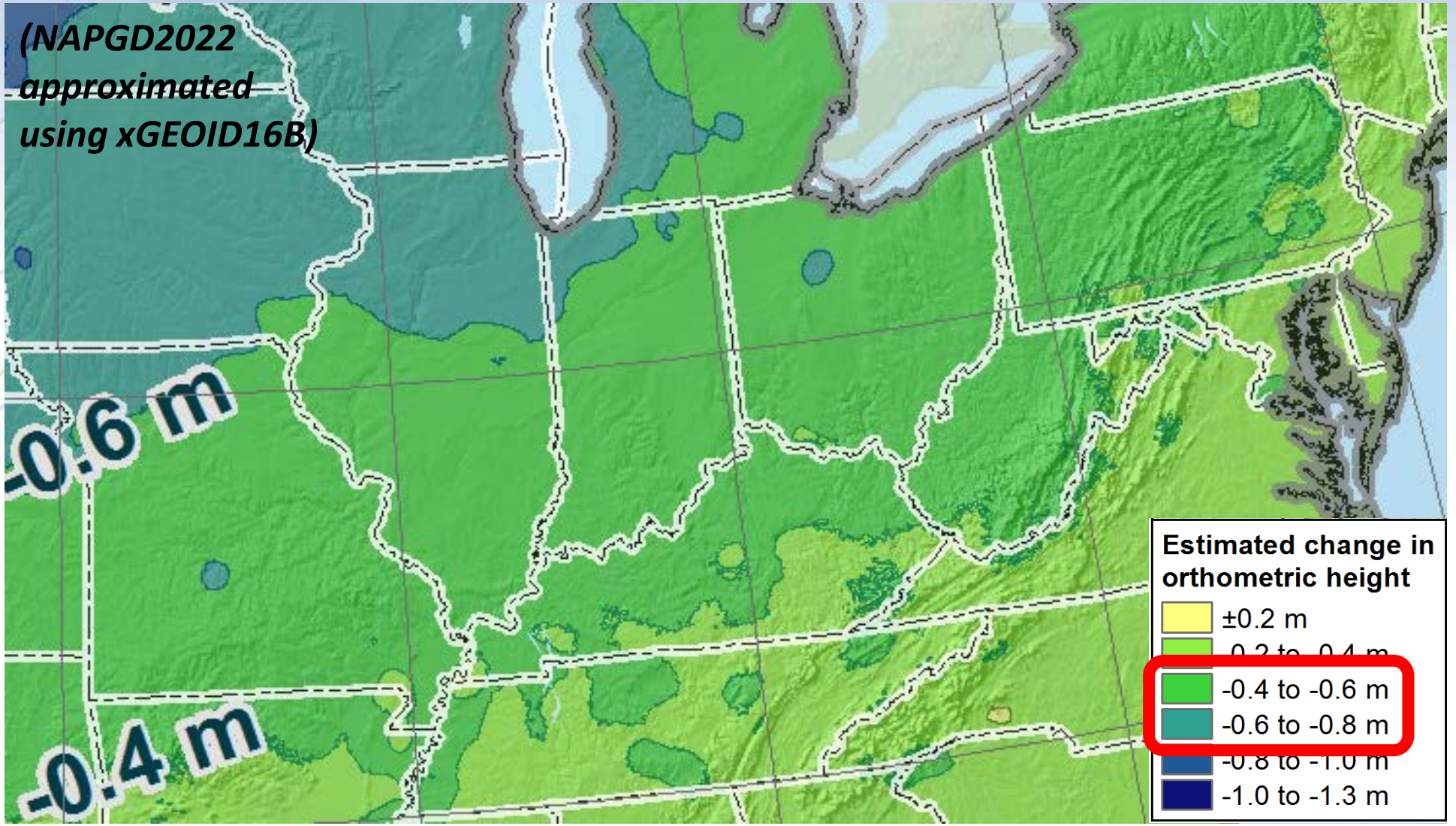
# NOAA Technical Report NOS NGS 64

## Blueprint for 2022, Part 2: Geopotential Coordinates

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



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




Vertical change of about -1.3 to -1.9 feet

Where did this all start?
And what will users get out of it?

Yeah, besides learning a whole new set of terminology and methods…

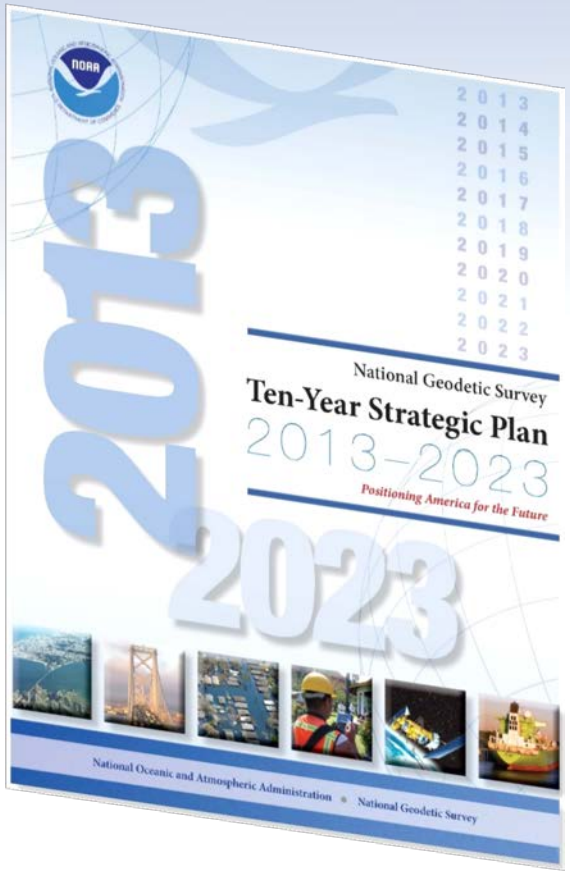
# National Geodetic Survey ***Ten-Year Strategic Plan***

By 2022, reduce all definitional & access-related errors in **geometric reference frame** to 1 cm when using 15 min of GNSS data

**aka "Replace NAD83"**

By 2022, reduce all definitional & access-related errors in orthometric heights in **geopotential datum** to 2 cm when using 15 min of GNSS data

**aka "Replace NAVD88"**




https://geodesy.noaa.gov/web/about_ngs/info/tenyearfinal.shtml

# Some terminology from Blueprint Part 3

# The NOAA CORS Network (NCN)

- As of 2019, this is the official name of the network managed at NGS
  - Historically referred to as "CORS" or "the CORS"

## NCN – NOAA CORS Network

# GPS Month

- A span of four consecutive GPS weeks, where the first GPS week in the GPS month is an integer multiple of 4
  - GPS Month 0 = GPS weeks 0, 1, 2 and 3
  - GPS Month 1 = GPS weeks 4, 5, 6 and 7
  - Etc.

# New Types of Coordinates

# NSRS Modernized: five types of coordinates

| Name | Generally on… | Description |
|---|---|---|
| Reported | Passive | "Quick and Dirty". Smartphone accuracy. (aka HD_HELD) |
| Preliminary | Passive | Computed by you with OPUS using your data. Unchecked by NGS. |
| Final Discrete | Passive | **Most accurate**. Time-dependent. Computed by NGS every four weeks. |
| Final Running | CORS | Continuous time-dependent CORS coordinates. Checked by NGS every day. |
| Reference Epoch | Passive and CORS | Modeled from Final Discrete, Final Running, IFVM2022 and GeMS. Computed by NGS every five years. |

# New Types of Coordinates - Reported

- **Reported**
  - *"These are from any source where the coordinate is directly reported to NGS without the data necessary for NGS to replicate the coordinate."*
    - Scaled
    - From NCAT or Vdatum
    - Hand Held (HD_HELD) / Smartphone
    - Reported directly from an RTK/RTN rover without data files

# Reported Coordinates

# New Types of Coordinates - Preliminary

- **Preliminary**
  - *"These are coordinates at survey epoch that have been computed from OPUS, but not yet quality checked and loaded into the National Spatial Reference System Database (NSRS DB)."*
    - *User-computed* values, such as they might get today from either OPUS-S or OPUS-Projects
    - "Preliminary" coordinates are the ***only*** coordinates a user will get directly from OPUS

# New Types of Coordinates – Reference Epoch

- **Reference Epoch**
  - *"These are coordinates which have been estimated by NGS, from time-dependent (final discrete and final running) coordinates, at an* **Official NSRS Reference Epoch (ONRE)***"*
    - NAD 83(2011) epoch 2010.00 (sorta) would fall under this category
    - These will be computed by NGS every 5 years
      - On a schedule 2-3 years past **ONRE**
        - » 2020.00 coordinates will be computed in CY 2022
        - » 2025.00 coordinates will be computed in CY 2027

# New Types of Coordinates – Final Discrete

- **Final Discrete**
  - *"These are coordinates computed by NGS using submitted data and metadata, checked and adjusted and referenced to a single survey epoch."*
    - Represent the best *estimates* of the time-dependent coordinates at any mark
    - Survey epochs:
      - GNSS: Each GPS Month
        - » Stand-alone occupations, RTK/RTN, Campaigns, etc
      - Leveling: Annually
        - » Orthometric heights: Leveling will be adjusted to GNSS-based orthometric heights

# New Types of Coordinates – Final Running

- **Final Running**
  - *"Of all types of coordinates on a mark, these are the only ones which will have a coordinate at any time."*
    - Generally will only be available at each CORS
      - Also being called the coordinate function
      - Which will be generated by a "fit" to daily processed data

# Using the modernized NSRS

- OPUS
  - ***Guidance*** (such as pre-selected CORSs and assistance in locating marks in project areas)
  - ***Users will decide*** what control to hold fixed and what epochs they wish to set for the adjustment
    - "Preliminary coordinates"
  - If submitted to NGS (aka "Shared"), we will harvest your raw data and use it to compute Final Discrete coordinates

# Using the modernized NSRS

- GNSS is your only entry (for now)
  - Leveling and Classical/TS surveys will need some GNSS if you wish to submit your survey to NGS for inclusion in the NSRS database
    - Some GNSS = RTK or RTN is fine
    - No decision yet on whether OPUS will operate if projects have no GNSS
      - If it does, this tends to encourage reliance upon passive control
        - » which is "so 90's" …1890s brah!

# So much more…

- New version of PAGES
  - Multi-Constellation → GPS, Galileo, GLONASS, Beidou, QZSS, etc.
  - Target: 15 minute occupations
- OPUS expansion plan
  - RTK/RTN: 2019
  - Leveling, Classical, Gravity: 2020-2025
  - Fully integrated (GPS projects with leveling and gravity? No problem!)
  - Ease of submission to NGS for inclusion in the NSRS
- New Mark Recovery Tool
  - Smart-phone enabled. In beta now! beta.ngs.noaa.gov/cgi-bin/recvy_entry_www.prl
- Fully integrated toolkit
  - NCAT and VDatum

# Mobile-enabled Mark Recovery

- Any major search engine: "**NGS survey Mark Recovery**"
- URL below

beta.ngs.noaa.gov/cgi-bin/recvy_entry_www.prl

Try it out! Give us feedback!

NGS.Feedback@noaa.gov

# State Plane Coordinate System of 2022

# (SPCS2022)

# SPCS2022 activity over the last year

- Publish State Plane history report: **March 6**
- Webinars on **March 8** and **April 12**
- Launch new SPCS web pages: **March 19**
- Publish Federal Register Notice (FRN) and draft SPCS2022 Policy & Procedures: **April 18**
- FRN response deadline: **August 31**
- Provide first preliminary design maps: **October 11**
- Finalizing policy & procedures: **May 5**

geodesy.noaa.gov

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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

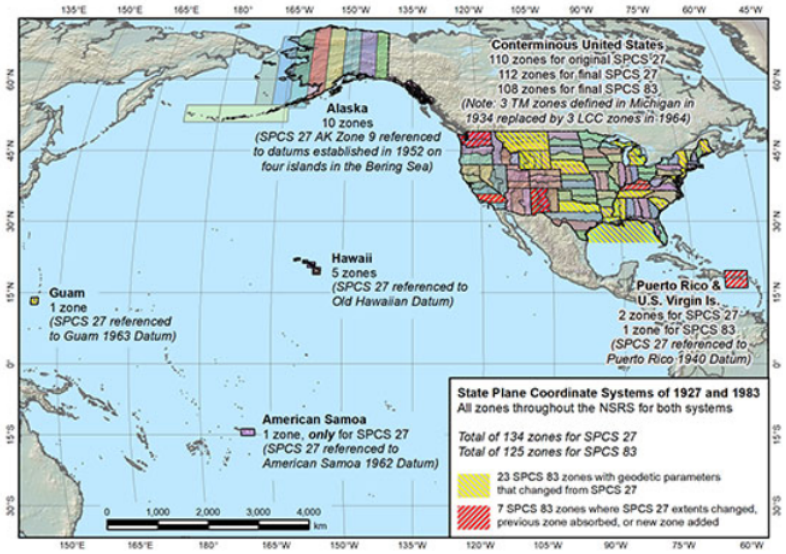
## State Plane Coordinate System (SPCS)

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**

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etic Survey (NGS) provides the framework for all the Nation. The foundational elements of latitude, horeline information impact a wide range of important

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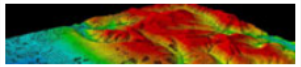

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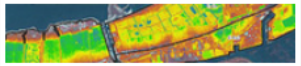

**Datums & Transformations**

NGS defines datums to help align data and tools to transform coordinates.

Learn More

**Notices**

**Register**: Geospatial Summit on May 6-7, 2019

**BETA Releases**: BETA GEOID18

BETA CORS ITRF14 Coordinates

**In the News**

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

**03/15/2019** - GEOID18 Products Released for Beta Testing and Public Comment

**03/08/2019** - NGS Updates its Strategic Plan

Previous News Stories

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# SPCS2022 Policy & Procedures

***Summary of main things that did* NOT *change***

- **Policy**
  - Limited to LCC, TM, and OM projections
  - Zones designed to reduce distortion at ground
  - Default zones designed by NGS if no consensus input
  - Parameters in meters, but feet allowed for output
- **Procedures**
  - Stakeholders must submit requests/proposals
  - 1-parallel LCC and local OM projection definitions
  - Specified a linear distortion design criterion
  - Limit NGS designs to minimum of ±50 ppm
  - 50 km min zone size for height range of 250 m or less

# *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 stakeholder request for something different
- 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
- Zones within a layer cannot overlap
- Require positive east longitudes

# *Changes* to SPCS2022 Procedures

***Summary of main changes***

- Delayed deadlines by 3 months
- Removed "contributing partner" category
- Moved submittal details to fillable forms
- Added section on zones numbers and names
- Added details on **linear distortion design criterion**
- Removed minimum distortion limit
- Added 10 km min zone size for height range > 250m

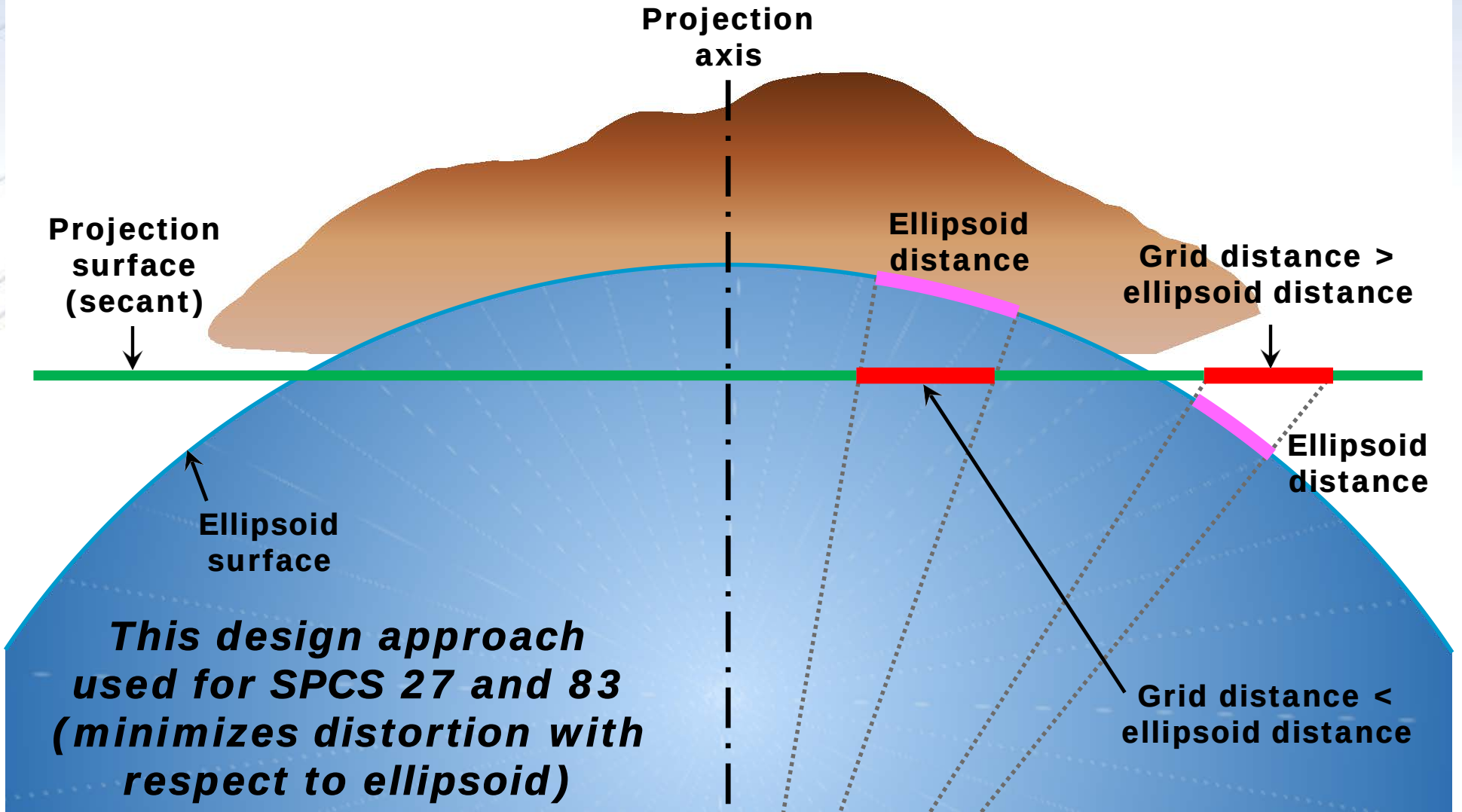
# SPCS2022 stakeholders

- **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 stakeholders
- Stakeholder input must be ***unanimous***

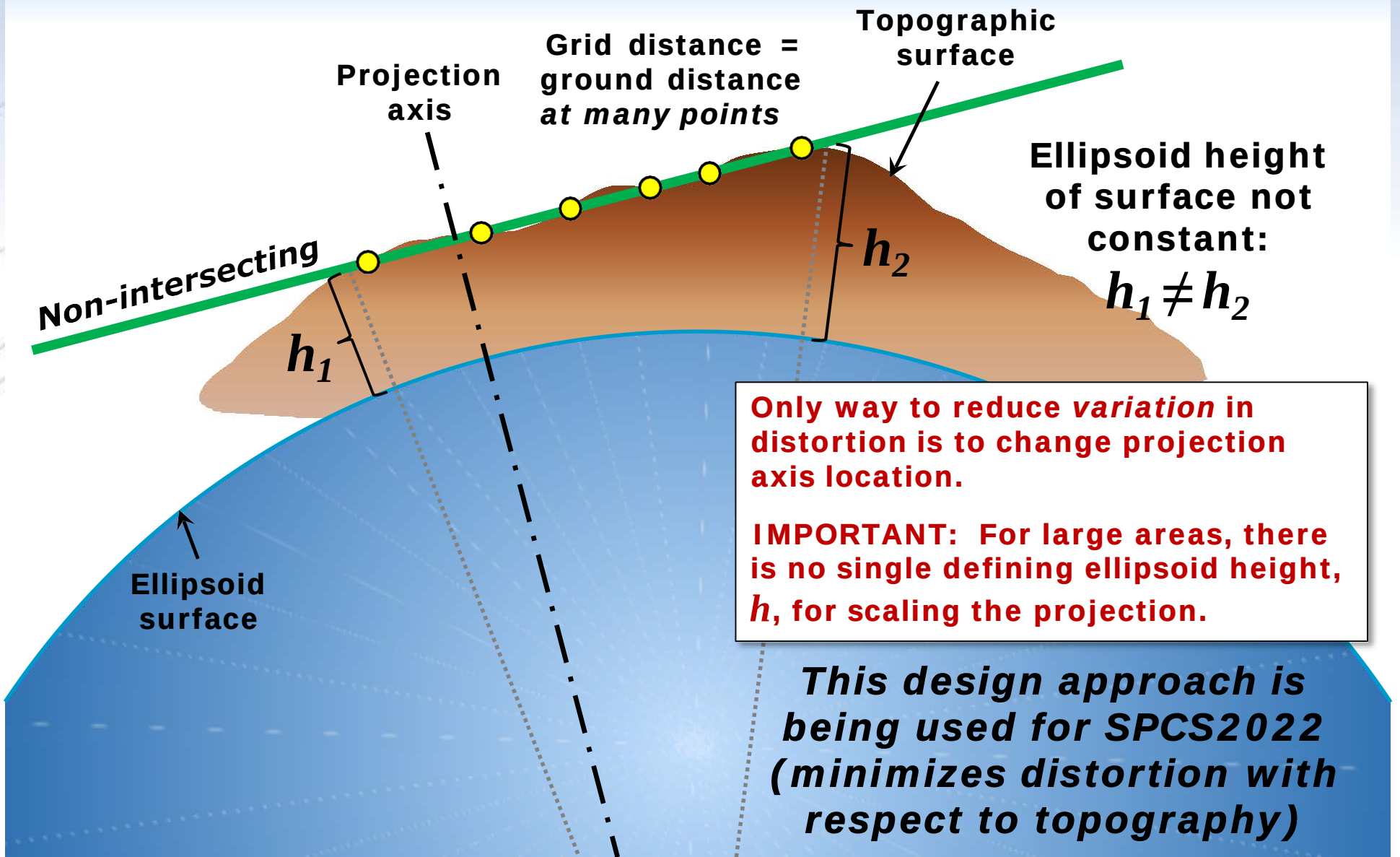
# General SPCS2022 characteristics

- Distortion design requirements
  - ***Linear distortion*** minimized at topographic surface (**not** at ellipsoid surface)
  - ***Purpose:*** to reduce difference between projected "grid" and actual "ground" distances
- Other characteristics
  - Default designs (if no consensus stakeholder input)
  - Statewide and "layered" zones
  - Positive east longitudes
  - Low-distortion projections (LDPs)
  - "Special use" zones

# Linear distortion *with respect to ellipsoid*



# Changing projection axis to reduce distortion variation

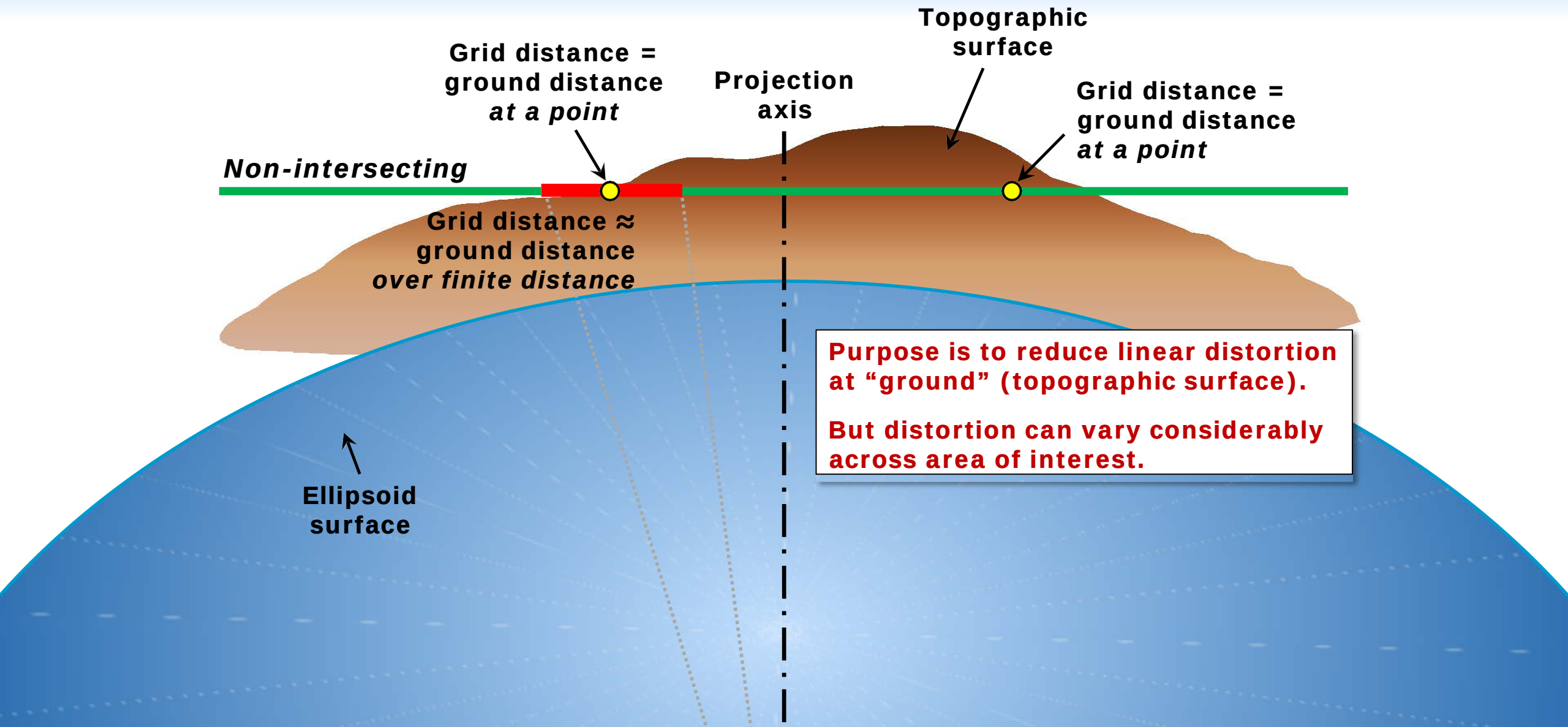



**Only way to reduce *variation* in distortion is to change projection axis location.**

**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)***

# “Non-intersecting” conformal map projection



# 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

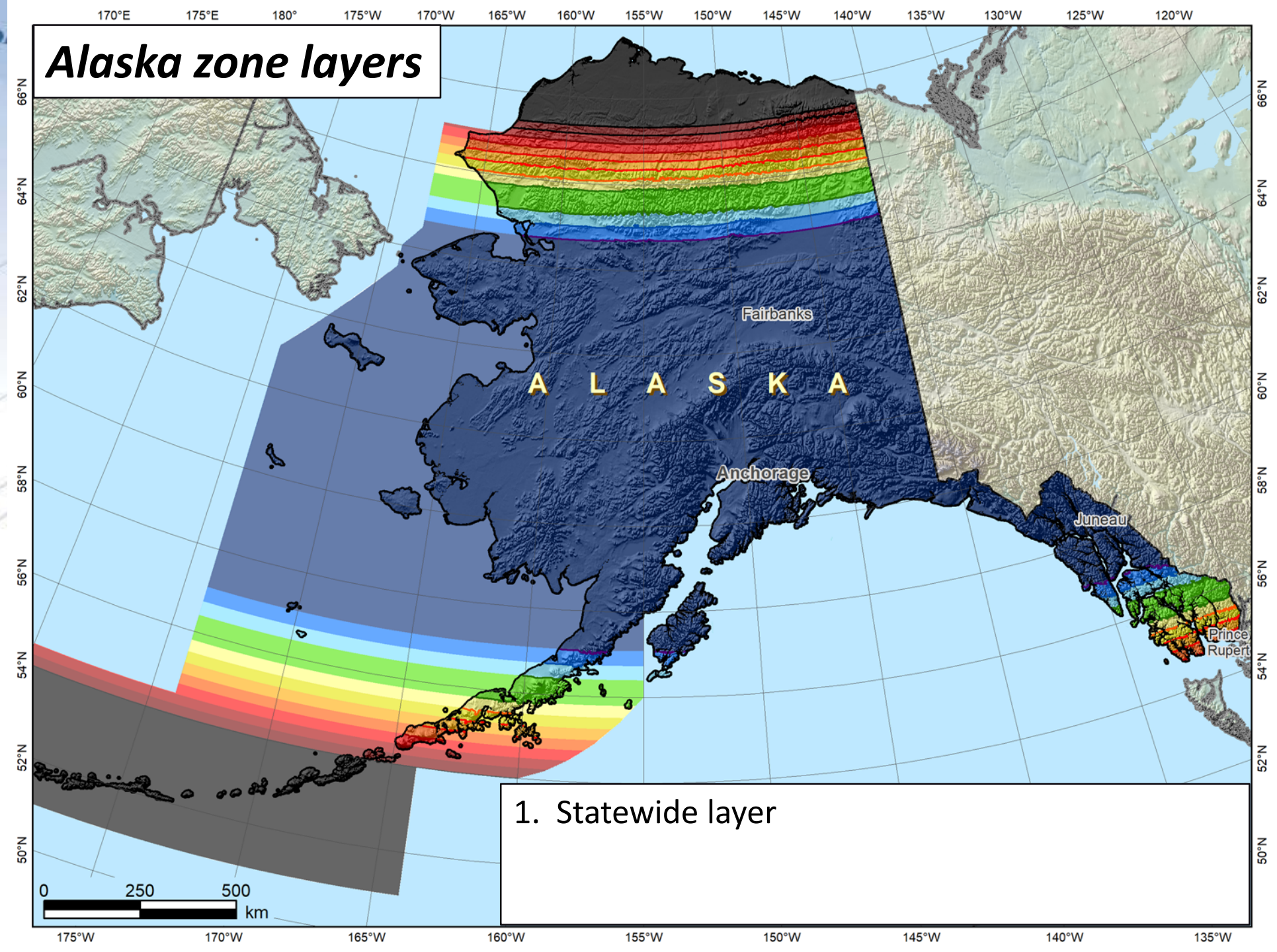
- **NGS will create a statewide zone for *all* states**

# 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

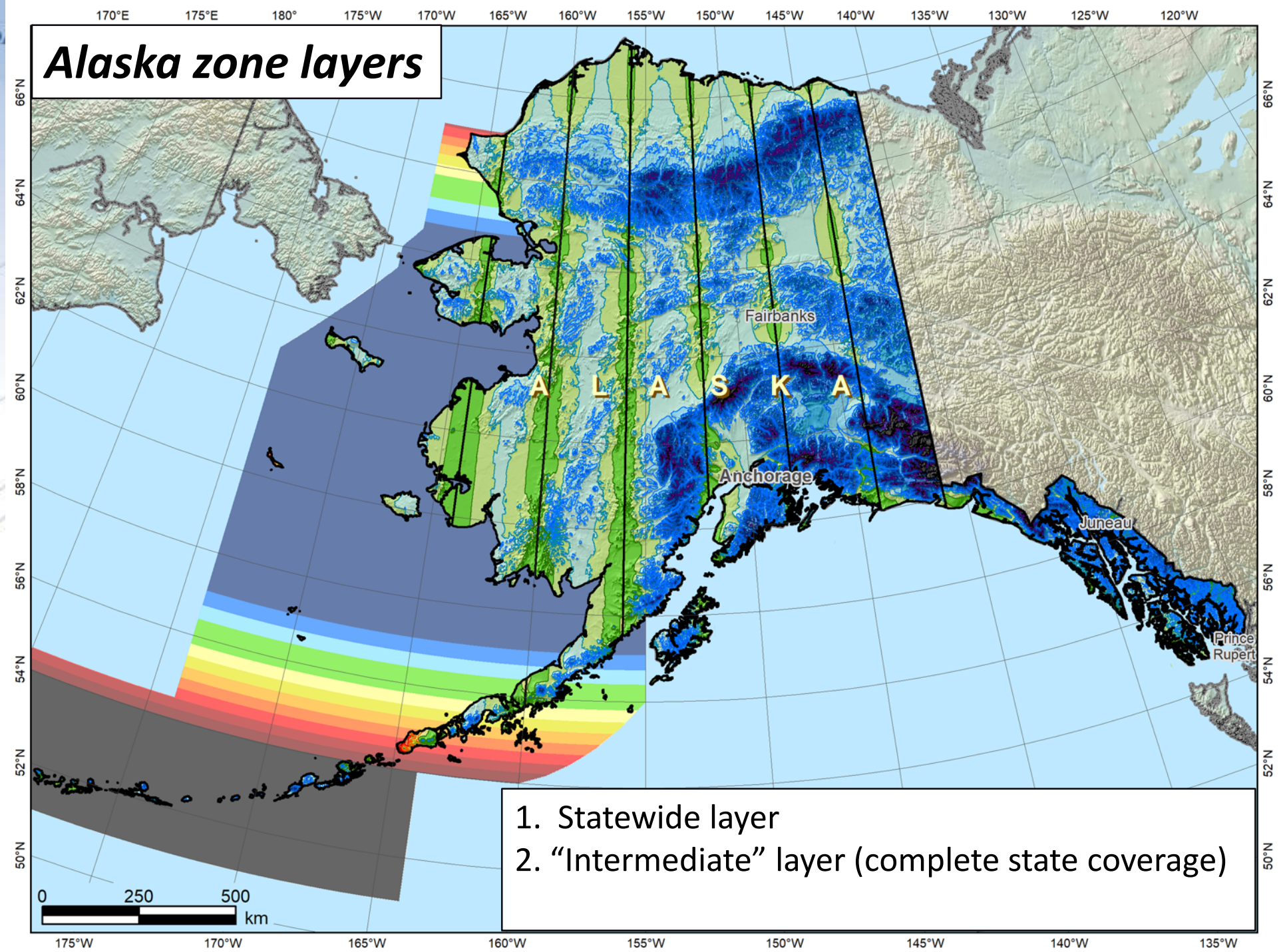
- Multi-zone layer can consist of LDPs
  - Designed by stakeholder "contributing partners"
  - Minimum zone width 50 km (if height range < 250 m)
    OR 10 km (if height range > 250 m)
  - LDP coverage can be discontinuous

# Alaska zone layers

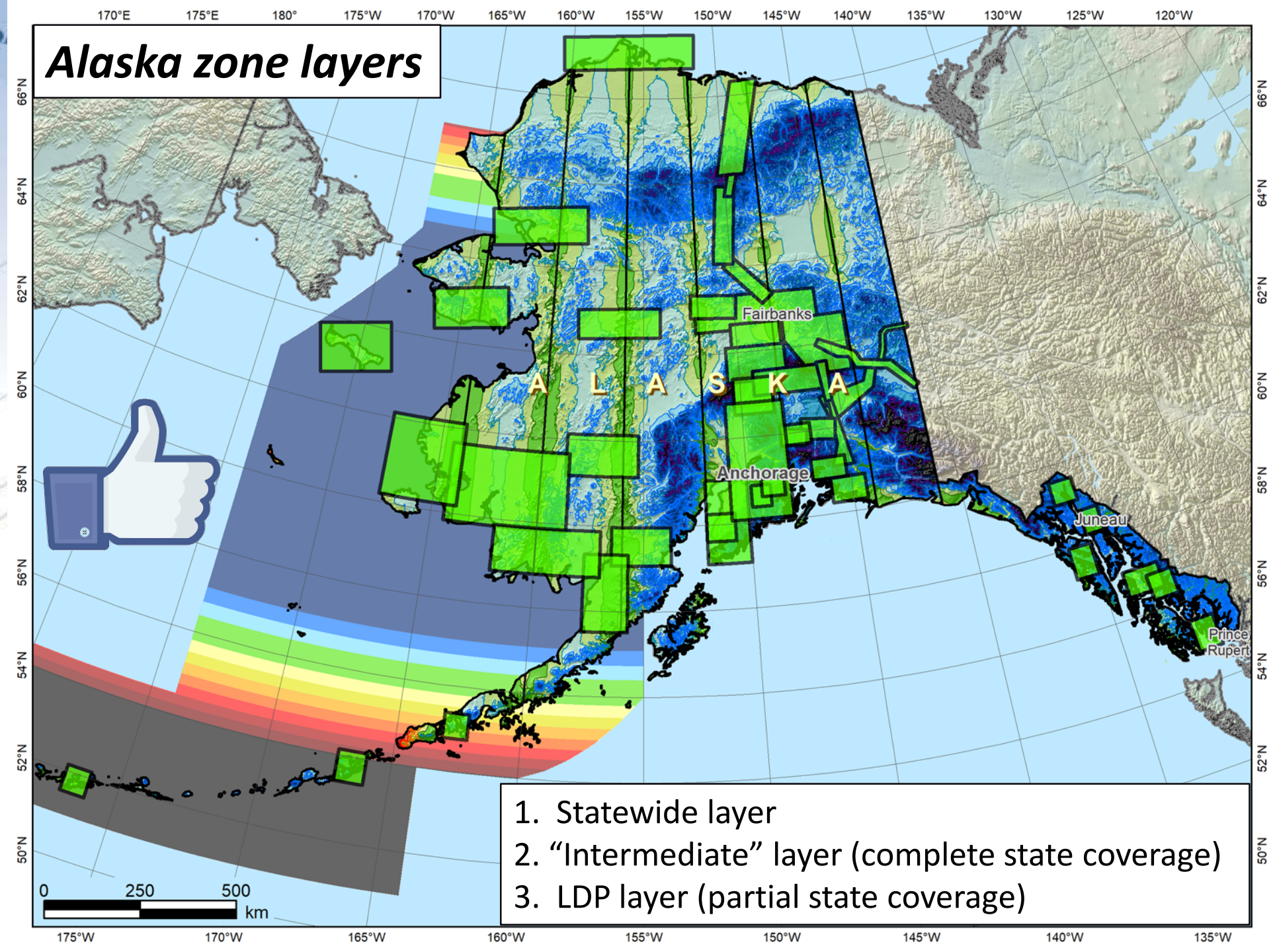



1. Statewide layer

# Alaska zone layers




1. Statewide layer
2. “Intermediate” layer (complete state coverage)


Alaska zone layers
ALASKA
Fairbanks
Anchorage
Juneau
Prince Rupert
1. Statewide layer
2. “Intermediate” layer (complete state coverage)
3. LDP layer (partial state coverage)
0 250 500 km

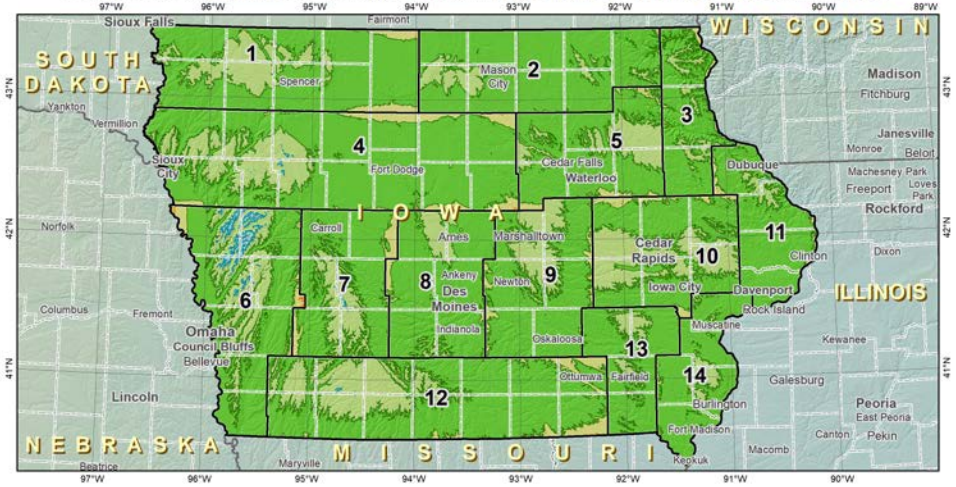
# Iowa with **TWO** SPCS2022 layers

**LDP multiple-zone layer**
***(complete state coverage)***

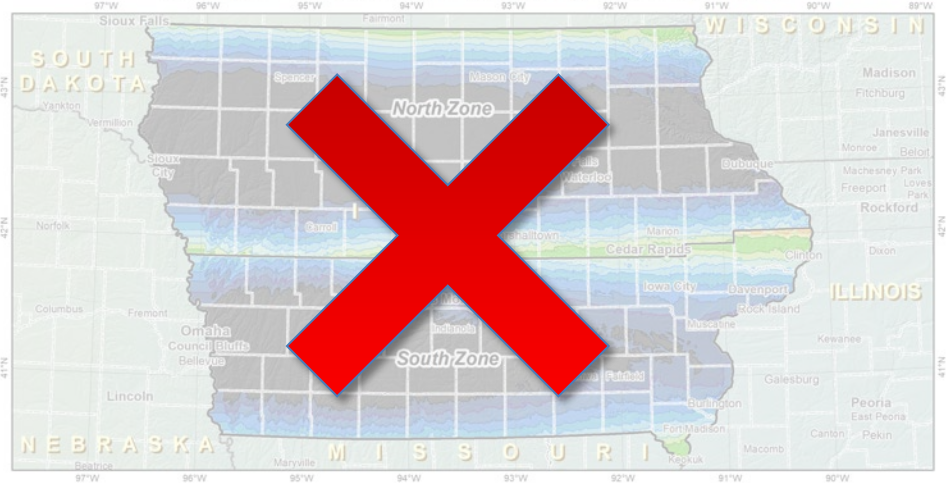
***OR***

**SPCS 83-like multiple-zone layer**
***(complete state coverage)***

***Proposed stakeholder design:*** **Iowa Regional Coordinate System Zones**

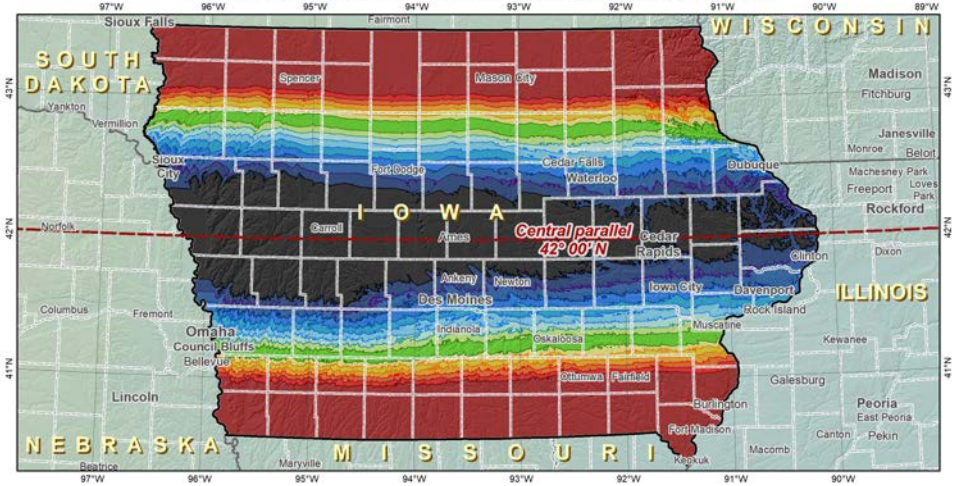



***Existing SPCS 83 design:*** **Iowa North and South Zones**




***Preliminary SPCS2022 statewide zone design:*** **Iowa**

**Statewide layer for EVERY state**




**Linear distortion at topographic surface** (parts per million)

| | | |
|---|---|---|
| < -80 | to -40 | to +30 |
| to -80 | to -30 | to +40 |
| to -70 | to -20 | to +50 |
| to -60 | ±10 | to +60 |
| to -50 | to +20 | > +60 |

0 50 100 150 200 km

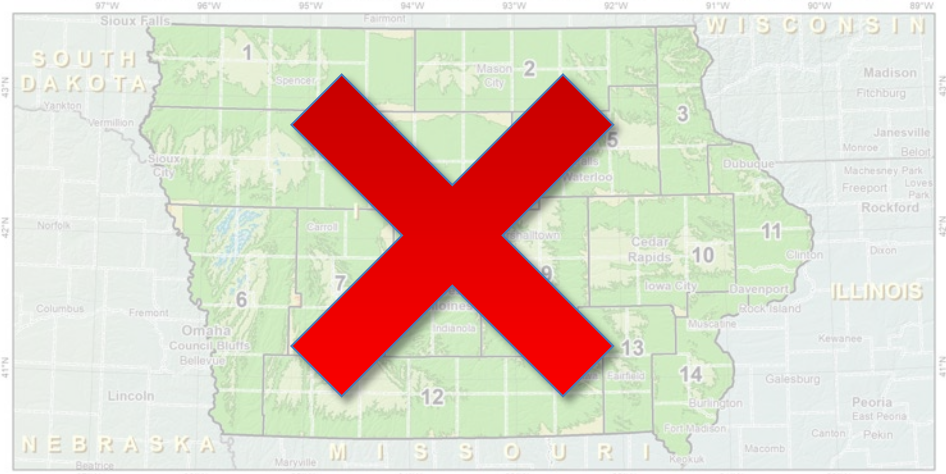
# Iowa with **TWO** SPCS2022 layers

LDP multiple-zone layer
*(complete state coverage)*

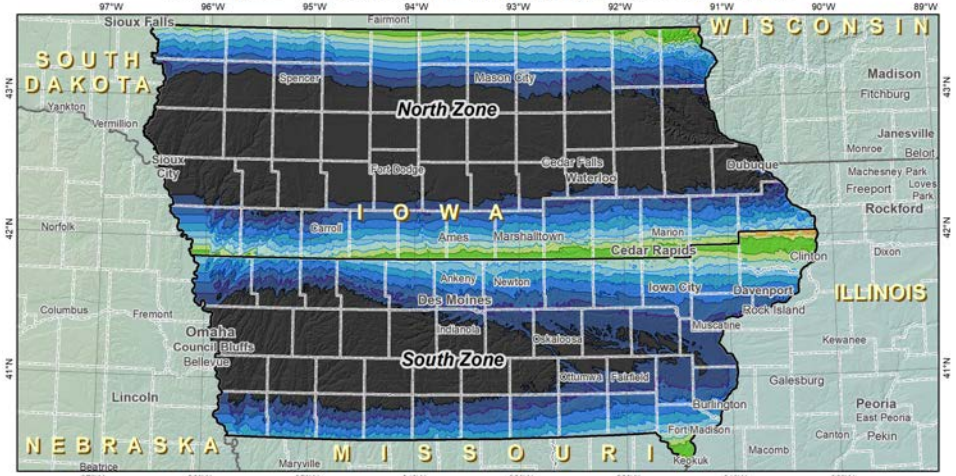
**OR**

**SPCS 83-like multiple-zone layer**
***(complete state coverage)***

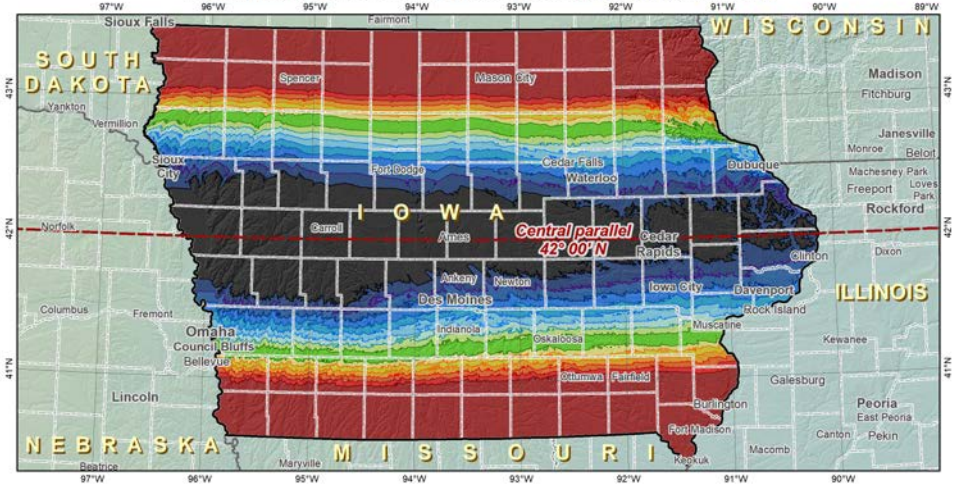
*Proposed stakeholder design:* Iowa Regional Coordinate System Zones




*Existing SPCS 83 design:* Iowa North and South Zones




*Preliminary SPCS2022 statewide zone design:* Iowa




**Statewide layer for EVERY state**

**Linear distortion at topographic surface** (parts per million)

| | | |
|---|---|---|
| < -80 | to -40 | to +30 |
| to -80 | to -30 | to +40 |
| to -70 | to -20 | to +50 |
| to -60 | ±10 | to +60 |
| to -50 | to +20 | > +60 |

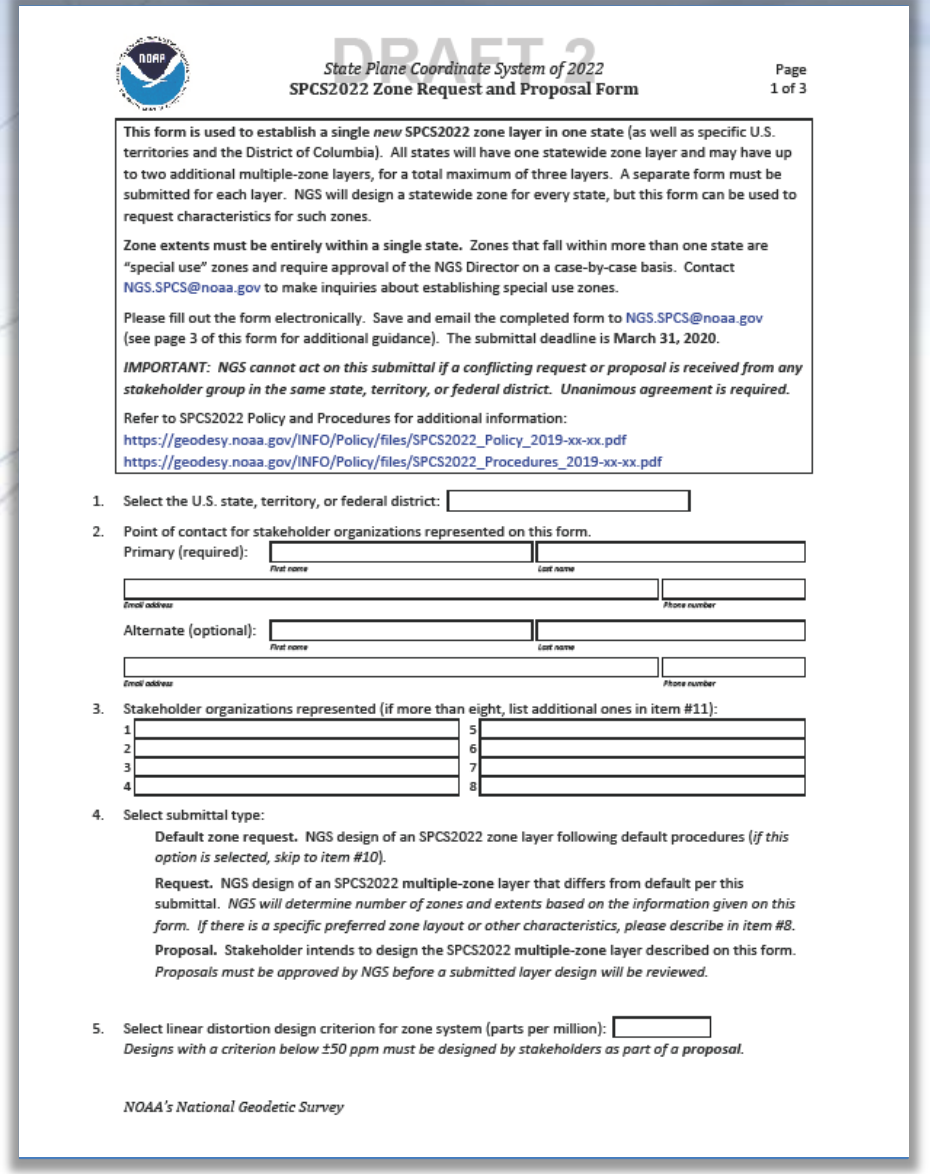
0 50 100 150 200 km

# 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

by **March 31, 2020** for ***requests*** and ***proposals***
by **March 31, 2021** for ***submittal*** of ***approved*** designs

# Fillable PDF stakeholder forms



DRAFT 2

*State Plane Coordinate System of 2022*
**SPCS2022 Zone Request and Proposal Form**

Page 1 of 3

**This form is used to establish a single *new* SPCS2022 zone layer in one state** (as well as specific U.S. territories and the District of Columbia). All states will have one statewide zone layer and may have up to two additional multiple-zone layers, for a total maximum of three layers. A separate form must be submitted for each layer. NGS will design a statewide zone for every state, but this form can be used to request characteristics for such zones.

**Zone extents must be entirely within a single state.** Zones that fall within more than one state are "special use" zones and require approval of the NGS Director on a case-by-case basis. Contact NGS.SPCS@noaa.gov to make inquiries about establishing special use zones.

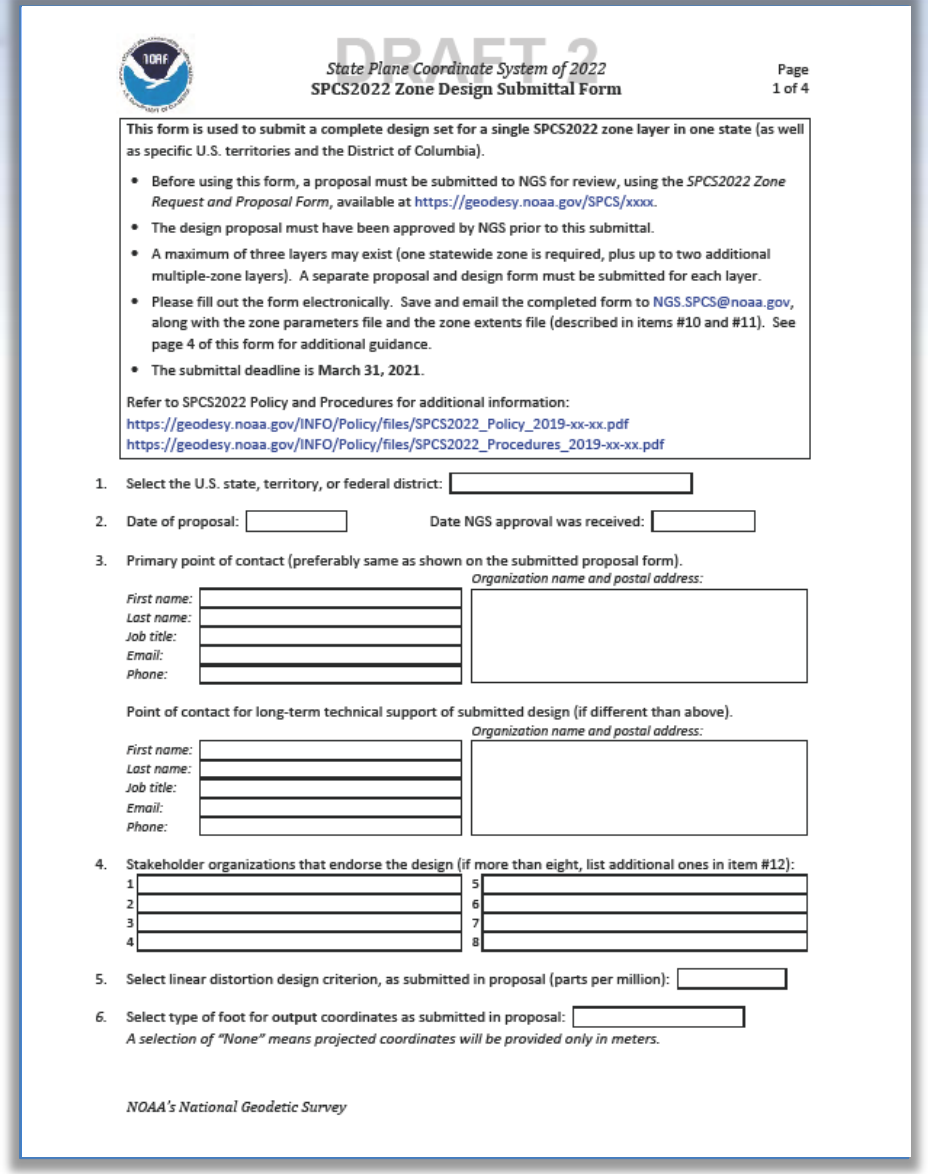
Please fill out the form electronically. Save and email the completed form to NGS.SPCS@noaa.gov (see page 3 of this form for additional guidance). The submittal deadline is **March 31, 2020**.

***IMPORTANT:** NGS cannot act on this submittal if a conflicting request or proposal is received from any stakeholder group in the same state, territory, or federal district. Unanimous agreement is required.*

Refer to SPCS2022 Policy and Procedures for additional information:
https://geodesy.noaa.gov/INFO/Policy/files/SPCS2022_Policy_2019-xx-xx.pdf
https://geodesy.noaa.gov/INFO/Policy/files/SPCS2022_Procedures_2019-xx-xx.pdf

1. Select the U.S. state, territory, or federal district: ____
2. Point of contact for stakeholder organizations represented on this form.
   Primary (required): ____ (First name) ____ (Last name)
   ____ (Email address) ____ (Phone number)
   Alternate (optional): ____ (First name) ____ (Last name)
   ____ (Email address) ____ (Phone number)
3. Stakeholder organizations represented (if more than eight, list additional ones in item #11):
   1 ____ 5 ____
   2 ____ 6 ____
   3 ____ 7 ____
   4 ____ 8 ____
4. Select submittal type:
   **Default zone request.** NGS design of an SPCS2022 zone layer following default procedures (*if this option is selected, skip to item #10*).
   **Request.** NGS design of an SPCS2022 **multiple-zone** layer that differs from default per this submittal. *NGS will determine number of zones and extents based on the information given on this form. If there is a specific preferred zone layout or other characteristics, please describe in item #8.*
   **Proposal.** Stakeholder intends to design the SPCS2022 **multiple-zone** layer described on this form. *Proposals must be approved by NGS before a submitted layer design will be reviewed.*
5. Select linear distortion design criterion for zone system (parts per million): ____
   *Designs with a criterion below ±50 ppm must be designed by stakeholders as part of a proposal.*

*NOAA's National Geodetic Survey*



DRAFT 2

*State Plane Coordinate System of 2022*
**SPCS2022 Zone Design Submittal Form**

Page 1 of 4

**This form is used to submit a complete design set for a single SPCS2022 zone layer in one state** (as well as specific U.S. territories and the District of Columbia).

- Before using this form, a proposal must be submitted to NGS for review, using the *SPCS2022 Zone Request and Proposal Form*, available at https://geodesy.noaa.gov/SPCS/xxxx.
- The design proposal must have been approved by NGS prior to this submittal.
- A maximum of three layers may exist (one statewide zone is required, plus up to two additional multiple-zone layers). A separate proposal and design form must be submitted for each layer.
- Please fill out the form electronically. Save and email the completed form to NGS.SPCS@noaa.gov, along with the zone parameters file and the zone extents file (described in items #10 and #11). See page 4 of this form for additional guidance.
- The submittal deadline is **March 31, 2021**.

Refer to SPCS2022 Policy and Procedures for additional information:
https://geodesy.noaa.gov/INFO/Policy/files/SPCS2022_Policy_2019-xx-xx.pdf
https://geodesy.noaa.gov/INFO/Policy/files/SPCS2022_Procedures_2019-xx-xx.pdf

1. Select the U.S. state, territory, or federal district: ____
2. Date of proposal: ____ Date NGS approval was received: ____
3. Primary point of contact (preferably same as shown on the submitted proposal form).
   *Organization name and postal address:*
   *First name:* ____
   *Last name:* ____
   *Job title:* ____
   *Email:* ____
   *Phone:* ____
   Point of contact for long-term technical support of submitted design (if different than above).
   *Organization name and postal address:*
   *First name:* ____
   *Last name:* ____
   *Job title:* ____
   *Email:* ____
   *Phone:* ____
4. Stakeholder organizations that endorse the design (if more than eight, list additional ones in item #12):
   1 ____ 5 ____
   2 ____ 6 ____
   3 ____ 7 ____
   4 ____ 8 ____
5. Select linear distortion design criterion, as submitted in proposal (parts per million): ____
6. Select type of foot for **output** coordinates as submitted in proposal: ____
   *A selection of "None" means projected coordinates will be provided only in meters.*

*NOAA's National Geodetic Survey*

# State Plane Coordinate System of 2022

# (SPCS2022)


# ...or Feets Don't Fail Me Now

# The problem (and some questions)

- **Two versions of same unit in current use**
  - "New" international foot and "old" U.S. survey foot
  - "New" shorter than "old" by 2 ppm (**0.01 ft per mile**)
  - A ***real*** problem with ***real*** costs
- **What's in a name?**
  - "U.S. survey" versus "international"
- **Who is using U.S. survey feet?**
  - Surveyors exclusively, in most (*not all*) states
  - But it impacts everyone

# What is this all about? *The Big Picture*

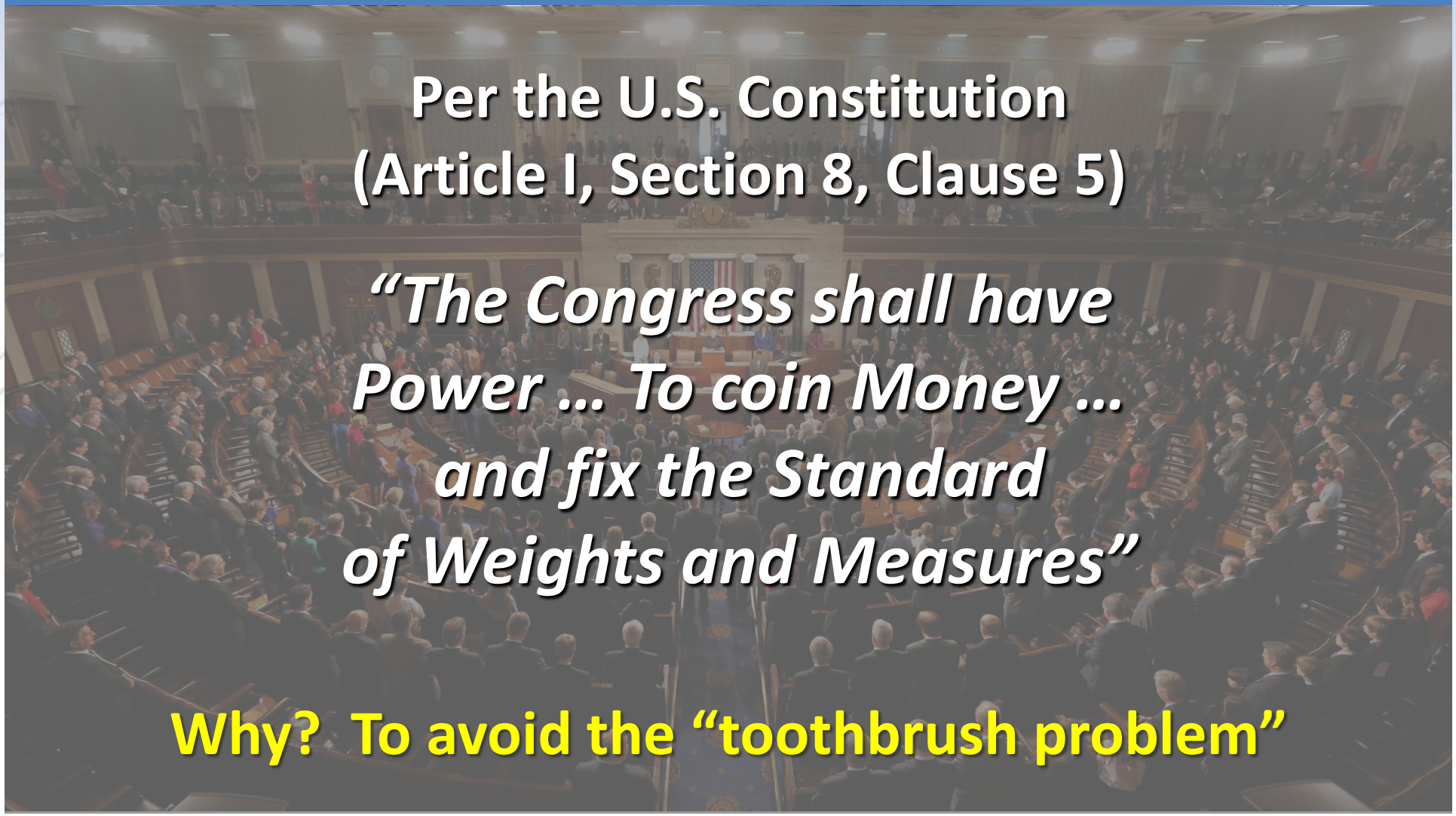
- **Science + Industry = COMMERCE**
  - Standards ***essential***
  - Without them we are lost
- **A history of change**
  - Not for own sake, but to make things ***better***
  - Vital component of ***progress***
- **The law, and *STANDARDS for weights & measures***
  - Taken for granted because things just "work"
  - Many years of effort behind what we have today
  - Legally binding and critical to functioning of society

# Who is responsible for standards?

***Today:***

**National Institute of Standards and Technology**

# Congress is the Authority



Per the U.S. Constitution
(Article I, Section 8, Clause 5)

*"The Congress shall have Power … To coin Money … and fix the Standard of Weights and Measures"*

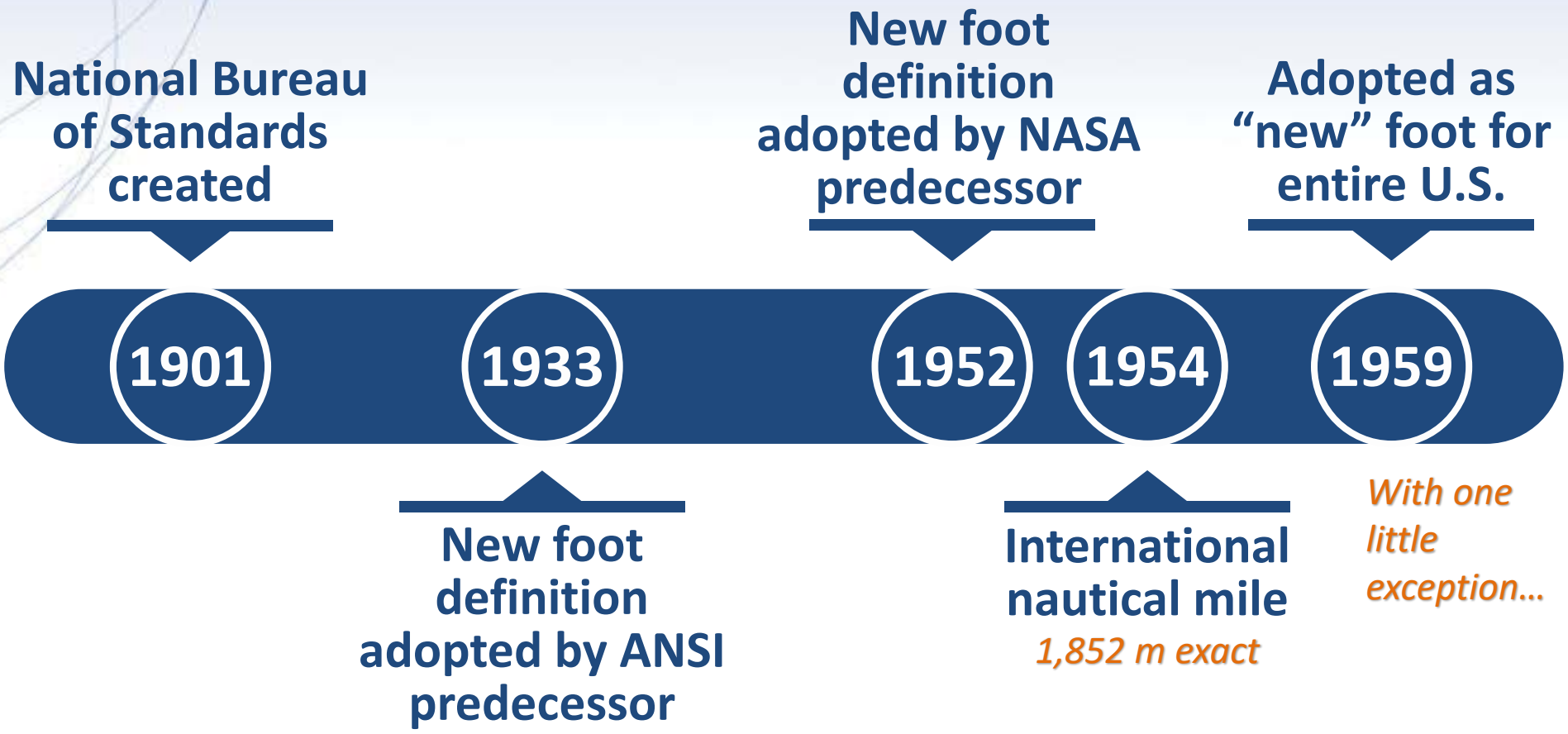
**Why? To avoid the "toothbrush problem"**

# The trouble with standards…


Image from beyondplm.com

# A new foot for a new century

**1 foot = 0.3048 meter *exactly* (1 yard = 0.9144 m)**



# Kicking the can (Federal Register)

"Any data expressed in feet derived from and published as a result of ***geodetic surveys*** within the United States will continue to bear the following relationship as defined in 1893:

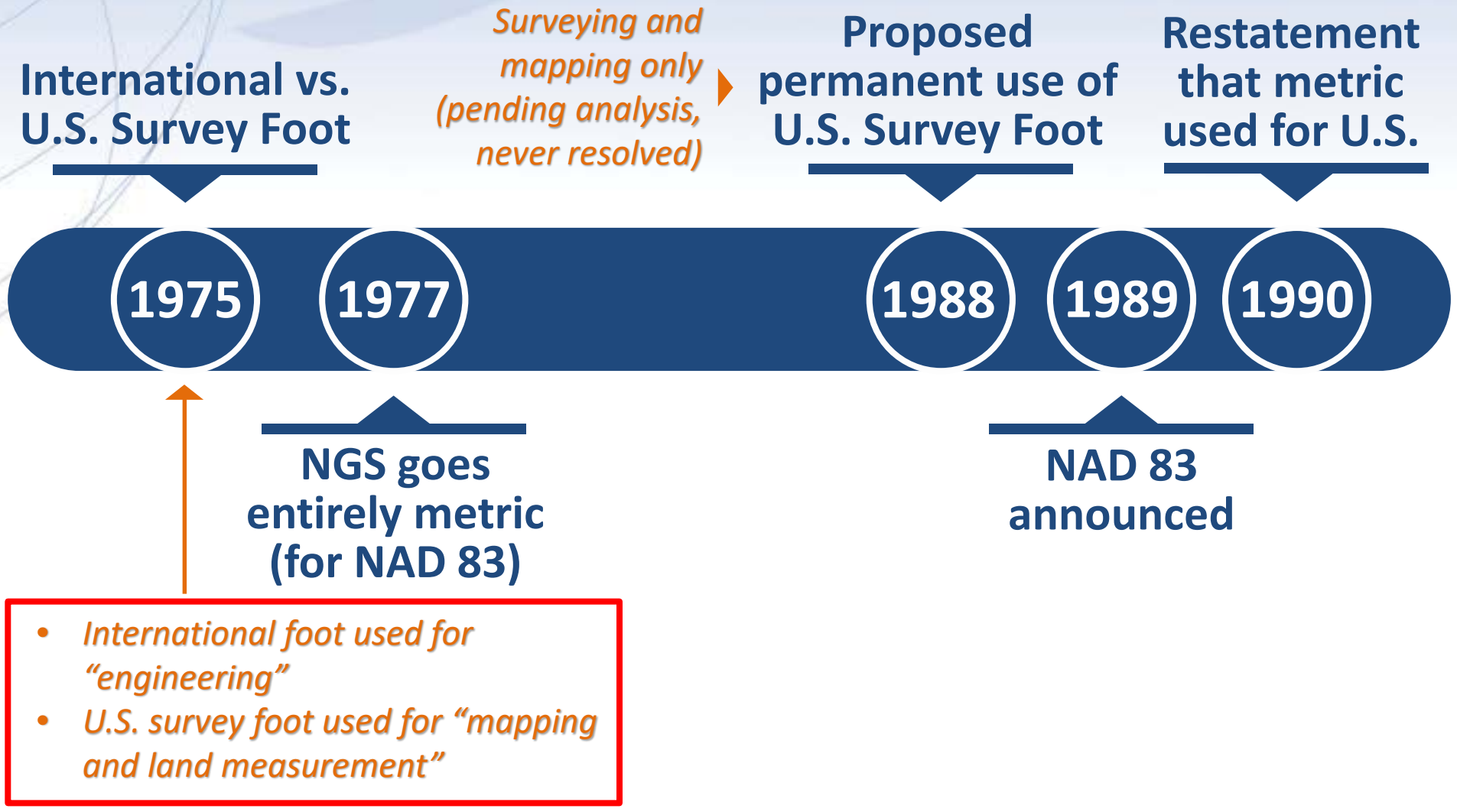
1 foot = 1200/3937 meter

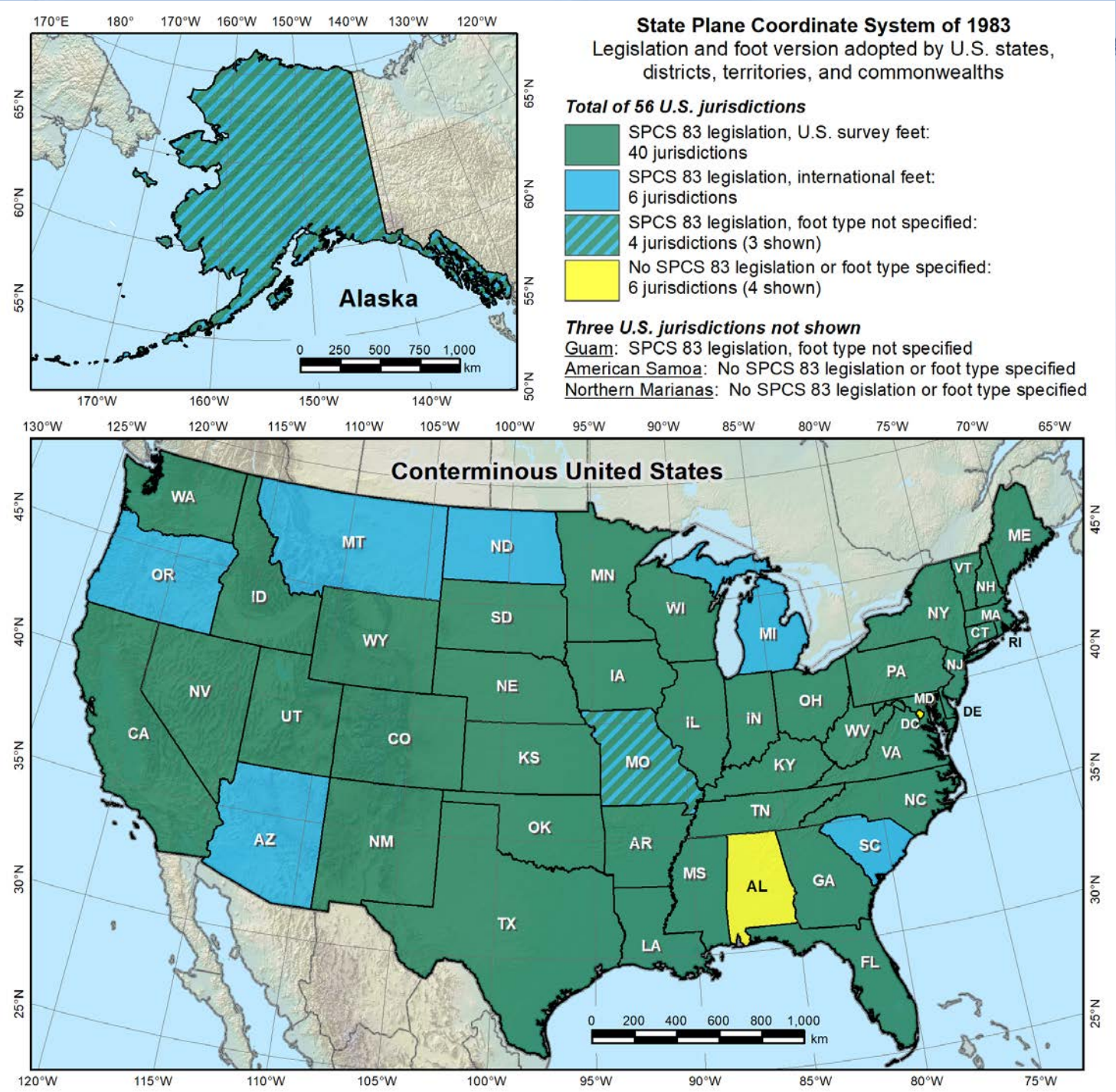
The foot unit defined by this equation shall be referred to as the **U.S. Survey Foot** and it shall continue to be used, for the purpose given herein, **until such a time as it becomes desirable and expedient to readjust the basic geodetic survey networks in the United States, after which the ratio of a yard, equal to 0.9144 meter, *shall apply***."

https://geodesy.noaa.gov/PUBS_LIB/FedRegister/FRdoc59-5442.pdf

Signed by NBS and C&GS directors, approved by Secretary of Commerce, June 25, 1959

# More Federal Register Notices




State Plane Coordinate System of 1983
Legislation and foot version adopted by U.S. states, districts, territories, and commonwealths
Total of 56 U.S. jurisdictions
SPCS 83 legislation, U.S. survey feet: 40 jurisdictions
SPCS 83 legislation, international feet: 6 jurisdictions
SPCS 83 legislation, foot type not specified: 4 jurisdictions (3 shown)
No SPCS 83 legislation or foot type specified: 6 jurisdictions (4 shown)
Three U.S. jurisdictions not shown
Guam: SPCS 83 legislation, foot type not specified
American Samoa: No SPCS 83 legislation or foot type specified
Northern Marianas: No SPCS 83 legislation or foot type specified
Alaska
0 250 500 750 1,000 km
Conterminous United States
WA OR CA ID NV MT WY UT AZ CO NM ND SD NE KS OK TX MN IA MO AR LA WI IL MI IN OH KY TN MS AL GA FL SC NC VA WV PA NY MD DE NJ CT RI MA VT NH ME DC
0 200 400 600 800 1,000 km

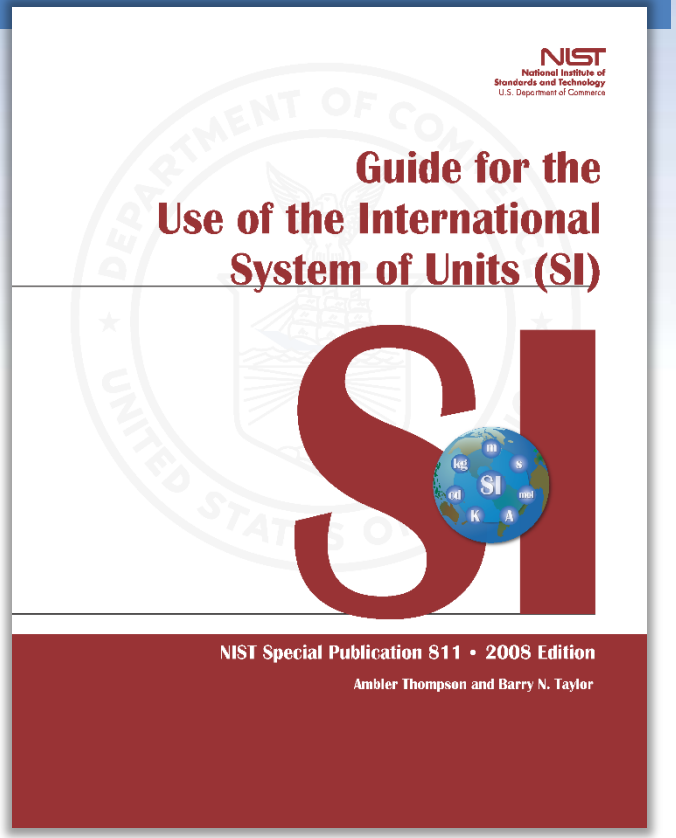
# Out of order, *chaos*

## A foot still in limbo

**2008 -** NIST "Guide to the Use of the SI"

- U.S. survey foot *still used*
  - but never **officially** permanently adopted
- Repeats 1975 FRN ideas about the two feet:
  - International ft used for ***engineering***
  - U.S. ft used for ***surveying & mapping***

***At odds with very idea of "standards"***



# *Oops!*

- Problem created and perpetuated by NGS
- In 1959. Then in 1986. And again in 2016…

**Template Draft NSRS Legislation**

II. The <state> Plane Coordinate System

When the values are expressed in feet, the <define which foot to be used. Either "U.S. Survey foot," (one U.S. Survey foot = 1200/3937 meters) or "International foot," (one International foot = 0.3048 meters)> shall be used as the standard foot for *PCS

# What are the choices?

- **Do nothing** (i.e., NGS stays "metric" only)
  - States choose whatever foot they want
  - The feet will creep back into NGS products & services
- **Officially adopt U.S. survey foot for specific things**
  - U.S. survey foot for surveying and mapping
  - International foot for engineering (and everything else)
- **Use international foot for everything**
  - Support only foot = 0.3048 meter after 2022, period
- **Use U.S. survey foot for everything** (highly unlikely)
- **Go entirely metric** (ideal situation, but also unlikely)

# An NGS proposal

- **Only one foot after 2022 (1 foot = 0.3048 meter)**
  - Make official through NIST
  - ***NO*** option for U.S. survey foot
- **NGS will help with the transition**
  - Will fully support backward compatibility
  - Use "correct" foot for SPCS 83 and SPCS 27
  - Automatically done by NGS products and services
- **Guiding ideas**
  - Of all changes in 2022, this is the least significant
  - About the ***future***, not the past

# Arguments for keeping "old" foot

- **Used for existing records and data**
  - Circular argument because issue never goes away
  - Such logic means old foot will always be retained
  - That's how we got into this mess in the first place
- **Old foot in state legislation**
  - But statute is usually (always?) tied to NAD 83
  - ***New statute for 2022 could break that connection***
- **Necessary to convey real property…**

# Coordinates, deeds, and distances

- Foot issue is a **coordinate** problem
- Deeds are concerned with **distances**
- Bigger issues with distances than type of foot
  - *U.S. survey vs. int'l foot:* 2 ppm = **±0.01 ft per mile**
    - "Standard" foot varied by tens of ppm before 1893

# In closing…

- **This is about the *future***
  - NSRS Modernization will bring many other changes
  - Can we foster a more organized future for the next generation of younger professionals?

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

-use any major search engine: "NGS advisors"

**Jeff Jalbrzikowski, P.S., GISP**

**Appalachian Regional Geodetic Advisor**

**jeff.jalbrzikowski@noaa.gov**

**240-988-5486**