Updates from NGS: Improvements to OPUS Projects and Updates on the National Spatial Reference System

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ISPLS 2023 Convention

My Background

- Great Lakes Regional Geodetic Advisor (IN, IL, WI, MI)
- Previously at NGS Headquarters Geosciences Research Division

- B.S. Surveying Engineering at Michigan Tech
- Ph.D. in Geodetic Science at The Ohio State University
- Professional Surveyor (MI)

Regional Geodetic Advisor Program

Deprecation of the US Survey Foot

- U.S. survey foot was deprecated on December 31, 2022
- But use can continue for SPCS 83 (and SPCS 27)
  - The 40 states that "officially" use U.S. foot for SPCS 83
  - All SPCS 27 zones
  - NGS will support such "legacy" use forever
  - But ***NOT*** supported for ***ANY*** zones in SPCS2022

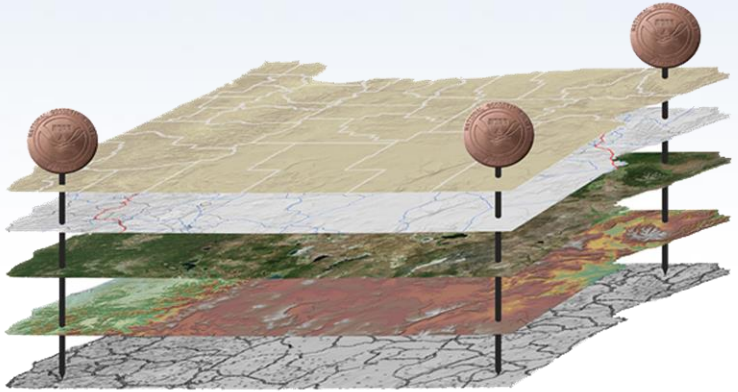
NGS will always support
U.S. survey foot for SPCS 83 and 27

NSRS MODERNIZATION STATUS AND UPDATES

The National Spatial Reference System (NSRS)

NGS defines, maintains and provides access to the NSRS to meet our Nation's economic, social & environmental needs

Latitude • Longitude • Elevation
• Gravity • Shoreline Position
+ changes over time



Today's NSRS

- North American Datum of 1983 **(NAD 83)**
- North American Vertical Datum of 1988 **(NAVD 88)**

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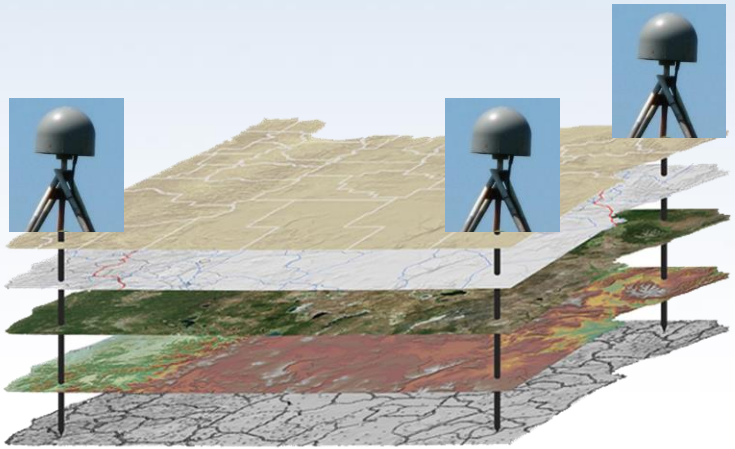
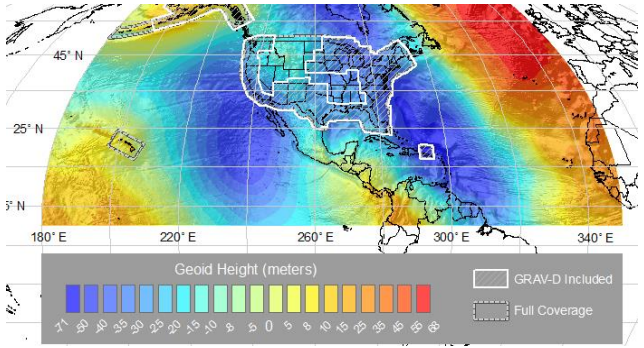


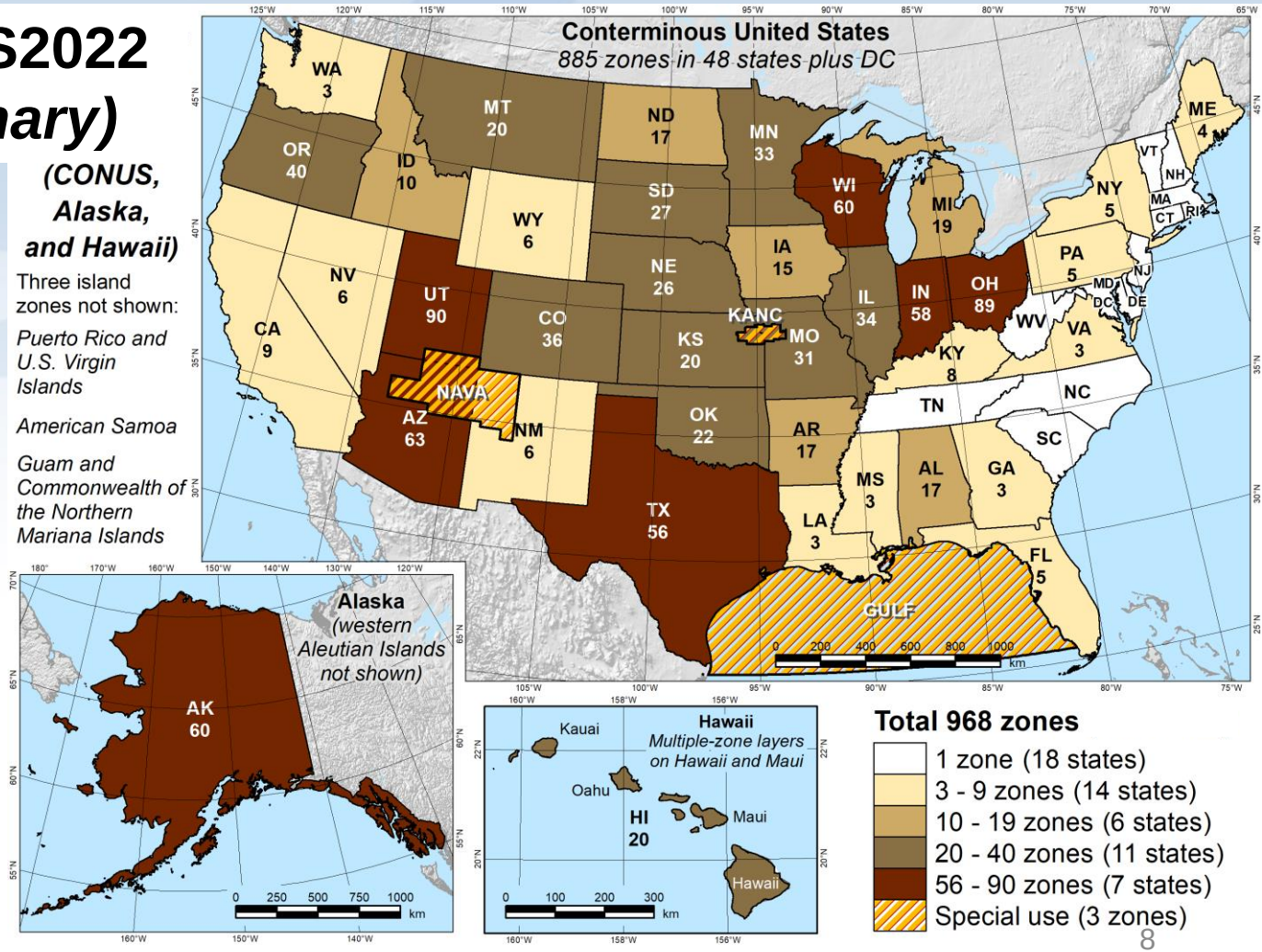
North American Terrestrial Reference Frame (NATRF2022)
Caribbean Terrestrial Reference Frame (CATRF2022)
Pacific Terrestrial Reference Frame (PATRF2022)
Marianas Terrestrial Reference Frame (MATRF2022)



North America and Pacific Geopotential Datum (NAPGD2022)

Number of SPCS2022 zones *(preliminary)*

- 968 total zones nationwide
- Indiana has 2 zone layers:
  - A statewide zone
  - 57 LDP zones

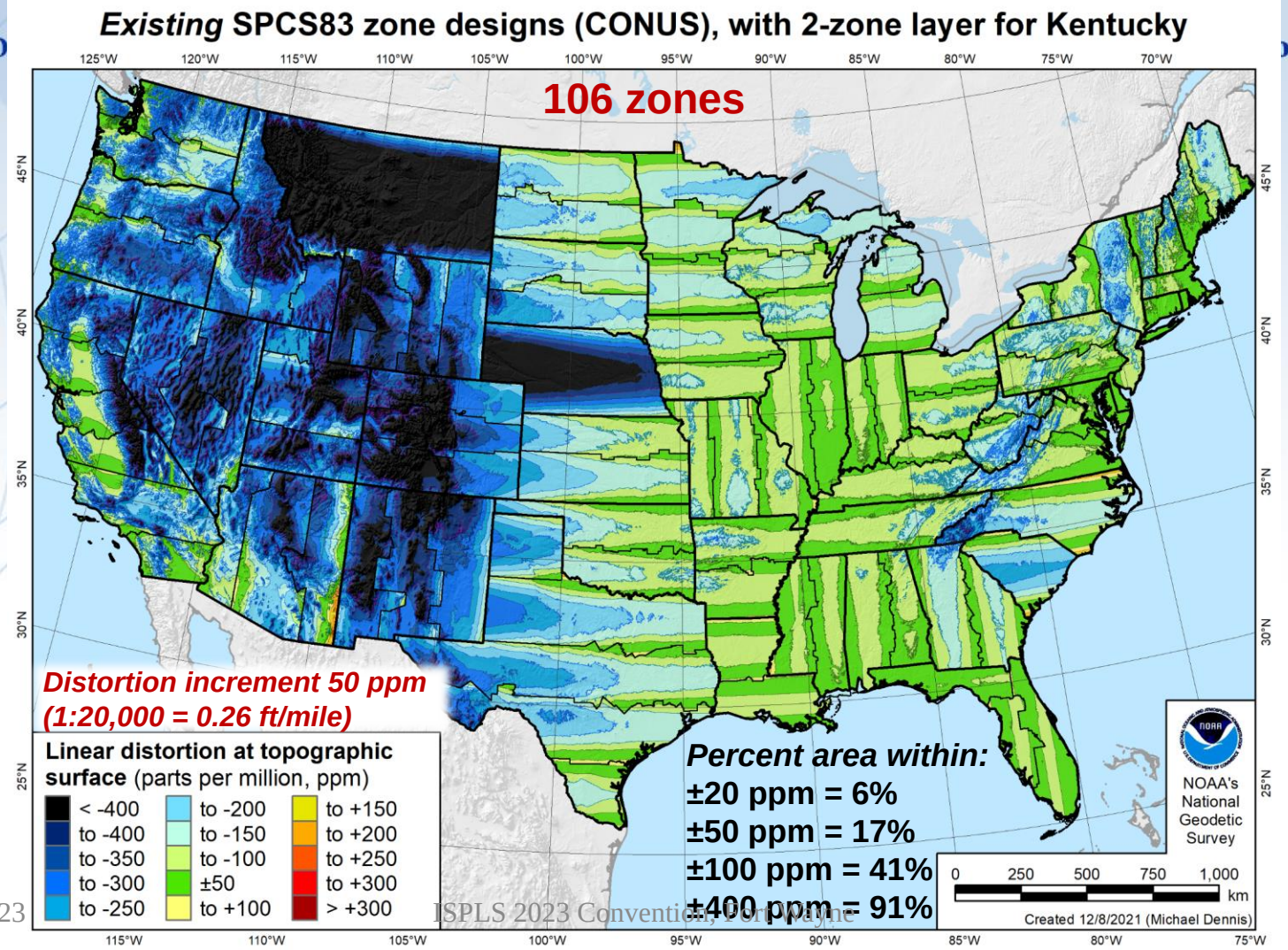


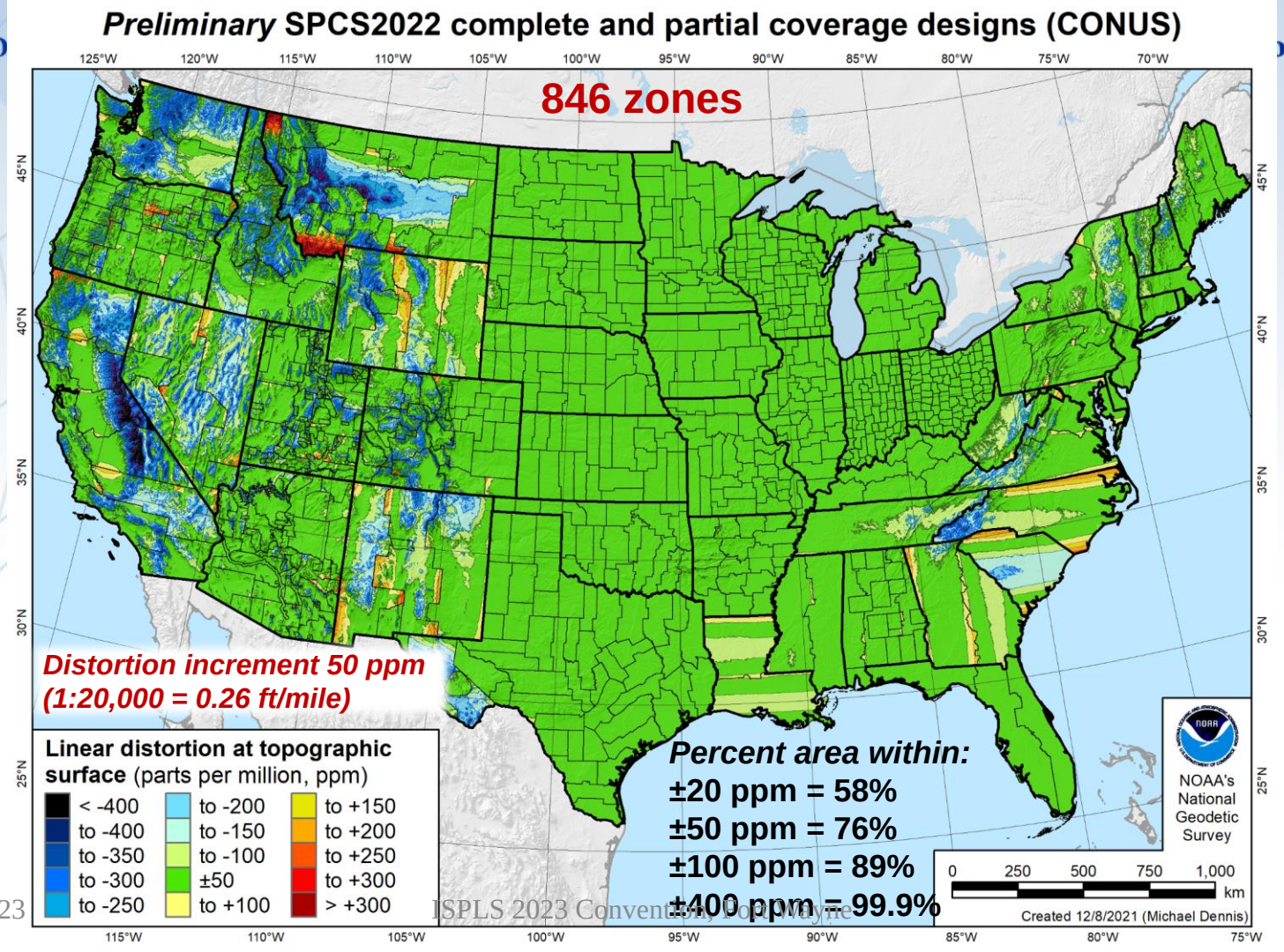
Getting acquainted with SPCS2022

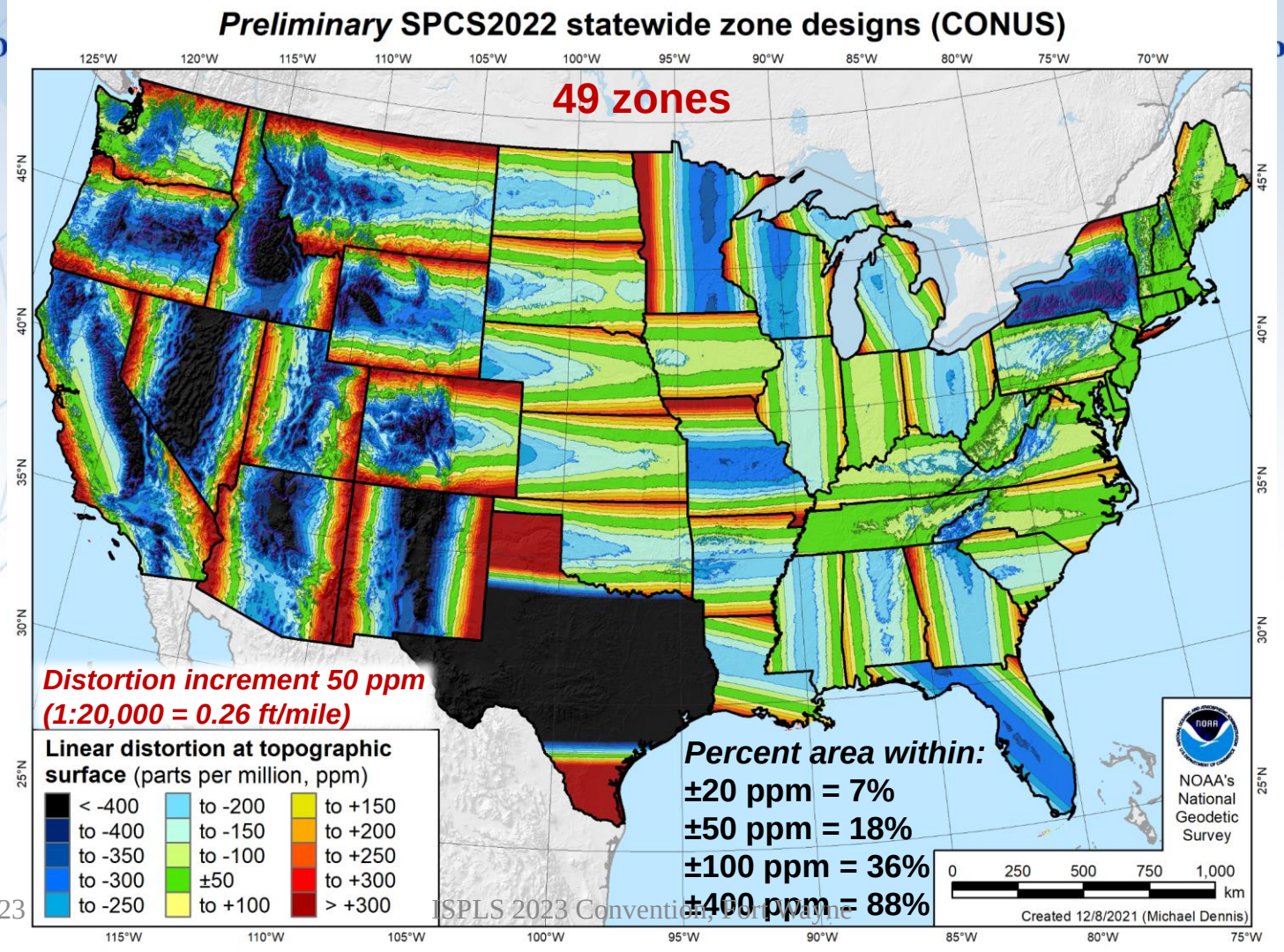
- **Distortion design philosophy**
  - ***Linear distortion*** minimized at topographic surface (***not*** at ellipsoid surface)
  - ***Purpose:*** to reduce difference between projected "grid" and actual "ground" distances
- **Other things:**
  - Zone "layers"
  - Low distortion projections (LDPs)
  - Indiana designs approved by NGS in October 2022
  - Will be implemented with the Modernized (2022) NSRS

Linear distortion magnitudes

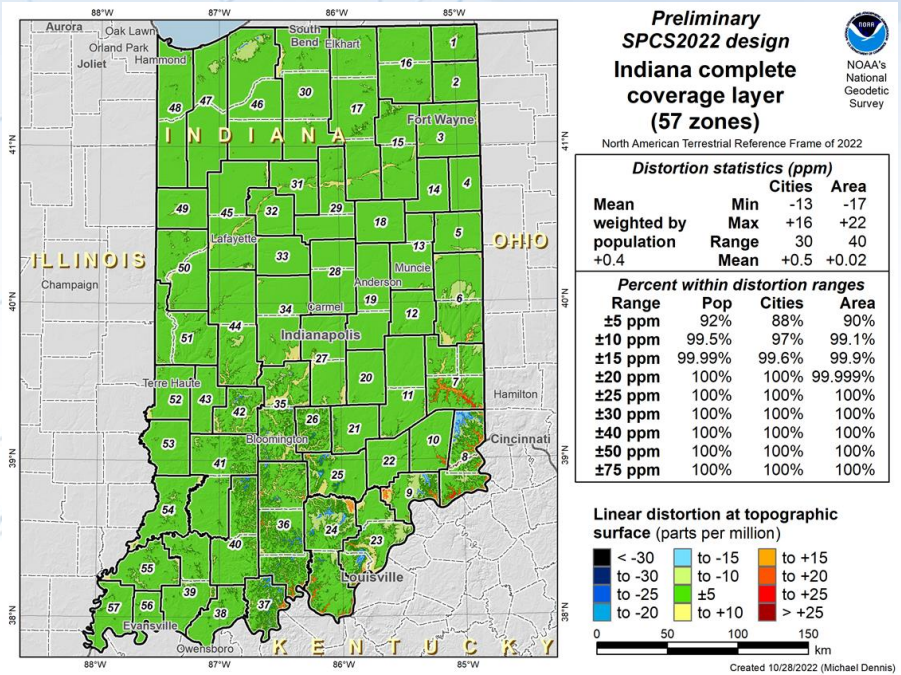
Parts per million	Centimeters per kilometer	Feet per mile	Dimensionless ratio
20 ppm	2 cm/km	0.1 ft/mile	1:50,000
50 ppm	5 cm/km	0.3 ft/mile	1:20,000
100 ppm	10 cm/km	0.5 ft/mile	1:10,000
400 ppm	40 cm/km	2.1 ft/mile	1:2,500

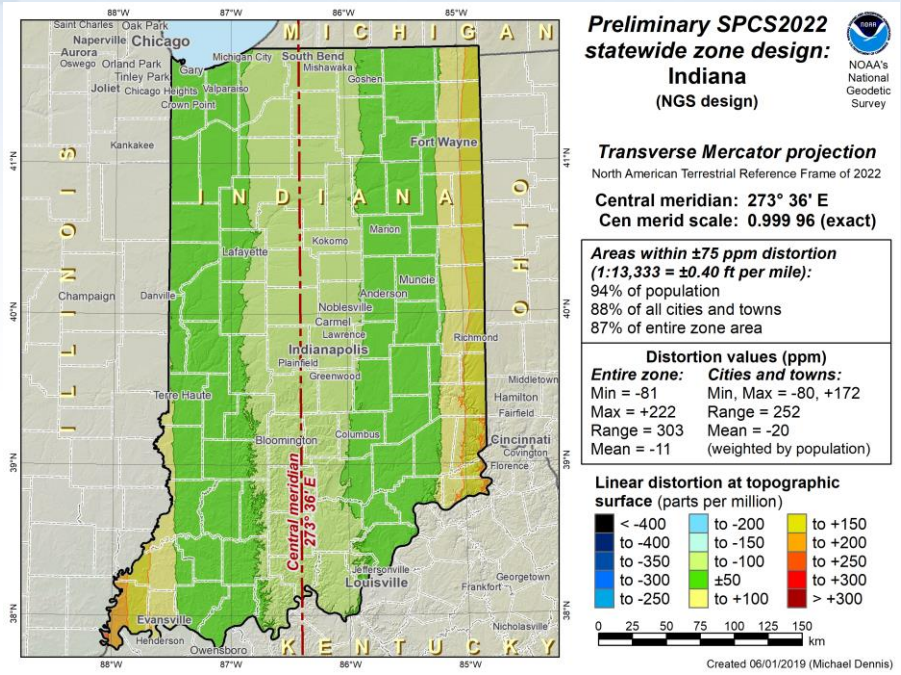

Existing SPCS83 zone designs (CONUS), with 2-zone layer for Kentucky
106 zones
Distortion increment 50 ppm
(1:20,000 = 0.26 ft/mile)
Linear distortion at topographic surface (parts per million, ppm)
< -400
to -400
to -350
to -300
to -250
to -200
to -150
to -100
±50
to +100
to +150
to +200
to +250
to +300
> +300
Percent area within:
±20 ppm = 6%
±50 ppm = 17%
±100 ppm = 41%
±400 ppm = 91%
NOAA's National Geodetic Survey
0 250 500 750 1,000 km
Created 12/8/2021 (Michael Dennis)


Preliminary SPCS2022 complete and partial coverage designs (CONUS)
846 zones
Distortion increment 50 ppm
(1:20,000 = 0.26 ft/mile)
Linear distortion at topographic surface (parts per million, ppm)
< -400
to -400
to -350
to -300
to -250
to -200
to -150
to -100
±50
to +100
to +150
to +200
to +250
to +300
> +300
Percent area within:
±20 ppm = 58%
±50 ppm = 76%
±100 ppm = 89%
±400 ppm = 99.9%
NOAA's National Geodetic Survey
0 250 500 750 1,000 km
Created 12/8/2021 (Michael Dennis)


Preliminary SPCS2022 statewide zone designs (CONUS)
49 zones
Distortion increment 50 ppm
(1:20,000 = 0.26 ft/mile)
Linear distortion at topographic surface (parts per million, ppm)
< -400
to -400
to -350
to -300
to -250
to -200
to -150
to -100
±50
to +100
to +150
to +200
to +250
to +300
> +300
Percent area within:
±20 ppm = 7%
±50 ppm = 18%
±100 ppm = 36%
±400 ppm = 88%
NOAA's National Geodetic Survey
0 250 500 750 1,000 km
Created 12/8/2021 (Michael Dennis)

Indiana SPCS2022 Layers





What to expect for SPCS2022

- **Coordinates will change by at least 10,000 m**
  - Latitude and longitude change about 1-2 m
  - Rest of change due to projection definition
- **Less difference between "grid" and "ground"**
- **More than one zone layer in most states**
  - Zones will be similar to SPCS 83 in some states
  - Zones will be very different in most states
- **Every state will have a statewide zone layer**

SPCS2022 summary

- Minimize distortion at ***topo surface***, *not* ellipsoid
- Up to ***3 zone "layers"*** allowed
  - Some layers very similar to existing SPCS 83
  - Some layers very different
- ***Total of 968 zones*** (likely will decrease somewhat):
  - 54 statewide zones
  - 911 zones that cover part of a state
  - 3 special use zones
- Will be implemented along with Modernized NSRS
  - Earlier usage with NAD 83 will not be supported by NGS
  - ***Can change/add/remove zones after modernized NSRS***

Deprecation of the US Survey Foot

- U.S. survey foot was deprecated on December 31, 2022
- But use can continue for SPCS 83 (and SPCS 27)
  - The 40 states that "officially" use U.S. foot for SPCS 83
  - All SPCS 27 zones
  - NGS will support such "legacy" use forever
  - But ***NOT*** supported for ***ANY*** zones in SPCS2022

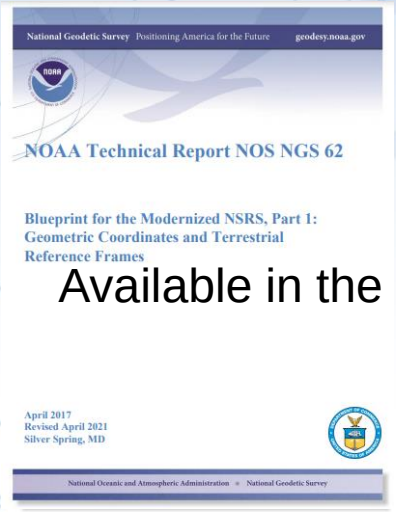
NGS will always support
U.S. survey foot for SPCS 83 and 27

It's the year 2022...

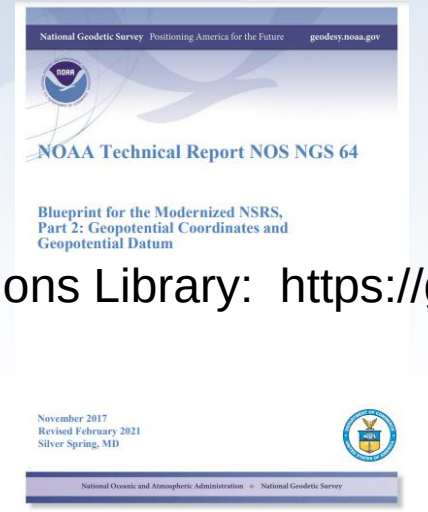
NSRS Modernization: Delay

- **Will names change?**
  - No, "GEOID2022", "NATRF2022", etc. will remain the same
- NGS anticipates the release of all data, and limited tools, by the **middle of 2025**.
  - Some of this may depend on things outside of NGS control (we have already delayed beyond 2022!)
- Work on additional tools will continue in the out-years

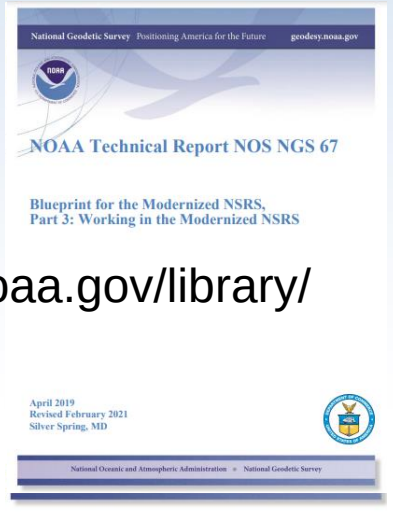
Updated blueprint documents



Geometric:
Sep 2017
Revised April 2021
NOAA TR NOS NGS 62
61 pages



Geopotential:
Nov 2017
Revised Feb 2021
NOAA TR NOS NGS 64
53 pages



Working in the Modernized NSRS:
April 2019
Revised Feb 2021
NOAA TR NOS NGS 67
133 pages

Available in the NGS Publications Library: https://geodesy.noaa.gov/library/

A two-track approach to coordinates

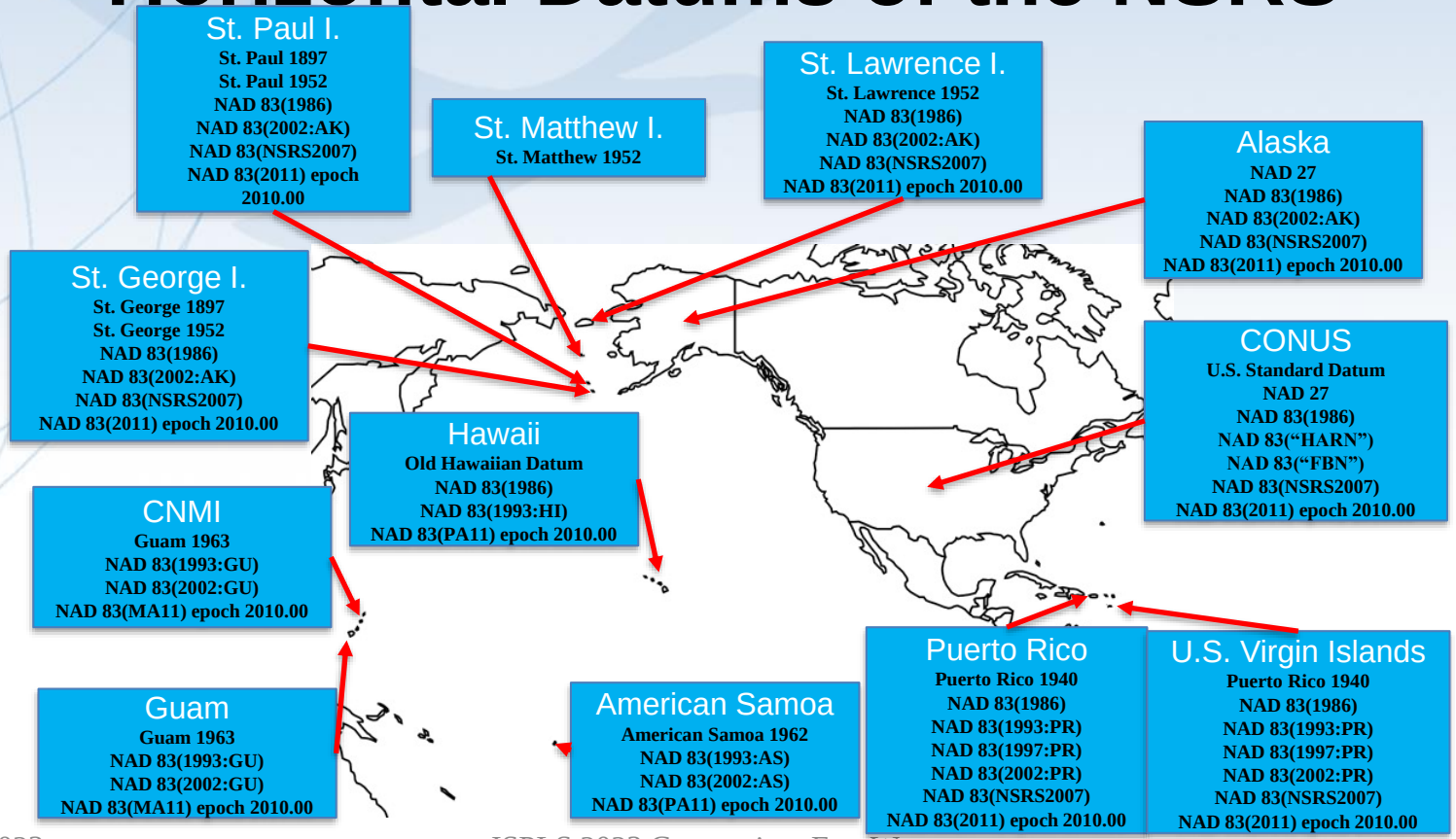
Reference Epoch Coordinates

- An estimated "snapshot" of entire network
- Every 5 or 10 years
- Similar to NAD 83(2011) epoch 2010.00

Survey Epoch Coordinates

- Time-dependent!
- Reflects coordinates at time of observation
- Multiple SECs can show changes over time

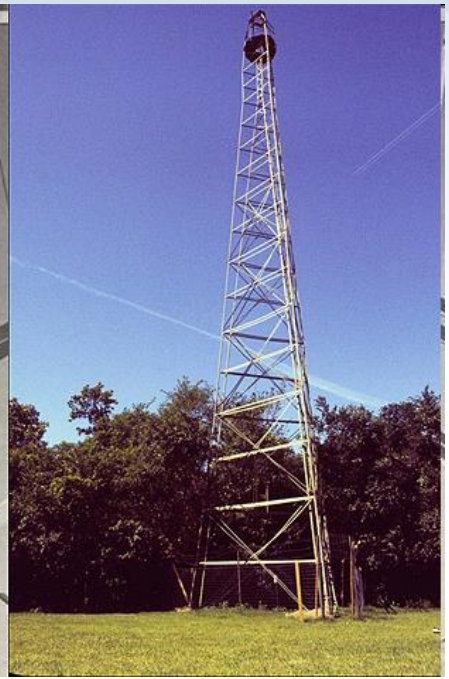
Horizontal Datums of the NSRS



Replacing the NAD 83s

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

Developing previous horizontal datums



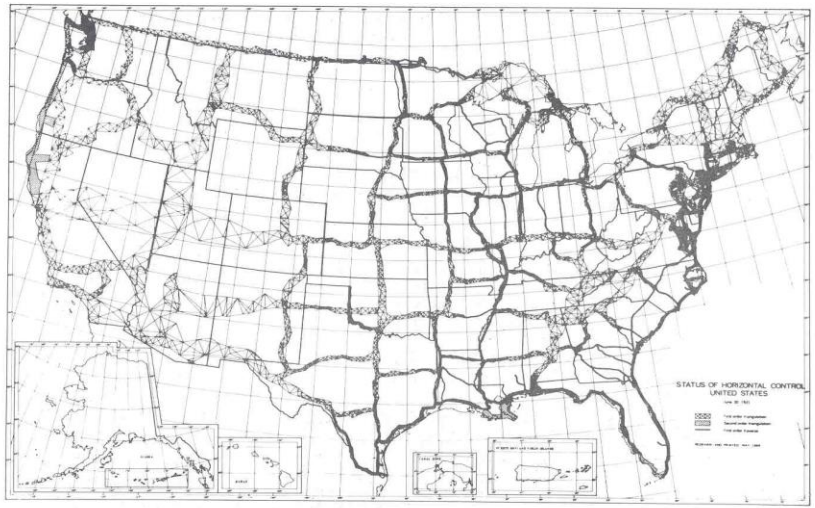
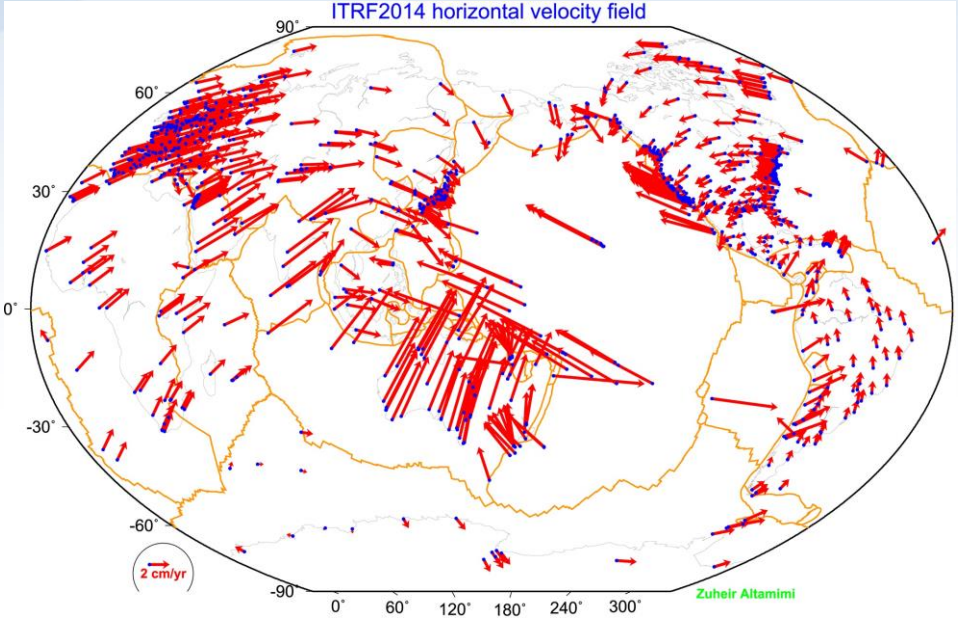


Figure 3

Horizontal Control Network of the United States June 1931

The IGS Reference Frame

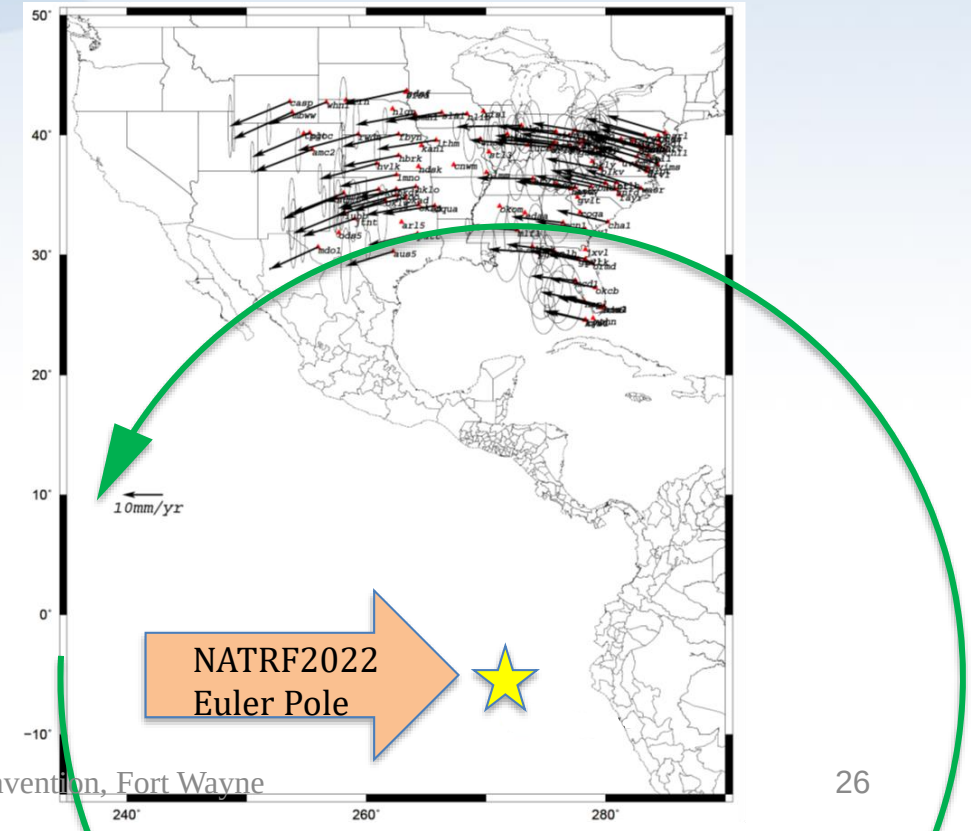
- The ITRF is defined by reference epoch coordinates AND velocities at stations
- The ITRF velocity field very closely resembles absolute plate motion
- The ITRF and IGS frames are both no-net-rotation frames – the sum of the angular velocities is constrained to be zero
- The Modernized (2022) NSRS Reference Frames will tie to ITRF2020



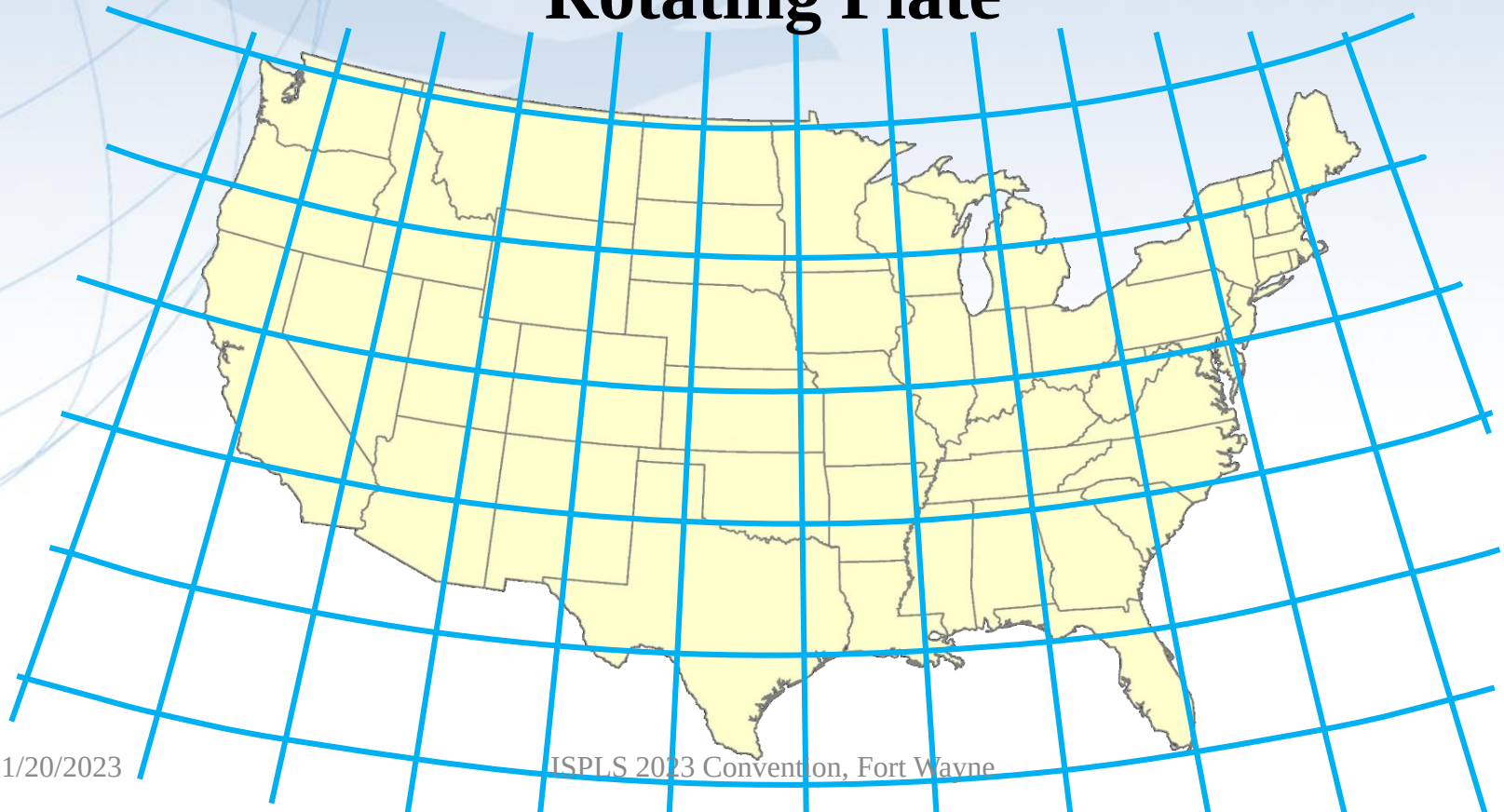
Altamimi et al., 2016, JGR

Euler Poles and "Plate-Fixed"

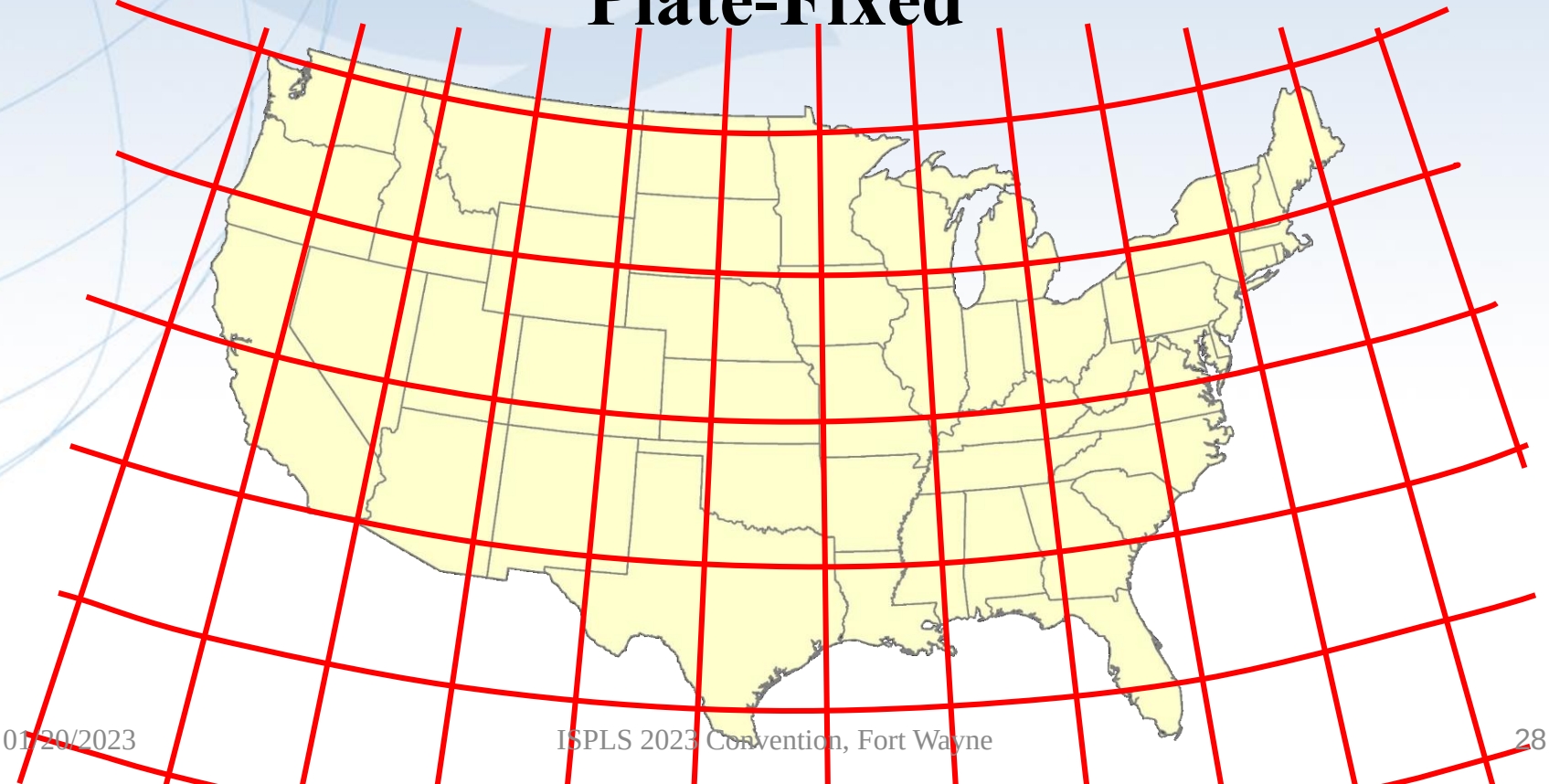
- In the ITRF, many tectonic plates have a *dominant* motion: **rotation**
- **Euler Pole** - point about which a plate rotates (yellow star)
- Euler Pole Parameters (**EPP**) define this rotation
- Residual motion is characterized in an Intra-Frame Deformation Model (**IFDM**)



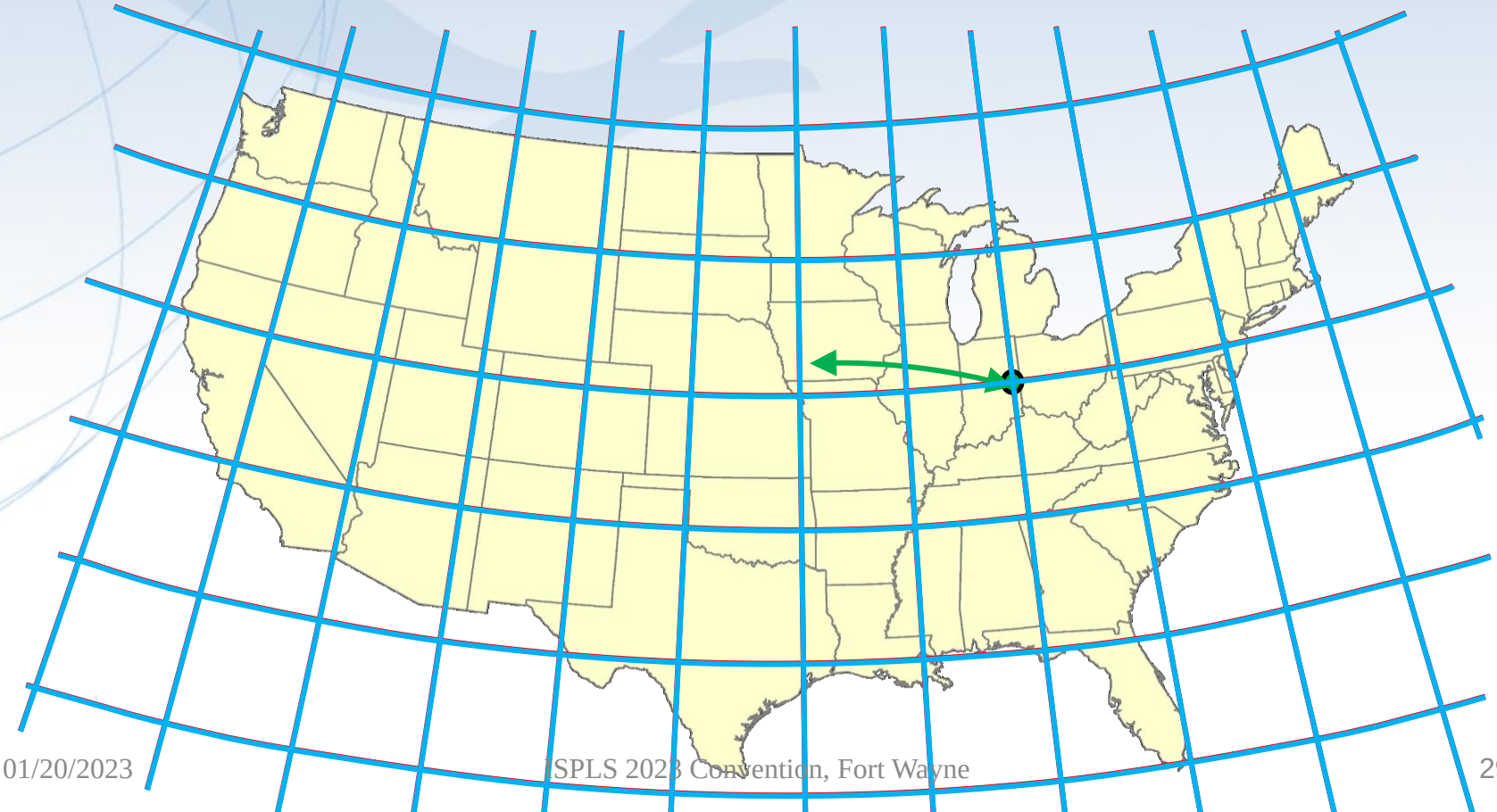
ITRF2020: Constant Frame, Rotating Plate



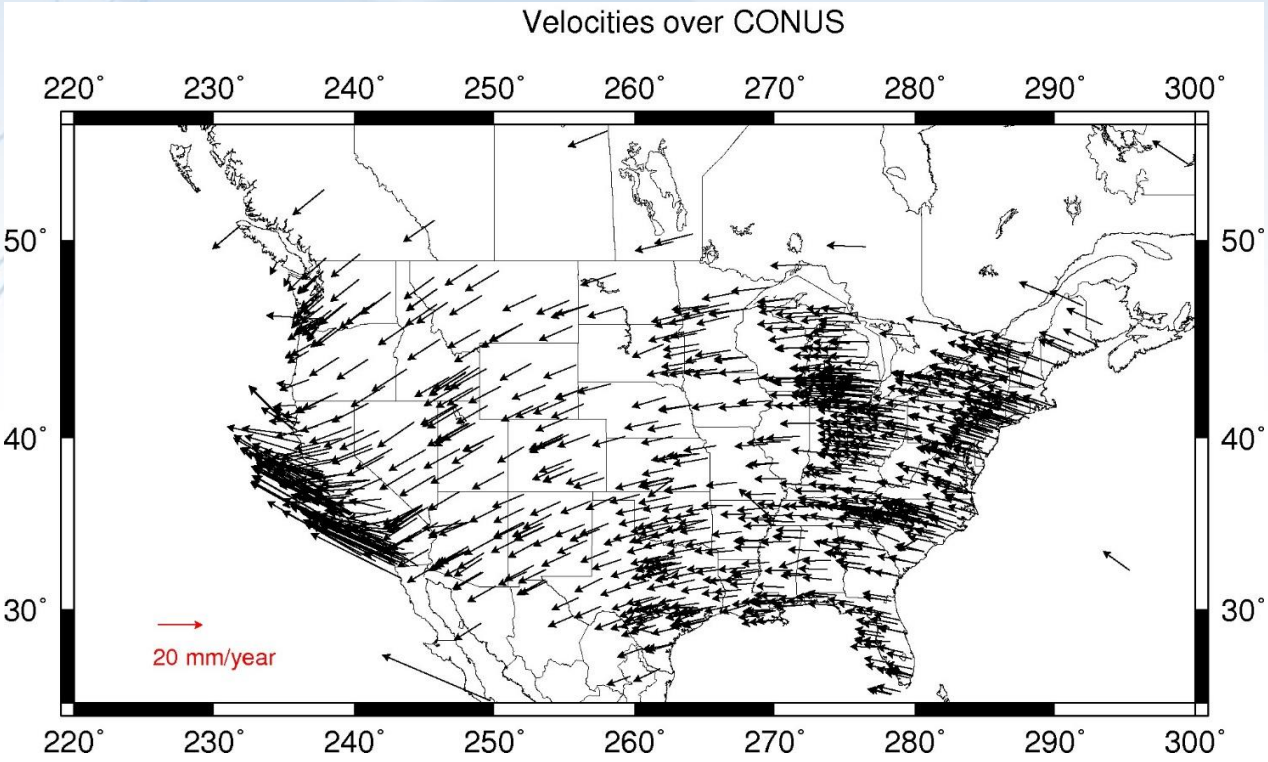
NATRF2022: Constant Frame, Rotating Plate "Plate-Fixed"



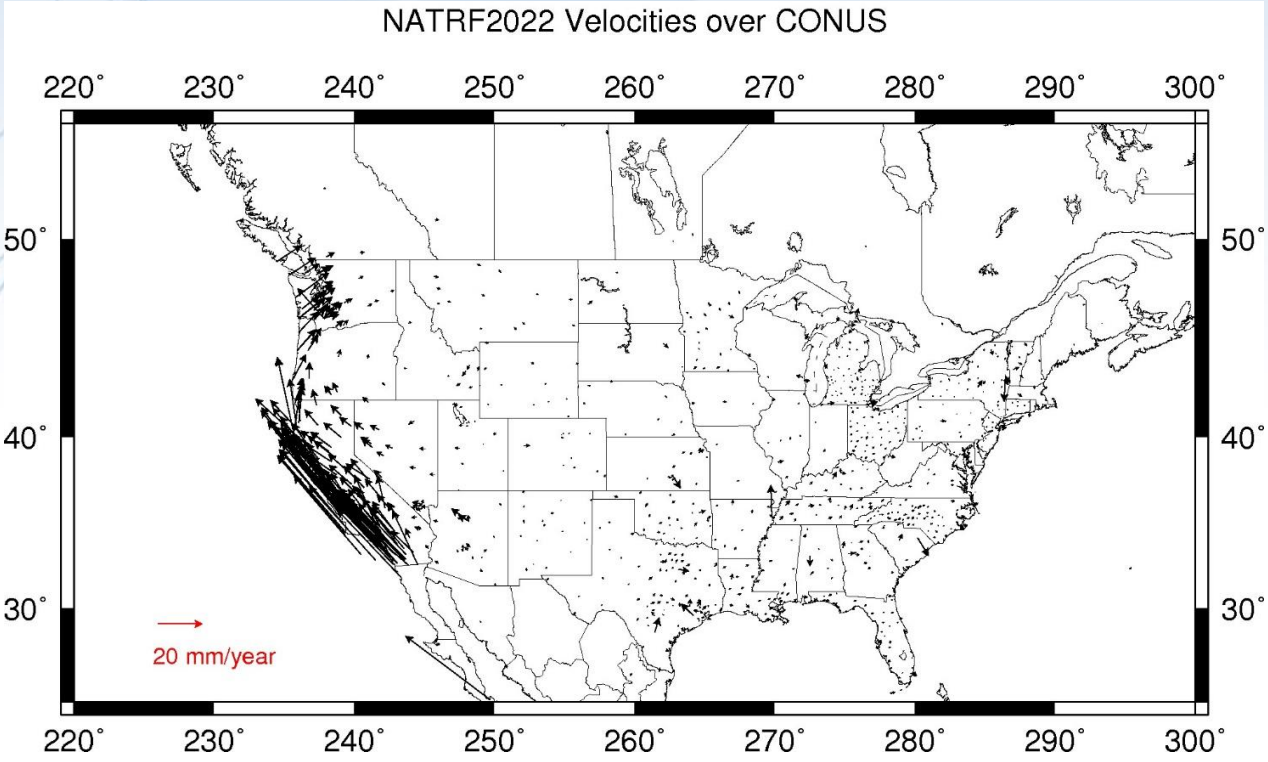
ITRF2020 or NATRF2022



Residual Velocities – ITRF2020/CONUS

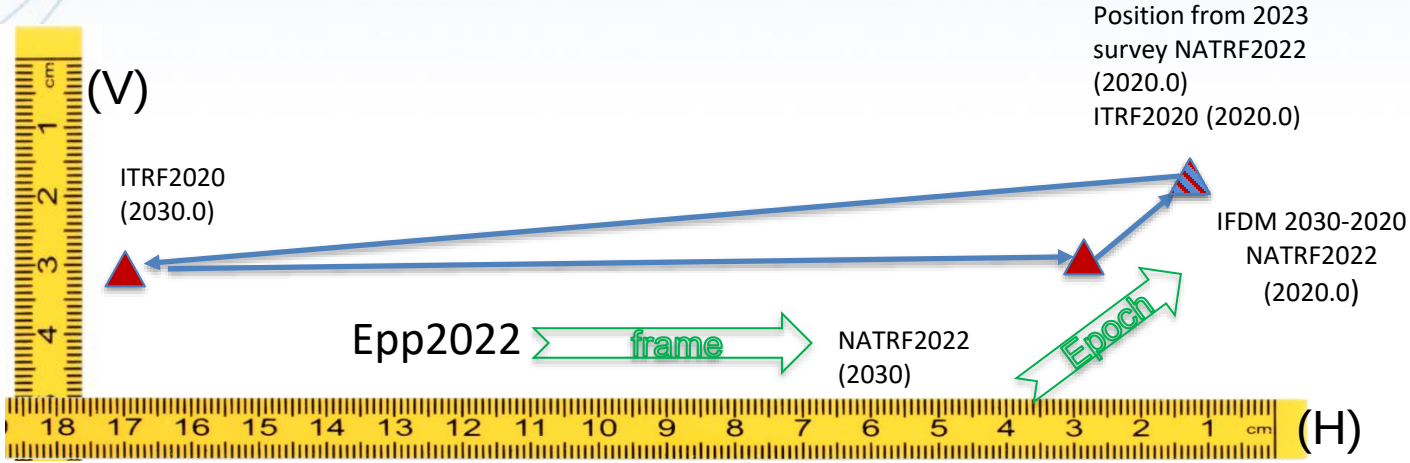


Residual Velocities – NATRF2022/CONUS

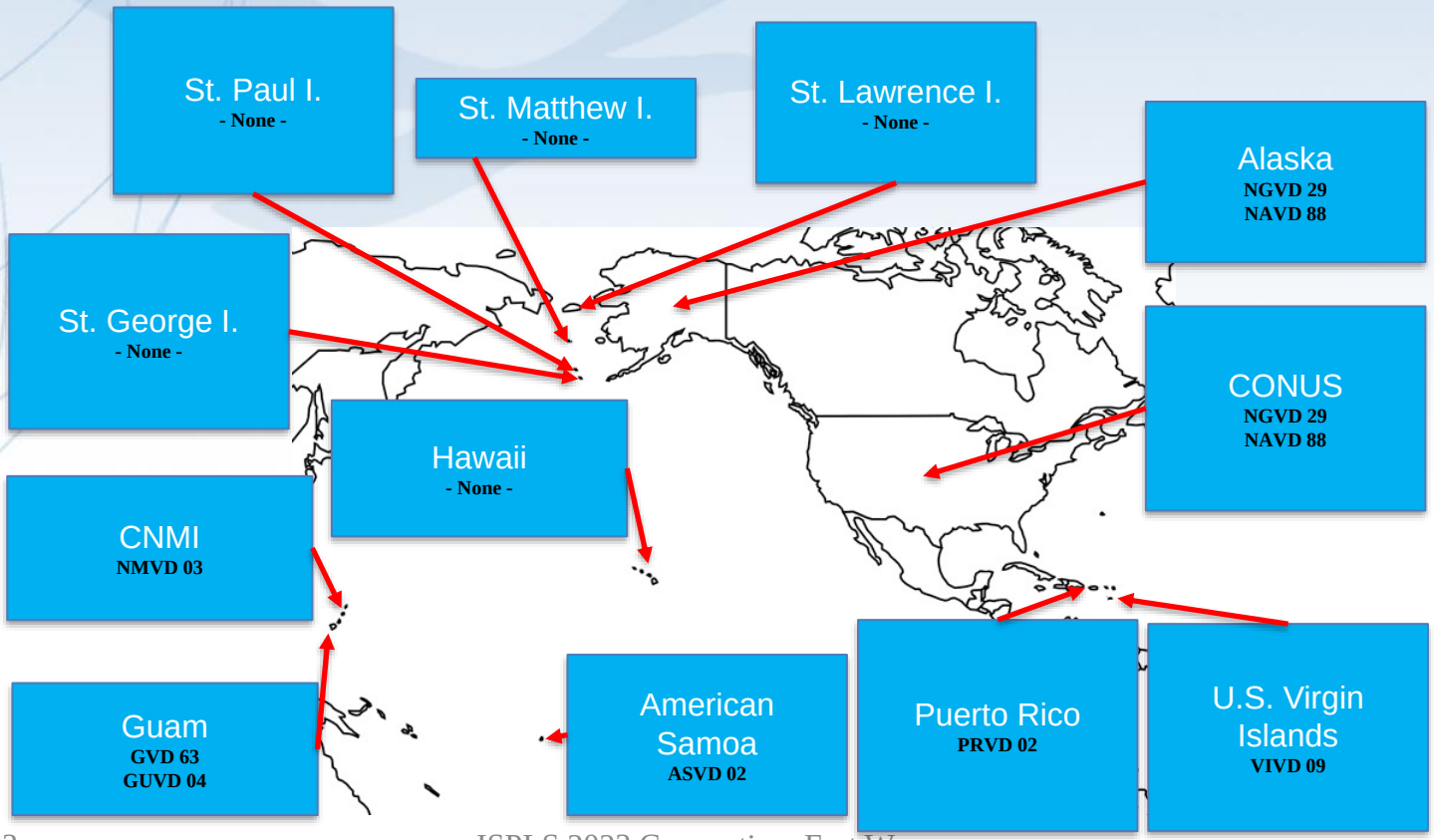


Coordinates, Frames, Epochs, EPP2022 and IFDM2022

1. A survey done Jan 1, 2023 and reported at epoch 2020.0
2. New Survey (same point) done Jan 1, 2030
3. Position of point in NATRF2022(2030)
4. Position of point in NATRF2022(2020)
5. If IFDM = 0, then NATRF2022 (2030) = NATRF2022 (2020)



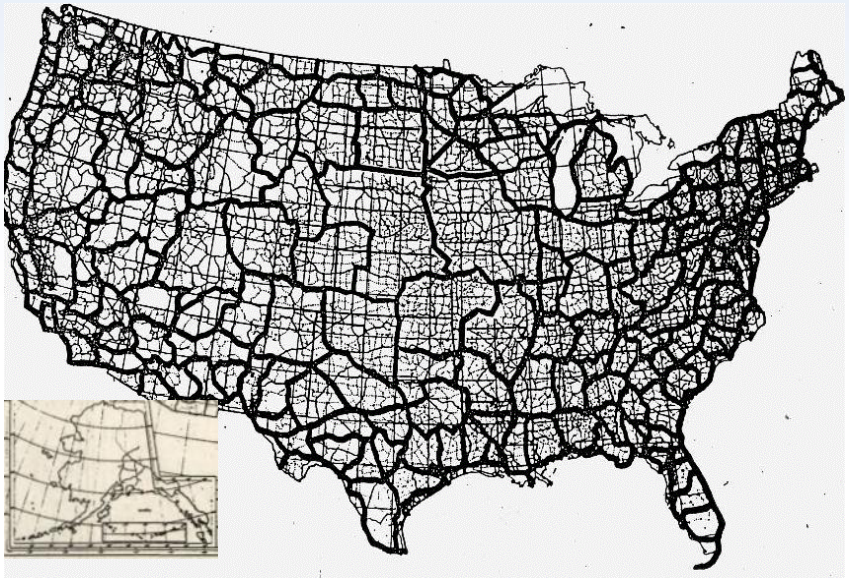
Vertical Datums of the NSRS



Developing the previous vertical datums

NGVD 29

NAVD 88



Leveling

Replacing NAVD 88

	The Old:
Orthometric Heights	NAVD 88
Normal Orthometric Heights	PRVD 02
	VIVD09
	ASVD02
	NMVD03
	GUVD04
Dynamic Heights	IGLD 85
Gravity	IGSN71
Geoid Undulations	GEOID18
Deflections of the Vertical	DEFLEC18

The New:

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

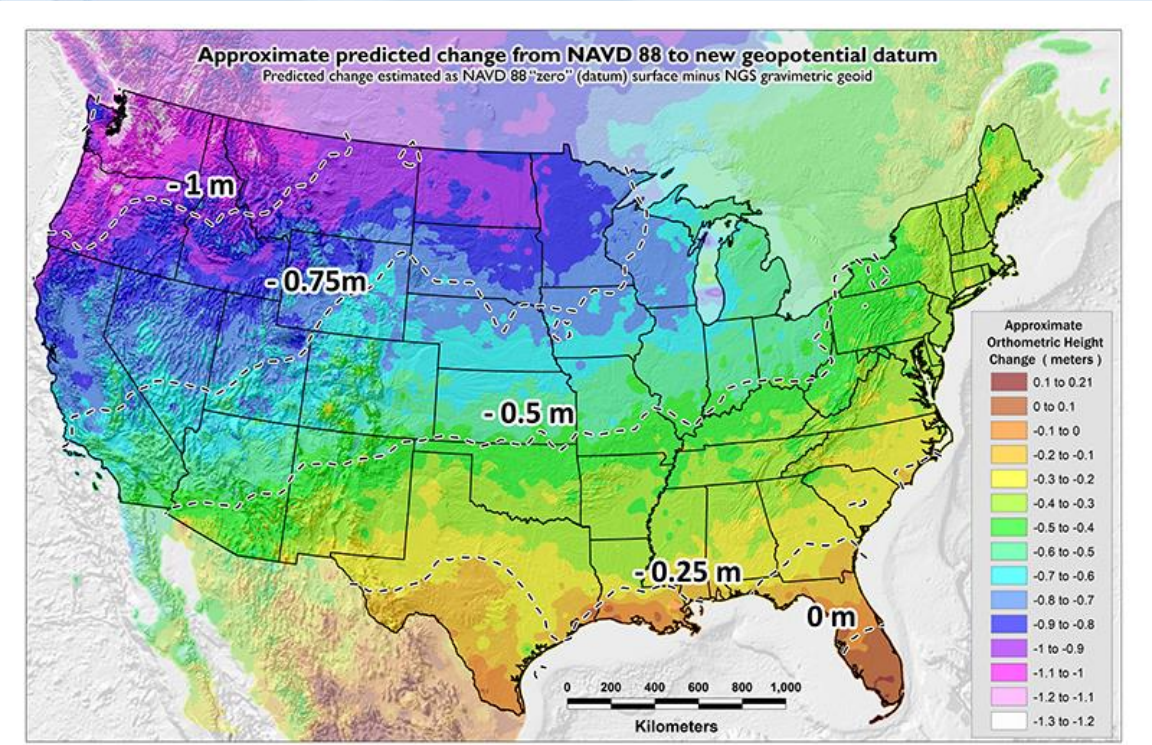
Will include:

- GEOID2022
- DEFLEC2022
- GRAV2022
- DEM2022
- More

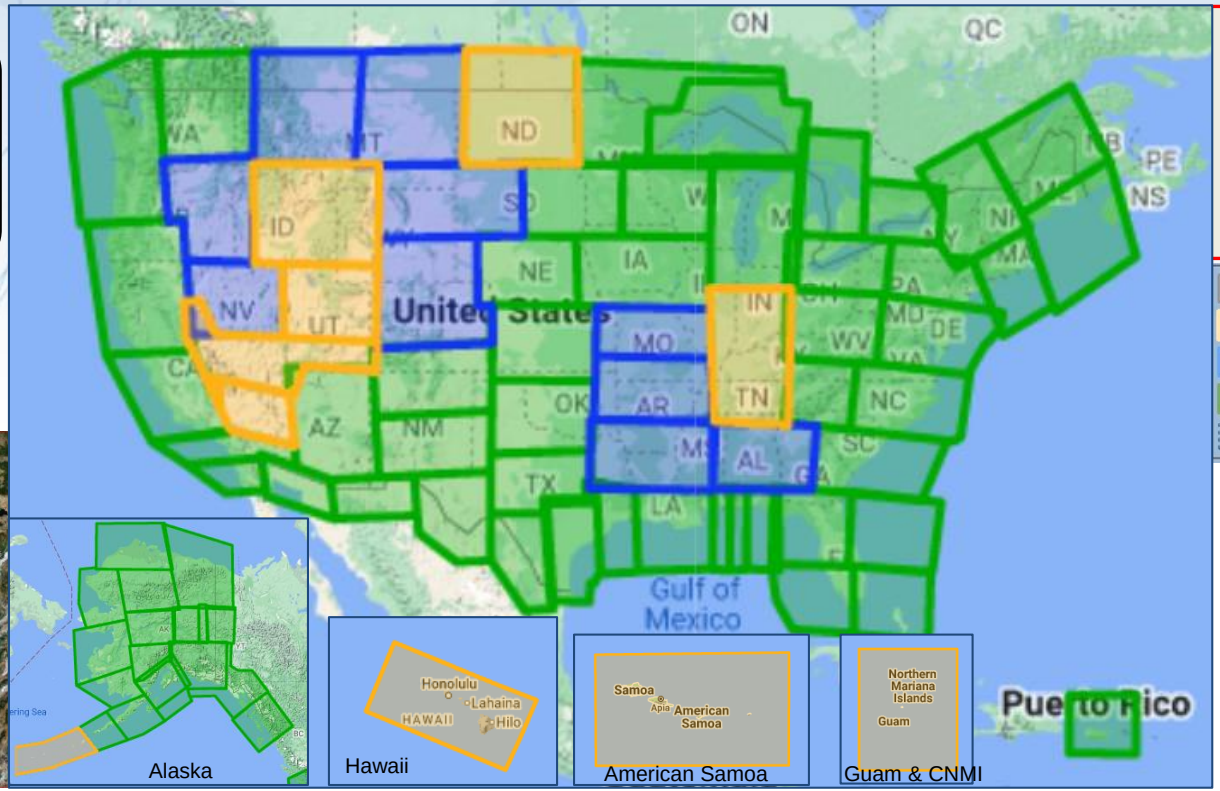
A HUGE component of this effort is GRAV-D:

Gravity for the Redefinition of the American Vertical Datum

NAVD 88 (epoch ?) to NAPGD2022 Epoch 2020.00 (estimate)



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



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

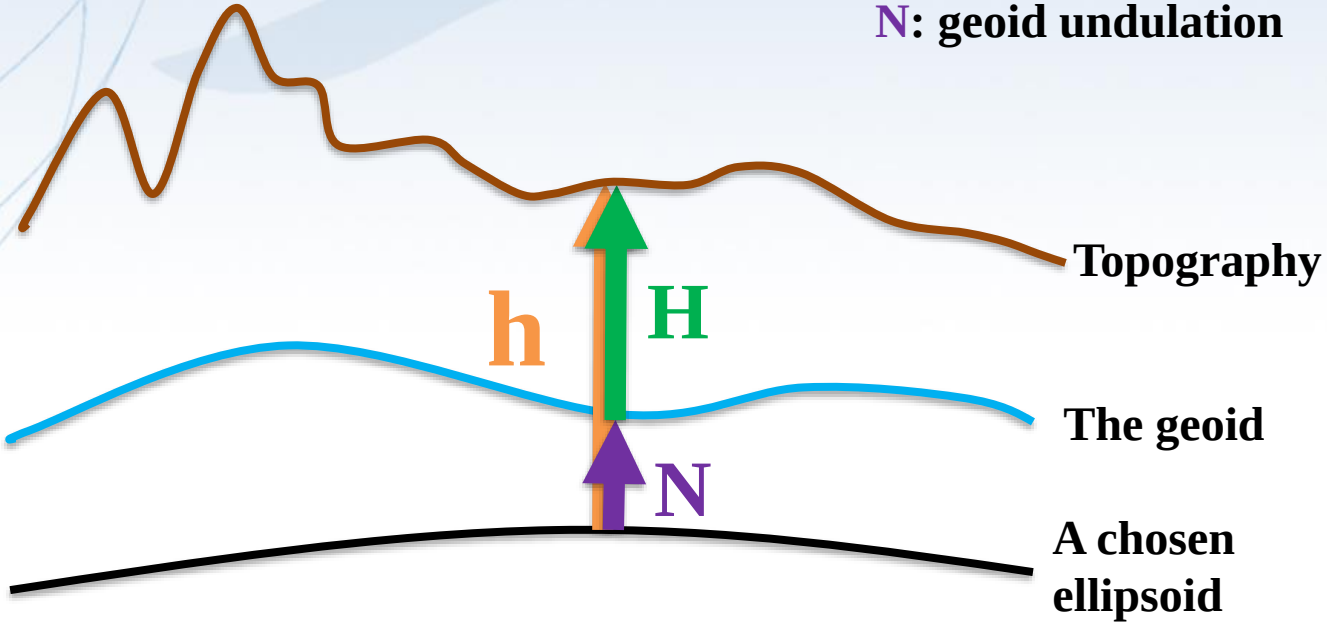
Planned
Partially Collected
Processing
Released
Target Area

Over 96% complete

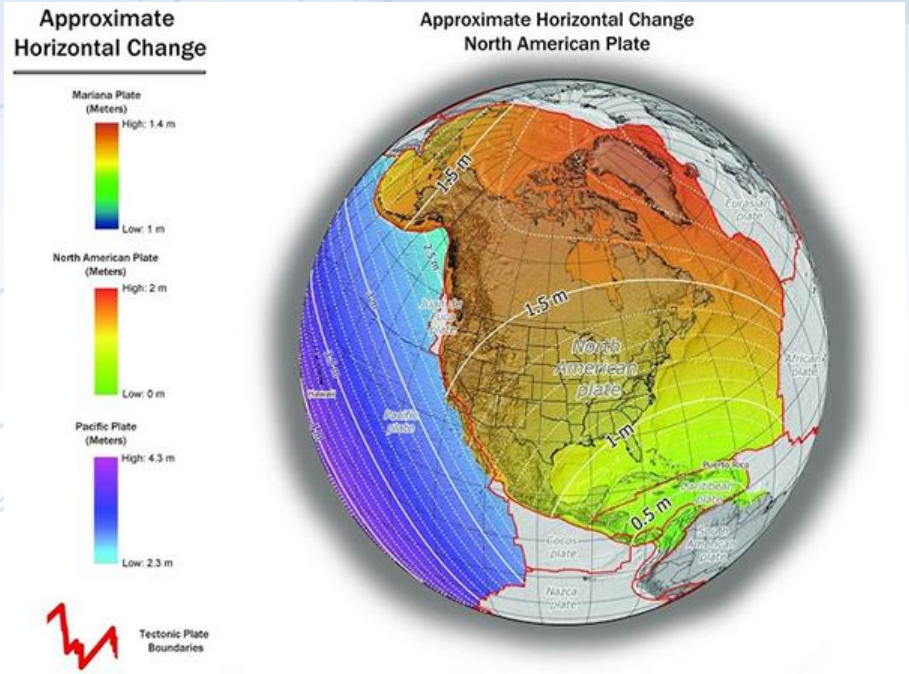
The Geoid, and Heights

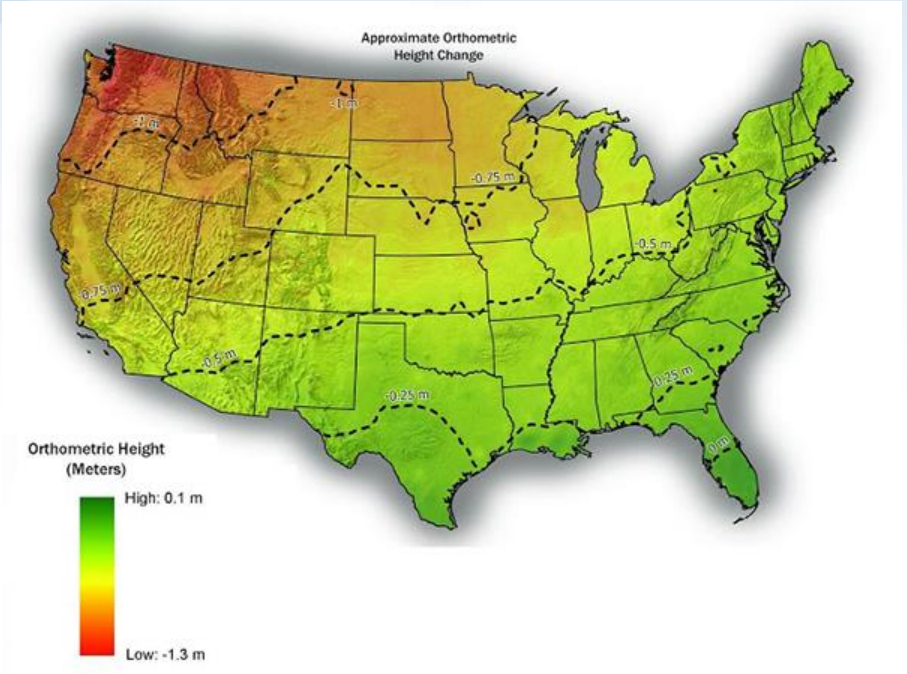
$h = H + N$

h: ellipsoidal height
H: orthometric height
N: geoid undulation

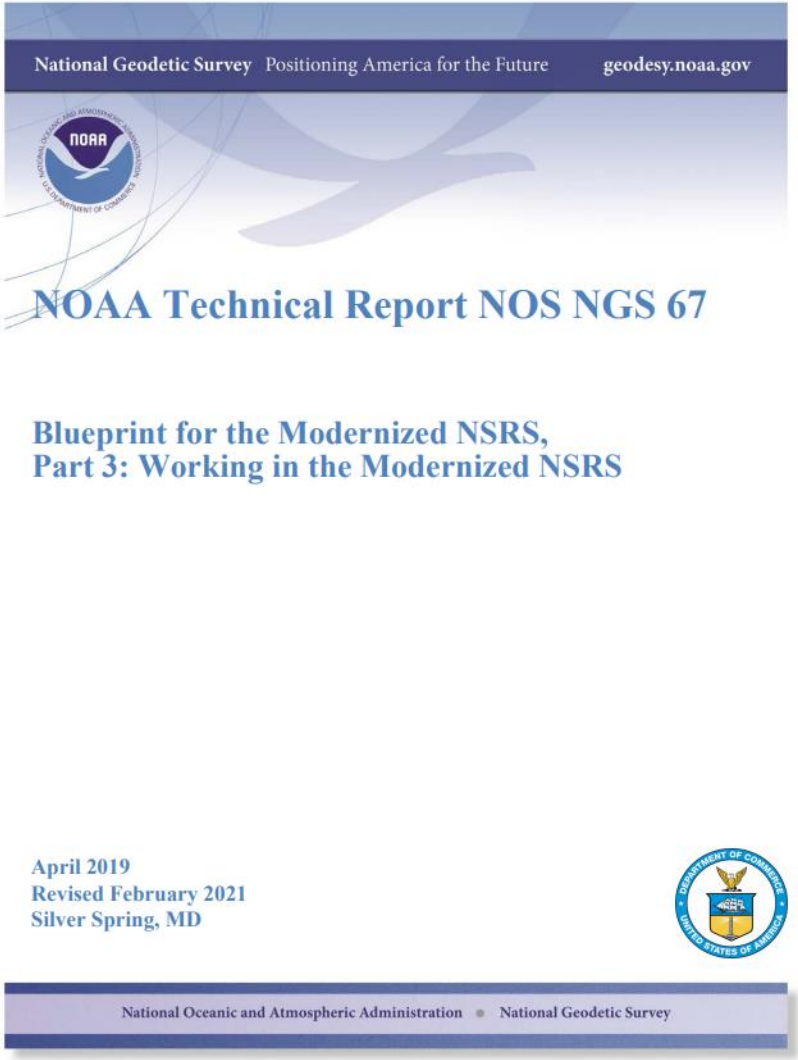


Modernized NSRS: Shift and Drift





NEW TYPES OF COORDINATES



Coordinate: One of a set of N numbers designating the location of a point in N-dimensional space. Specific to the modernized NSRS, five types of coordinates will be supported.

New Types of Coordinates

NGS anticipates that 5 types of coordinates will be used in the NSRS. They are:

Reported
OPUS
Reference Epoch
Survey Epoch
Active

"Part of the NSRS"

- Only coordinates computed by NGS and stored in the NSRS database are *"part of the NSRS"*
  - *Reference Epoch*
  - *Survey Epoch*
  - *Active*
- OPUS Coordinates can be *"tied to the NSRS"*

Passive Control

- Any geodetic control point that is not active control. Common examples include a metal disk set in concrete or stone, or a stainless steel rod driven into the ground.

Active Control

- A geodetic control point at a station occupied by equipment intended for and capable of continuously collecting geodetic quality data for multiple years and with active defined by or adopted by NGS.
- CORS

Shift and Drift

When transitioning off of NAD 83, your coordinates will experience shift and drift

- Shift: A one-time jump somewhere in the 0 to 4 meter range (latitude, longitude, ellipsoid height)
- Drift: Coordinates are now time-dependent. The shift will take you to 2020.00. Working at any other epoch means you must account for the drift (velocity, as well as any other motions over time) of your coordinates

New Types of Coordinates

- ***Reported***
  - *"Coordinates directly reported to NGS without the data necessary for NGS to replicate or evaluate them. These coordinates are neither 'part of the NSRS' nor 'tied to the NSRS.'"*
    - Scaled from a map
    - Transformed using NCAT or VDatum
    - Smartphone
    - Reported directly from an RTK rover without data files

Reported Coordinates

Buyer Beware!

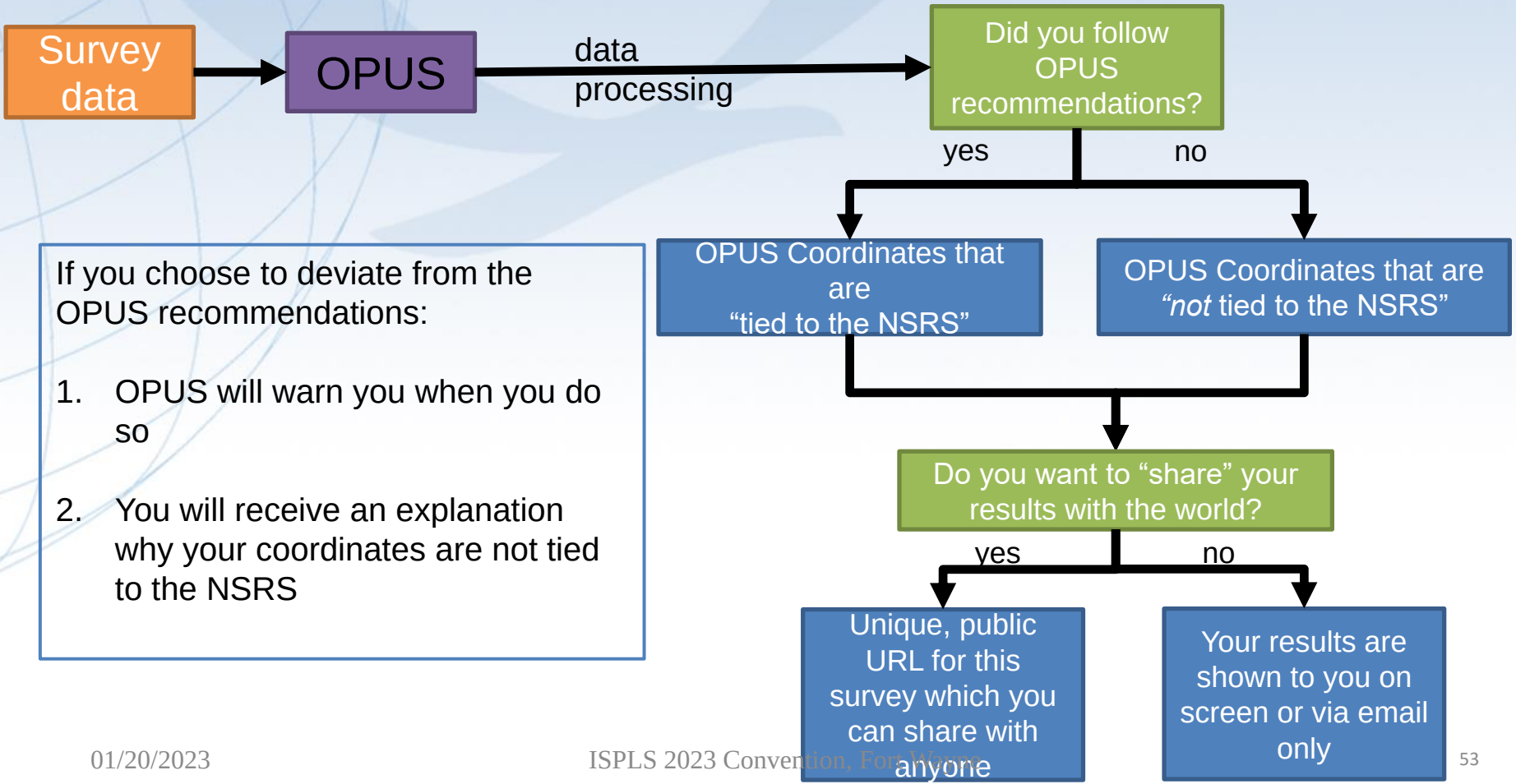
- ***Reported*** coordinates might be *very* wrong!
  - Reported in NAD 27 or NAD 83 or WGS 84
    - Systematic Error: 2–100 meters
  - Scaled off of a USGS topographic map
    - Random Error: ± 600 meters
  - Smartphone
    - Random Error: ± 10–50 meters
- NGS ***will show you*** reported coordinates
  - But their function is to get you "in the neighborhood" of a mark, not to use as geodetic control!

New Types of Coordinates

- ***OPUS***
  - *"Coordinates computed by OPUS that have not been evaluated by anyone at NGS. As these coordinates are not computed by NGS they are not considered "part of the NSRS." However, if NGS-provided OPUS recommendations are followed, they may be 'tied to the NSRS.' "*
    - *User-computed* values, such as they might get today from either OPUS-S or OPUS Projects
    - "OPUS" coordinates are the ***only*** coordinates a user will get directly from OPUS
    - NGS will *not* evaluate your OPUS coordinates!

New Types of Coordinates

- ***OPUS*** coordinates *may* also come with the label "**tied to the NSRS**"
  - **Only** if a user restricts their computations to OPUS-recommended constraints
  - Users who deviate from OPUS-recommended constraints can still perform computations and will get OPUS coordinates, but they will not be "tied to the NSRS", nor have any NSRS label at all.
  - In neither case will OPUS coordinates be considered "***part of the NSRS***" however.



If you choose to deviate from the OPUS recommendations:

1. OPUS will warn you when you do so
2. You will receive an explanation why your coordinates are not tied to the NSRS

New Types of Coordinates

Reference epoch coordinates (RECs)

- *"Coordinates estimated by NGS for one of the official reference epochs. As these coordinates are computed by NGS they are considered 'part of the NSRS'"*
- These will be computed by NGS every 5 or 10 years
  - On a schedule 2–3 years past the reference epoch

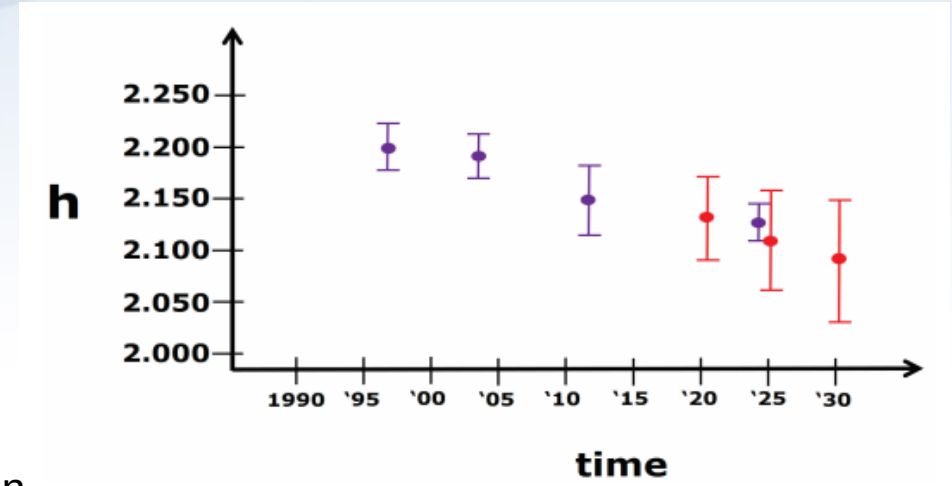
New Types of Coordinates

Survey epoch coordinates (SECs)

- *"Coordinates computed by NGS for one survey epoch. As these coordinates are computed by NGS they are considered 'part of the NSRS.'"*
  - These represent the best estimates NGS has of the time-dependent coordinates at any mark
  - Adjusting multiple surveys in timespans called "adjustment windows", to a single epoch within that window.
    - Initial plan: 4 weeks for GNSS; 1 year for leveling

More on SECs and RECs

- At passive control
- SECs: adjusted to a midpoint epoch near the survey
  - (4 weeks for GNSS; 1 year for leveling)
- RECs: adjusted to a ref. epoch (2020.00, etc.)
- REC adjustments will include Some ***age-limited*** span of data
  - If that age-limit were 10 years prior and 2 years post R.E., Then 2020.00 RECs come from data spanning 2010.00 to 2021.99999

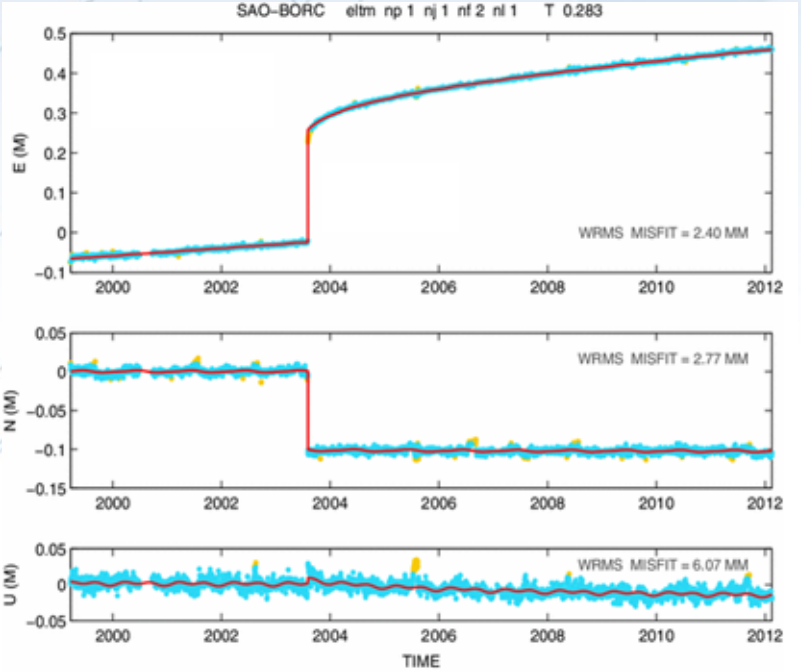


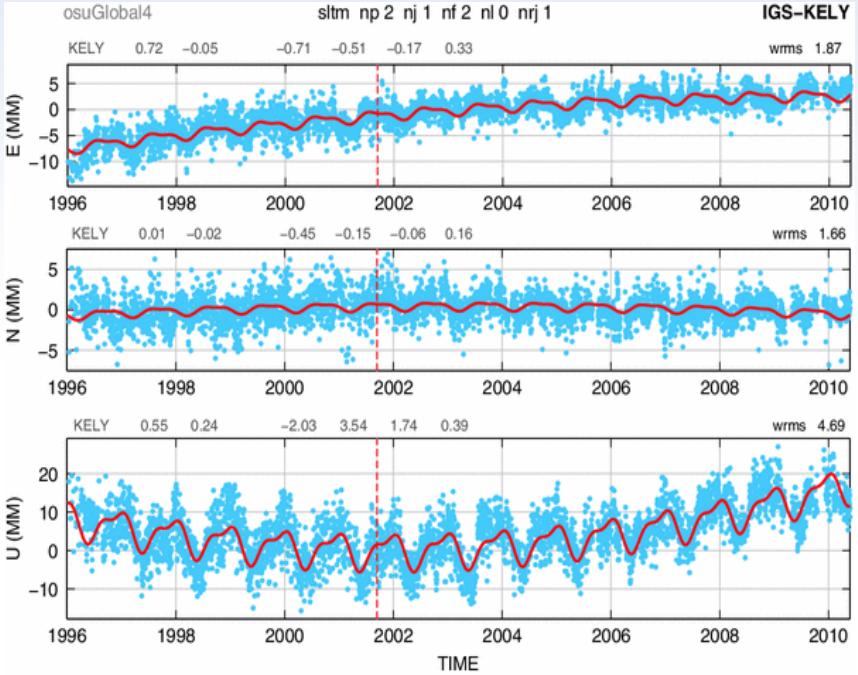
New Types of Coordinates

Active coordinates (ACs)

- Coordinate functions in time, generated by NGS, and not associated with a specific epoch. As these coordinates are computed by NGS (or adopted by NGS) they are considered "part of the NSRS."
- Which will be generated by a "fit" to regularly computed coordinates

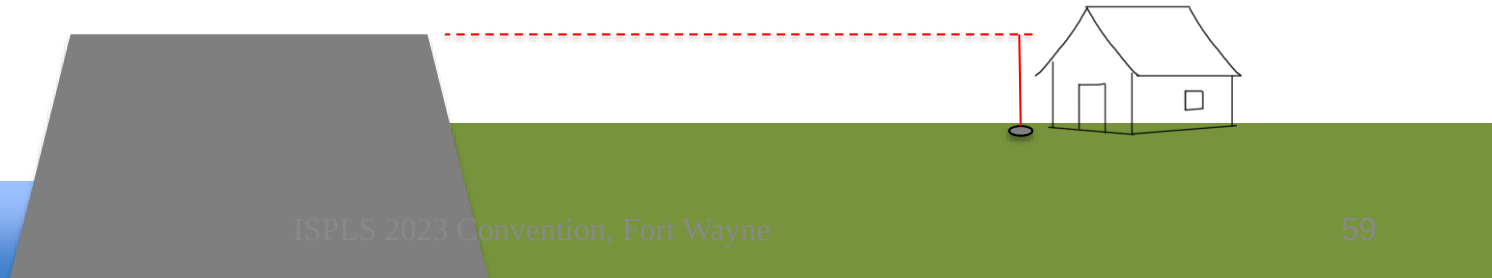
Examples of How Non-Linear CORS Coordinate Functions Might Look





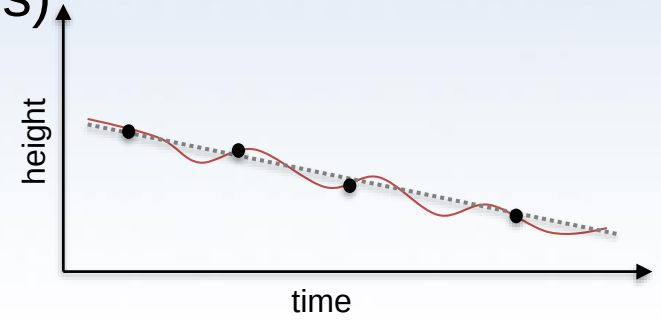
Published Coordinates

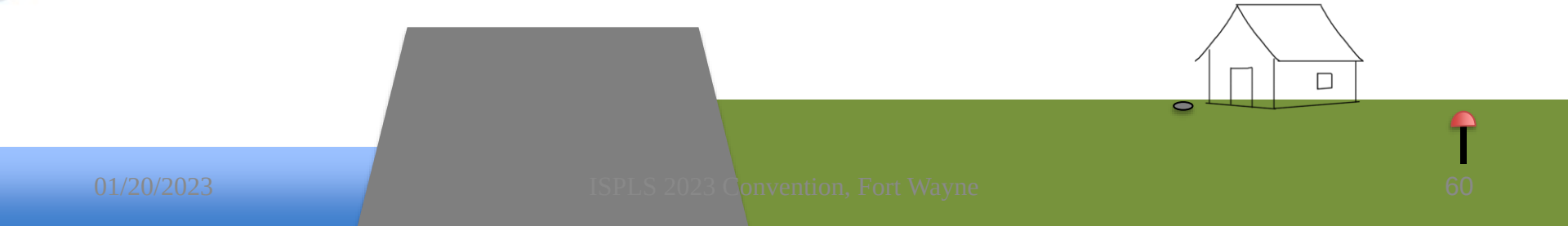
- **RECs** 'stable' at project scales (5-10 years)



Published Coordinates

- **RECs** 'stable' at project scales (5-10 years)
- **SECs** reflective of narrow window in time
- **ACs** or ***Coordinate Function*** at CORS





Coordinates

- Five types:
  - **Active**: Continuous functions at a CORS
  - **Survey Epoch**: "Time dependent coordinates"
  - **Reference Epoch**: "Estimated at 2020, 2025, 2030, …"
  - **OPUS**: Computed by you, and as accurate or inaccurate as the choices you make
    - *Tied to the NSRS if you follow OPUS recommendations*
  - **Reported**: Good for finding a point somewhere on Earth.
    - *Not to be used as geodetic control*

NGS TOOLS AVAILABLE

or the Future

geodesy.noaa.gov

www.ngs.noaa.gov

beta.ngs.noaa.gov

OPUS Projects

National Geodetic Survey

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OPUS menu

upload
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projects
shared solutions
support / feedback

OPUS Projects gives users web-based access to simple management and processing tools for projects involving multiple sites and multiple occupations. The advant

- Data uploading throug
- Customizable data pr
- Visualization and man

What is OPUS projects?

- One page class desc
- What is OPUS Proje
- User Manual.
- Manager training vid

The NOAA CORS Net reference system in Se projects will be created

The IGS08 reference s here, in BETA OPUS a copy your project to BE support for the IGS08 r encourages you to con ITRF2014 reference sy time option to convert a offered the first time th

Create a new project.
Create RESTRICTE completed O create a new

Configure, edit, and proc
Session Project Ident Session Key Your Email:
Privacy Act Sta

Manage, edit, process, a
Manage Project Ident Manager Key

NOS Home ▪ NGS Employees ▪ Privacy Policy ▪

BETA

This is a BETA Release Site

OPUS Projects

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OPUS Projects gives users web-based access to simple management and processing tools for projects involving multiple sites and multiple occupations. The advantages of OPUS Projects a

- Data uploading through OPUS.
- Customizable data processing via the PAGES
- Visualization and management aids.

What is OPUS projects?

- One page class description.
- What is OPUS Projects.
- User Manual.
- Manager training videos.

If you're interested in submitting your project's res NGS Integrated Database (IDB) and have not dor Project Tracking web site to request a required

The NOAA CORS Network (NCN) and OPUS c reference system in September, 2019. While the is still offered through the BETA OPUS tools, IG discontinued in early 2020. more

Create a new project.
Create RESTRICTED to trained project mana completed OPUS Projects training, yo create a new project. All others, see th

Configure, edit, and process individual network se
Session Project Identifier:
Session Keyword:
Your Email:
Privacy Act Statement

Manage, edit, process, and publish the project.
Manage Project Identifier:

DEV

Internal Development Area

OPUS Projects

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OPUS Projects gives users web-based access to simple management and processing tools for projects involving multiple sites and multiple occupations. The advantages of OPUS Projects are:

- Data uploading through OPUS.
- Customizable data processing via the PAGES software suite.
- Visualization and management aids.

What is OPUS projects?

- One page class description.
- What is OPUS Projects.
- User Manual.
- Manager training videos.

CORS and OPUS converted to the ITRF2014 reference system in September 2019. From that point forward, all new projects will be created in the ITRF2014 reference system. more

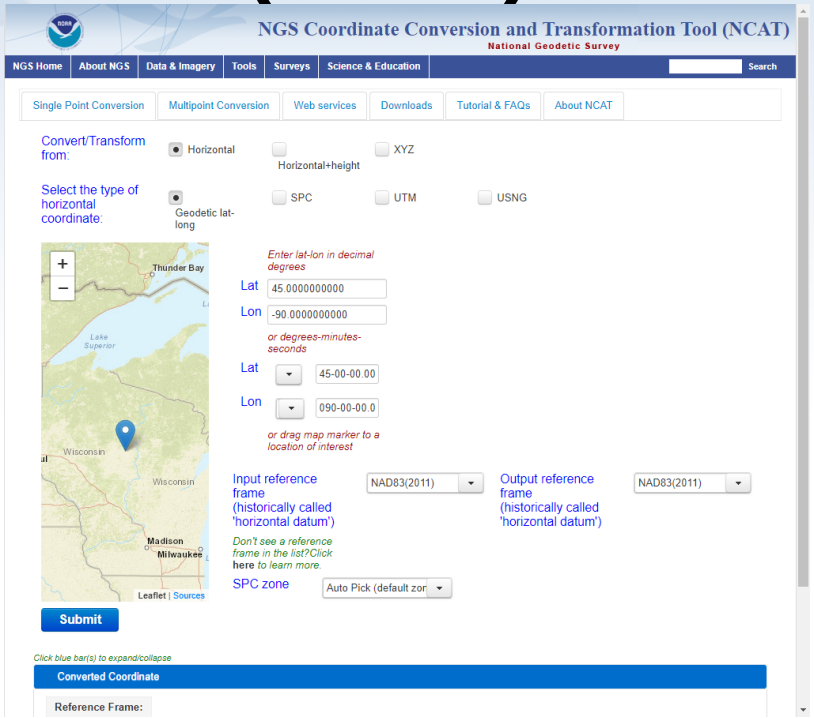
The IGS08 reference system will be supported through the end of 2019 here, in BETA OPUS and in BETA OPUS-Projects. The OPUS team can copy your project to BETA OPUS-Projects on request; however, OPUS support for the IGS08 reference system will end. NGS strongly encourages you to complete existing projects or convert them to the ITRF2014 reference system by the end of the year. Until that time, a one-time option to convert an existing IGS08 project to the ITRF2014 will be offered the first time the project is accessed.

NGS Products and Services

- Not just OPUS
- All exist in three environments:
  - **Development** (DEV) - internal testing and development
    - same as when you hear a company talk about an "Alpha" product
  - **Beta** - continued internal testing, open for public testing
    - key features have already been vetted/tested
  - **Production** - final product, open to public use
    - this is what you see first when navigating our website

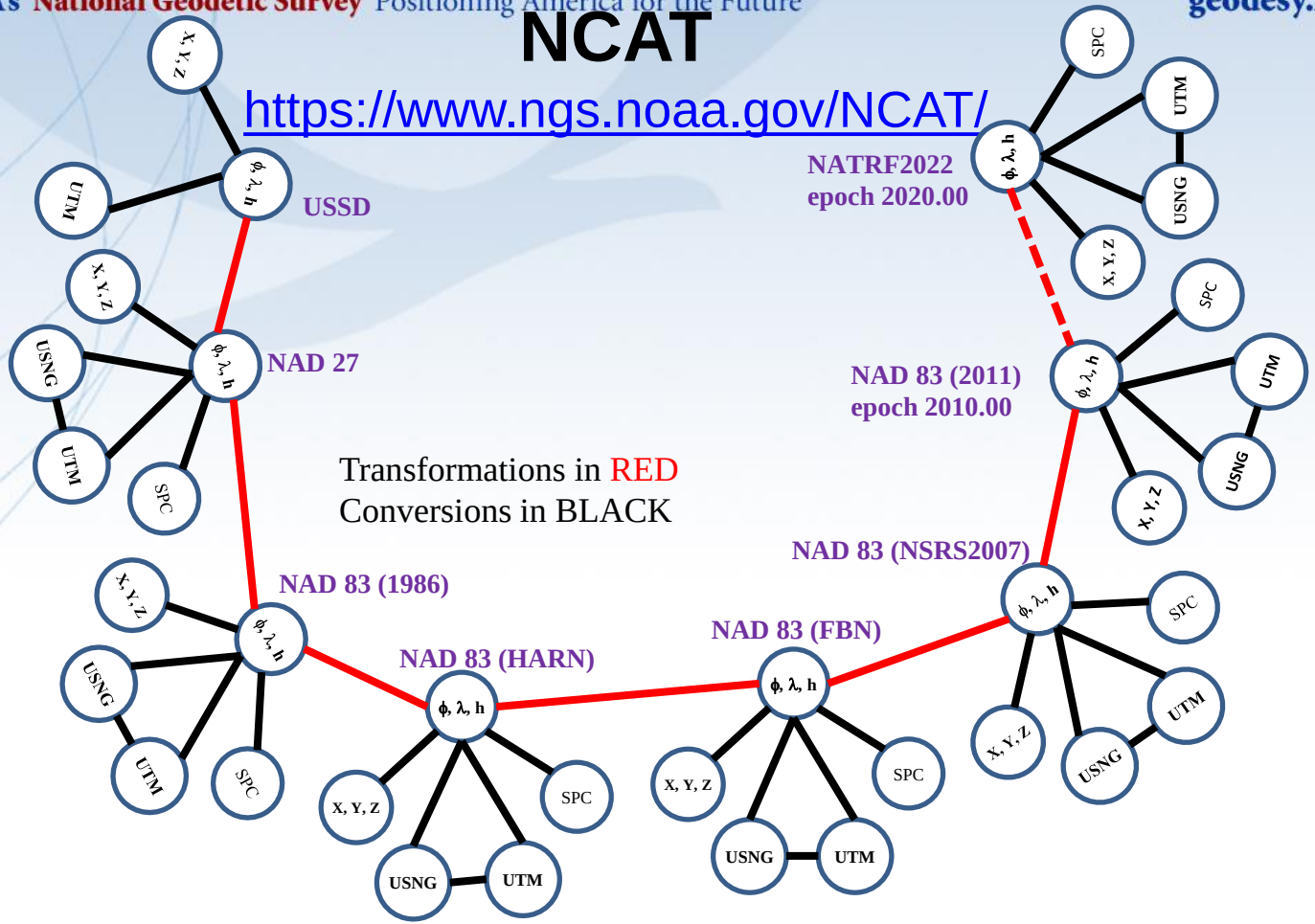
NGS Coordinate Conversion and Transformation Tool (NCAT)

- Converts between types of coordinates
- Transforms between datums
- Works with vertical and horizontal datums in the NSRS



NCAT

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



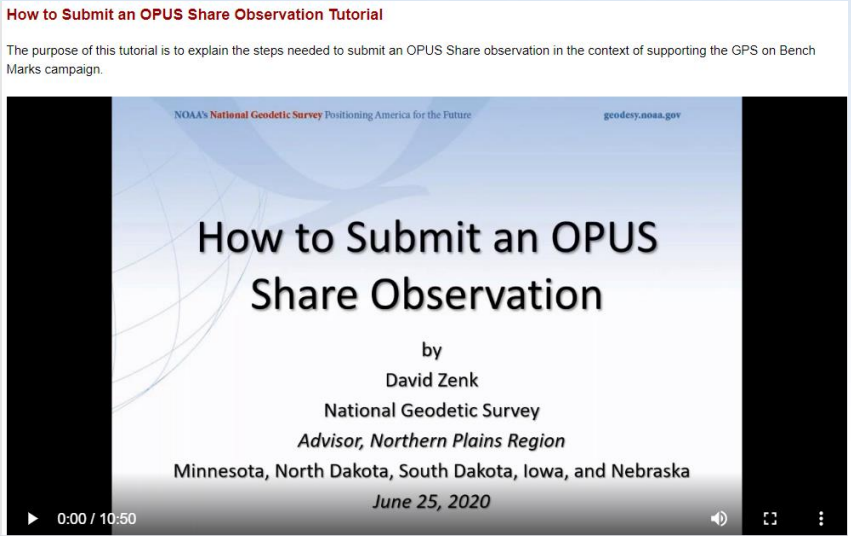
OPUS-PROJECTS UPDATES

What is OPUS?

- OPUS-S (static processing, 2-48 hours)
- OPUS-RS (rapid-static, 15 minutes – 2 hours)
- Sharing database of solutions
- OPUS Projects
  - campaign style survey-processing, adjustments, publication

Share GPS observations through OPUS

- Upload 4+hour GPS observation file
- Provide antenna type, antenna height, and email address
- Click “Options” & Select “Yes, Share”
- Identify the Mark by PID
- Write a “To Reach” description
- Attach 2 photos: Close up & Horizon
- Respond to confirmation email



geodesy.noaa.gov/corbin/class_description/opus-share-tutorial/

Why use OPUS-Projects?

- Supports both static GPS and RTK GNSS surveys
- Organizes data for multiple occupations on more than one mark
  - Campaign-style surveys for control
- Performs least squares adjustments of control survey networks
  - Estimate relative accuracy between marks
- Constrains NAVD 88 bench marks – check/establish NAVD 88 heights
- Ensures survey is tied to the NSRS
  - CORS data and published coordinates/heights
  - Official models (HTDP, GEOID18)
- Submits survey to NGS for review, loading in database, and publication on datasheets
  - Establishment of geodetic control
  - NGS will use data for making models (e.g., future transformation model for the new datums)

OPUS-Project 4.0

- Currently on Production
- What does this version add?
  - Allows you to submit campaign style GPS survey to NGS for inclusion in the IDB (Integrated DataBase)
    - Upload GPS data to OPUS-S
    - Upload photos and mark descriptions ← (must be created using WinDesc)
    - Process simultaneous/overlapping sessions
    - Run network adjustment (using GPSCOM and ADJUST)
    - Click the "Submit" button to send to NGS!

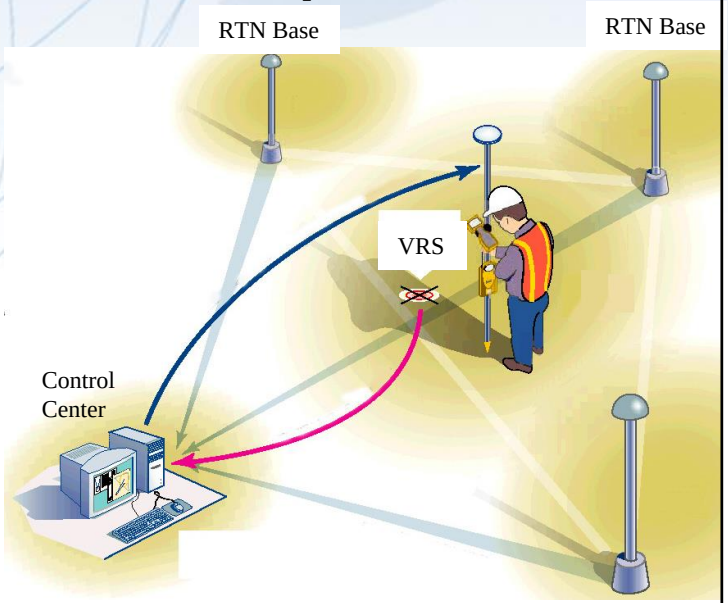
OPUS-Projects 5

- Available on BETA at: https://beta.ngs.noaa.gov/OP-bluebook/OpusProjects.shtml
- Continues to support static GPS baseline processing and network adjustments
- Continues to prepares all files according to FGCS Bluebook for submission to NGS for loading in the NGS Integrated Database and publication on Datasheets
- Supports GVX → uploading of previously processed GNSS vectors
  - Single-base RTK vectors
  - Network RTK vectors
  - Vectors post-processed in other software
- Automatically "weights" uploaded vectors in a network least squares adjustment

Real-Time Networks

Virtual Reference Stations (VRS)

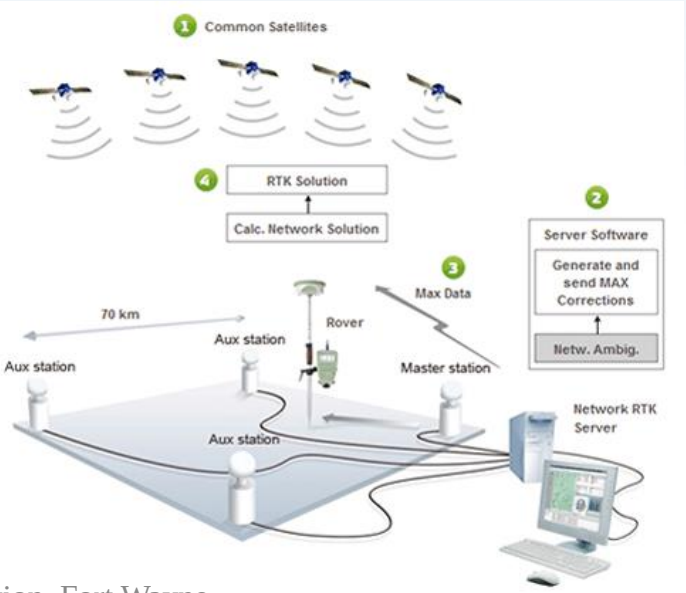
- Vector "tails" referenced to virtual base station
- Base station position is variable



(Landau et al. 2002)

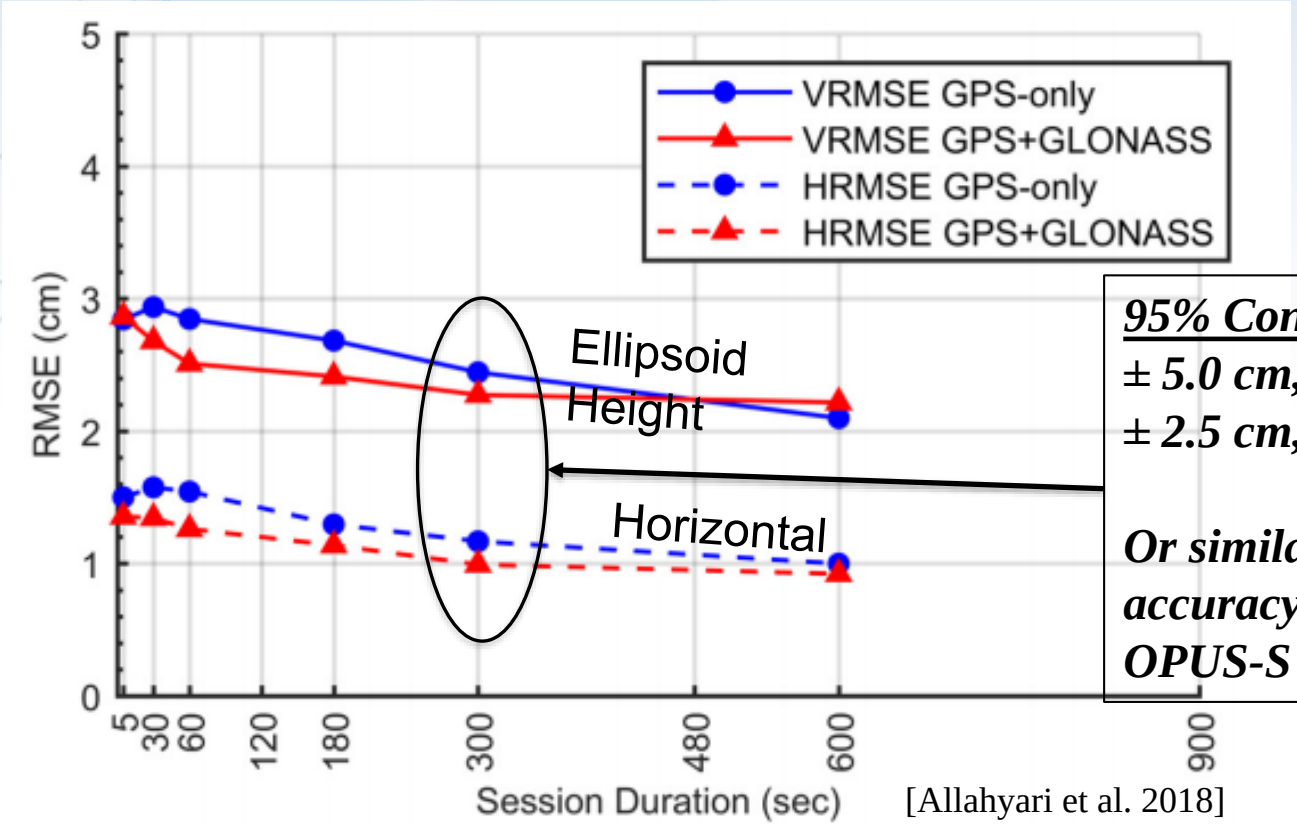
Master-Auxiliary Concept (MAC)

- Vector "tails" connected to physical base station
- Base station position is fixed



(Leica 2005)

Empirical Evaluation of the Accuracy of RTNs



95% Confidence
± 5.0 cm, vertical
± 2.5 cm, horizontal

Or similar to accuracy of a 2-h OPUS-S solution!

[Allahyari et al. 2018]

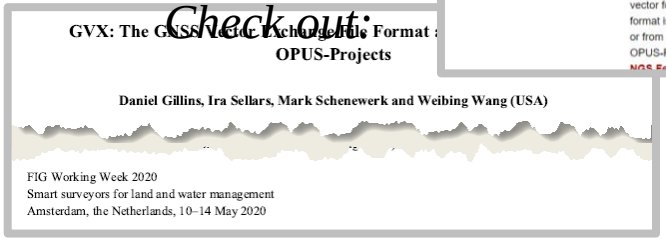
GNSS Vector eXchange (GVX)

Hyperlink to GVX Info Page

- Detailed documentation, Schema, and Example File available
- Any major search engine: "ngs gvx file format"
- Open standard for anyone to use or integrate

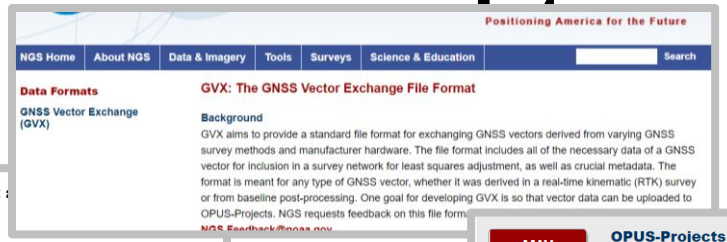
GVX is sort of like… RINEX for RTK/RTN

GVX details? Check out:


GVX: The GNSS Vector Exchange Format
OPUS-Projects

Daniel Gillins, Ira Sellars, Mark Schenewerk and Weibing Wang (USA)

FIG Working Week 2020
Smart surveyors for land and water management
Amsterdam, the Netherlands, 10–14 May 2020


Positioning America for the Future

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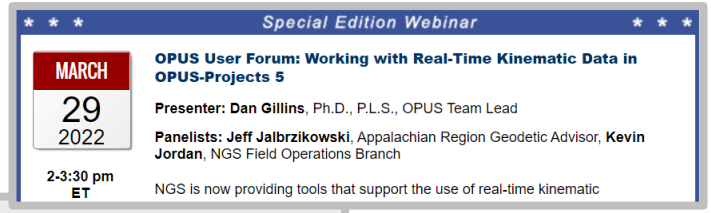
Data Formats

GNSS Vector Exchange (GVX)

GVX: The GNSS Vector Exchange File Format

Background

GVX aims to provide a standard file format for exchanging GNSS vectors derived from varying GNSS survey methods and manufacturer hardware. The file format includes all of the necessary data of a GNSS vector for inclusion in a survey network for least squares adjustment, as well as crucial metadata. The format is meant for any type of GNSS vector, whether it was derived in a real-time kinematic (RTK) survey or from baseline post-processing. One goal for developing GVX is so that vector data can be uploaded to OPUS-Projects. NGS requests feedback on this file form


Special Edition Webinar

MARCH 29 2022

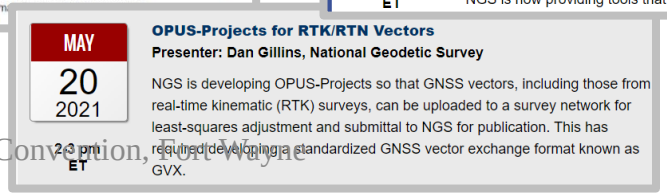
2-3:30 pm ET

OPUS User Forum: Working with Real-Time Kinematic Data in OPUS-Projects 5

Presenter: Dan Gillins, Ph.D., P.L.S., OPUS Team Lead

Panelists: Jeff Jalbrzikowski, Appalachian Region Geodetic Advisor, **Kevin Jordan**, NGS Field Operations Branch

NGS is now providing tools that support the use of real-time kinematic


MAY 20 2021

2-3 pm ET

OPUS-Projects for RTK/RTN Vectors

Presenter: Dan Gillins, National Geodetic Survey

NGS is developing OPUS-Projects so that GNSS vectors, including those from real-time kinematic (RTK) surveys, can be uploaded to a survey network for least-squares adjustment and submittal to NGS for publication. This has required developing a standardized GNSS vector exchange format known as GVX.

GVX ≈ RINEX for RTK/RTN data

RINEX

Uncorrected Observations
- That's why we post-process them

Static Observations
- One observation per file

Proprietary Format → Open Standard
- Export RINEX using your COTS software

Metadata
- Antenna, Rx, HI, Point Name, Start Time, SVs at each epoch

Based on ASCII Text File Format
- Longtime industry standard
  - Way too many to list!

GVX

Corrected/Processed **Positions**
- *And* the Vectors used to create them

RTN, RTK, PP Static, even PPK
- Many observations, any mix of above

Proprietary Format → Open Standard
- Export GVX using your COTS software

Metadata - same as RINEX, *plus…*
- Project Info, Solution Types, PDOP, Mount Points, Correlation Matrices, QC data

Based on XML File Format
- Longtime industry standard
  - e.g. LandXML, JXL, MAXML, KML/KMZ

Status of GVX Exporters

...that we know of.

Available Now

- Trimble Business Center (TBC) v5.60 - released Nov 2021
- Topcon MAGNET Software v7.2 - released Nov 2021
- Leica Infinity 4.0.0 - released May 2022

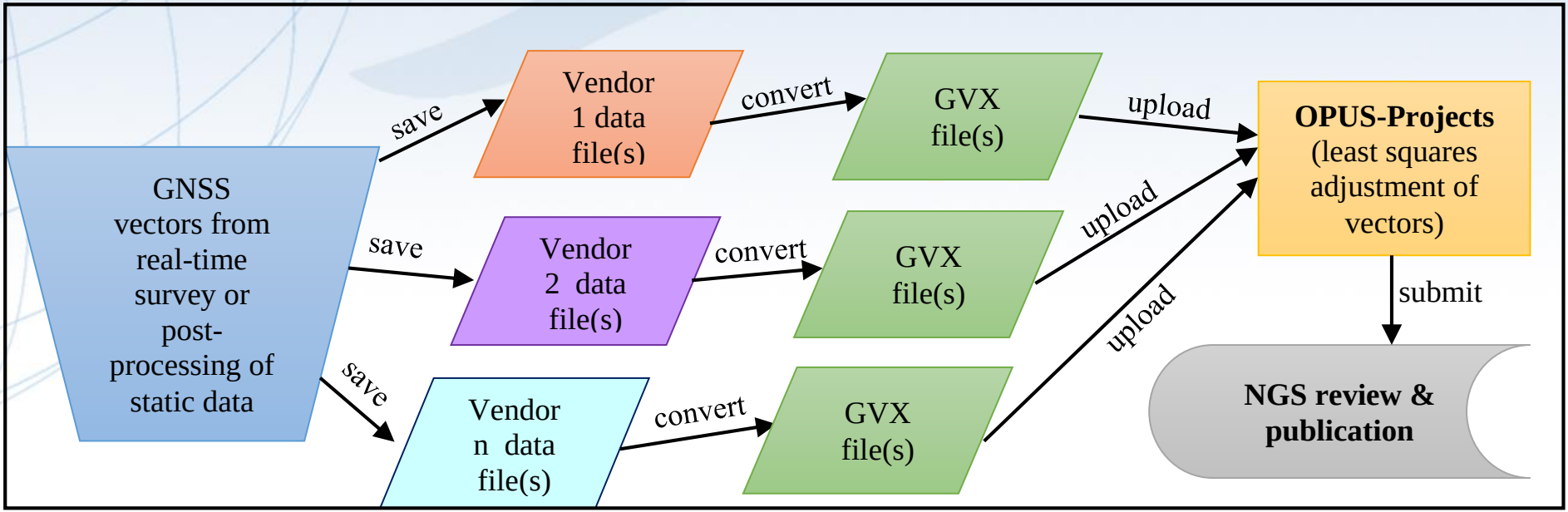
Developers who have expressed interest to us

- iGage
- Carlson
- Emlid

Available, but not fully functional

- JAVAD J-field - onboard Triumph-LS device

GVX Flow Chart



Steps for Submitting a Survey to NGS

1. Submit a survey project proposal and obtain a project tracking ID
2. Create descriptions for marks in WinDesc. Tutorial video available
3. Upload all static data via Beta OPUS-S
4. **Upload GVX file(s)**
5. Upload description files from WinDesc
6. Perform session baseline processing
7. Run all 5 network adjustments
8. Upload 3 photos per mark (close-up of mark, horizon photo, and downward from eye-level)
9. Upload observation logs (as a single PDF), and a project report
10. Submit to NGS (*button not enabled on Beta*)

All but step 4 is currently explained in the OPUS-Projects User Guide!

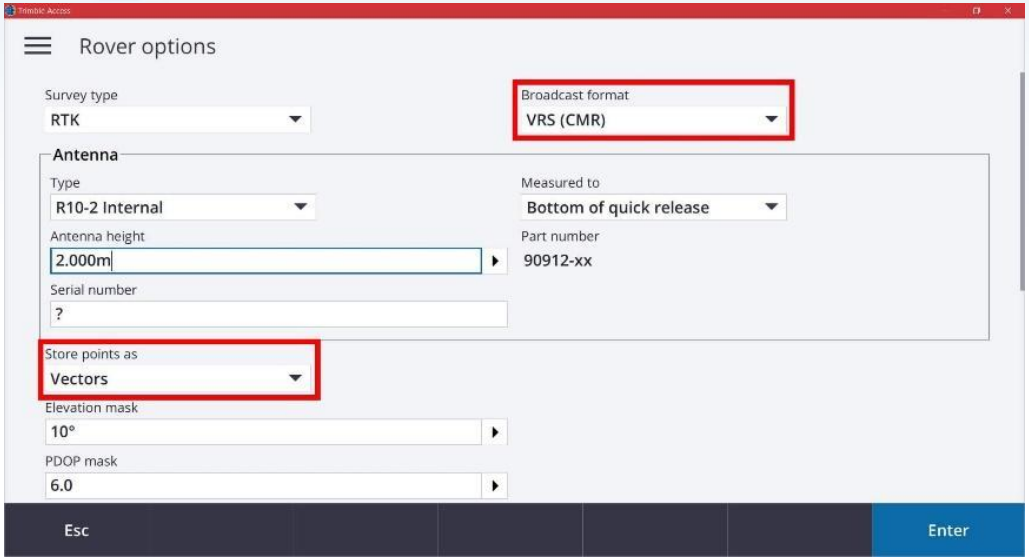
Guidance for RTK Surveys

Table 11-2. Recommended Number and Duration of Network RTK Observations on Marks to Meet Certain Vertical (Ellipsoid Height) Accuracy Standards at 95% Confidence in OPUS-Projects.

	Number of repeat network RTK observations			
Vertical standard (cm)	GPS-only	GPS + more (GNSS)	Observation duration (min)	Minimum epochs used
3.0	3	3	5	300
2.5	4	3	5	300
2.0	6	5	5	300

Equipment Setup

- When using VRS, store points as vectors

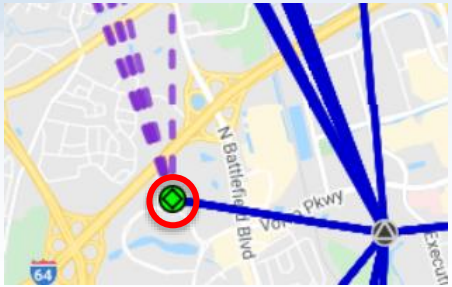


Three Cases for RTK/RTN Bases

1. RTN Base = CORS

- Automatically attaches GVX vectors to official coordinates for CORS
- Constrain CORSs

2. RTK/RTN Base = Not a CORS and new to NGS



- Upload static GPS data logged at the base during the days of the RTK survey
- Perform session baseline processing to connect to CORSs
- Constrain CORSs

3. RTK/RTN Base = Not a CORS but has a datasheet

- Could constrain coordinates on datasheet
- Or, upload static data at the RTN base, logged during the days of the RTK survey; perform session baseline processing; constrain CORSs

Future Directions

- Perform Beta Testing and respond to feedback from users
  - Provide your feedback! NGS.Feedback@noaa.gov
- Finish OPUS-Projects 5 development and enable "submit" button
- Update OPUS-Projects User Guide materials to include GVX workflow
- Draft new guidelines for surveying with RTK/RTN to replace NGS-58/59

Brief overview: Re-inventing "Bluebooking" or

The Modernized OPUS AKA "OPUS 6"

Future of OPUS

Static GNSS

RINEX

RTK/RTN

GVX

Classical

CVX

Leveling

LVX

Rel. Gravity

RGX

Future of OPUS

- Upload multiple types of data and multiple files into a single survey project
- Process RINEX into a position
- Process RINEX into mark-to-mark vectors
- Process Classical into mark-to-mark angles/distances
- Process Leveling into mark-to-mark ortho. differences
- Process Relative Gravity into mark gravity
- Combine GNSS, RTK/N, Classical in a Geometric Adjustment
- Combine Classical and Leveling in an Orthometric Adjustment
- Adjust Relative Gravity for either gravity or vertical gradients in a Gravimetric Adjustment
- Special settings for "Calibration Base Lines"
- Choose your epoch and frame
- All coordinates returned are "OPUS Coordinates"
- Submit your data to NGS for QA/QC, database loading, and improvement of future passive mark coordinates (RECs and SECs)

The future of datasheets

DATA DELIVERY SYSTEM

Data Delivery System

- The **Data Delivery System** (DDS) is a system for querying the new **NSRS database**
  - The most common query will be for a new version of **datasheets**
  - But other queries will be part of the DDS
    - Mark recovery and mark reporting
    - Active control (CORSs)
    - Projects, observations, data, etc.

```
PROGRAM = datasheet95, VERSION = 8.12.5.14
Starting Datasheet Retrieval...
1        National Geodetic Survey,   Retrieval Date = DECEMBER 14, 2021
 DE9524 ***********************************************************************
 DE9524  DESIGNATION -  SP 0109
 DE9524  PID         -  DE9524
 DE9524  STATE/COUNTY-  IL/SANGAMON
 DE9524  COUNTRY     -  US
 DE9524  USGS QUAD   -  SPRINGFIELD WEST (2018)
 DE9524
 DE9524                        *CURRENT SURVEY CONTROL
 DE9524  ______________________________________________________________________
 DE9524* NAD 83(2011) POSITION- 39 49 41.85939(N) 089 39 02.64176(W)   ADJUSTED
 DE9524* NAD 83(2011) ELLIP HT-   147.185 (meters)        (06/27/12)   ADJUSTED
 DE9524* NAD 83(2011) EPOCH    -  2010.00
 DE9524* NAVD 88 ORTHO HEIGHT -   179.776 (meters)      589.82  (feet) ADJUSTED
 DE9524  ______________________________________________________________________
 DE9524  GEOID HEIGHT    -        -32.579 (meters)                    GEOID18
 DE9524  NAD 83(2011) X  -     29,900.259 (meters)                    COMP
 DE9524  NAD 83(2011) Y  - -4,904,962.342 (meters)                    COMP
 DE9524  NAD 83(2011) Z  -  4,063,456.865 (meters)                    COMP
 DE9524  LAPLACE CORR    -          1.42  (seconds)                   DEFLEC18
 DE9524  DYNAMIC HEIGHT  -        179.677 (meters)      589.49  (feet) COMP
 DE9524  MODELED GRAVITY -    980,077.1   (mgal)                      NAVD 88
 DE9524
 DE9524  VERT ORDER      -  SECOND    CLASS I
 DE9524
 DE9524  Network accuracy estimates per FGDC Geospatial Positioning Accuracy
 DE9524  Standards:
 DE9524         FGDC (95% conf, cm)     Standard deviation (cm)     CorrNE
 DE9524            Horiz  Ellip           SD_N   SD_E   SD_h      (unitless)
 DE9524  ----------------------------------------------------------------------
 DE9524  NETWORK    0.59   1.37           0.27   0.20   0.70     -0.03058419
 DE9524  ----------------------------------------------------------------------
 DE9524  Click here for local accuracies and other accuracy information.
 DE9524
 DE9524
 DE9524.The horizontal coordinates were established by GPS observations
 DE9524.and adjusted by the National Geodetic Survey in June 2012.
 DE9524
 DE9524.NAD 83(2011) refers to NAD 83 coordinates where the reference frame has
 DE9524.been affixed to the stable North American tectonic plate. See
 DE9524.NA2011 for more information.
 DE9524
 DE9524.The horizontal coordinates are valid at the epoch date displayed above
 DE9524.which is a decimal equivalence of Year/Month/Day.
 DE9524
 DE9524.The orthometric height was determined by differential leveling and
 DE9524.adjusted by the NATIONAL GEODETIC SURVEY
 DE9524.in September 2015.
 DE9524
 DE9524.Significant digits in the geoid height do not necessarily reflect accuracy.
 DE9524.GEOID18 height accuracy estimate available here.
 DE9524
 DE9524.Click photographs - Photos may exist for this station.
 DE9524
 DE9524.The X, Y, and Z were computed from the position and the ellipsoidal ht.
```

- Datasheets are the current way to access the NSRS
- Give information about passive marks, including coordinates

The Data in the Datasheet

In ASCII format

```
Starting Datasheet Retrieval...
1        National Geodetic Survey,   Retrieval Date = JULY  1, 2022
 AC6803 ***********************************************************************
 AC6803  HT_MOD      -  This is a Height Modernization Survey Station.
 AC6803  PACS        -  This is a Primary Airport Control Station.
 AC6803  DESIGNATION -  AZC A
 AC6803  PID         -  AC6803
 AC6803  STATE/COUNTY-  AZ/MOHAVE
 AC6803  COUNTRY     -  US
 AC6803  USGS QUAD   -  LOST SPRING MOUNTAIN EAST (2018)
 AC6803
...
```

In JSON format

```
{"datasheet":
   {
      "datasheetHeading":"National Geodetic Survey",
      "datasheetRetrievalDate":"JULY  1, 2022",
      "htMod":"This is a Height Modernization Survey Station.",
      "pacs":"This is a Primary Airport Control Station.",
      "determinedProjects":[

{"project":"GPS1154"},{"project":"GPS2300"},{"project":"GPS2507"},{"project":"GPS280"},
            {"project":"GPS2846"}
      ],
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      "occupiedProjects":[{"project":"GPS1154"},{"project":"GPS1195/11"}],
      "designation":"AZC A",
      "pid":"AC6803",
      "state":"AZ",
      "county":"MOHAVE",
      "country":"US",
      "quad":"LOST SPRING MOUNTAIN EAST (2018)",

...
   }
}
```
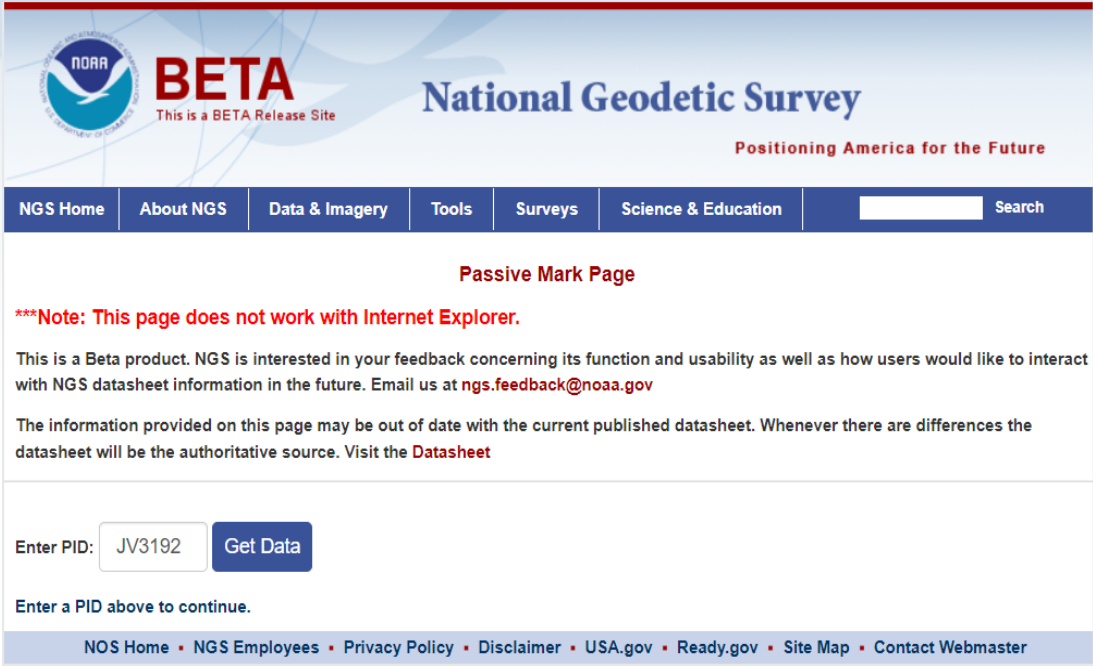

Beta Passive Marks page

- Easier to read
- Includes geospatial information
- A preview of the future data delivery system



https://beta.ngs.noaa.gov/datasheets/passive-marks/index.html

Beta Passive Marks page

BETA
This is a BETA Release Site

National Geodetic Survey
Positioning America for the Futur

NGS Home | About NGS | Data & Imagery | Tools | Surveys | Science & Education | Search

Passive Mark Page

***Note: This page does not work with Internet Explorer.**

This is a Beta product. NGS is interested in your feedback concerning its function and usability as well as how users would like to i with NGS datasheet information in the future. Email us at ngs.feedback@noaa.gov

The information provided on this page may be out of date with the current published datasheet. Whenever there are differences the datasheet will be the authoritative source. Visit the Datasheet

Enter PID: DE9524 | Get Data | Recover this mark | Go to Datasheet

Designation: ⓘ	SP 0109
Setting: ⓘ	7 = SET IN TOP OF CONCRETE MONUMENT
Last Recovery Date/Condition/By: ⓘ	08/06/2020 - Recovered in good condition - ILLINOIS DEPARTMENT OF TRANSPORTATION

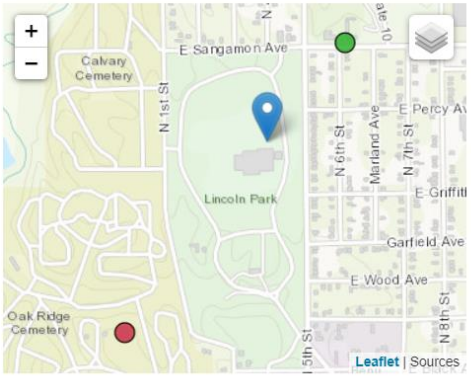
PID: ⓘ	DE9524
Stability: ⓘ	C
GNSS Useable: ⓘ	Y
Orthometric Ht. (m): ⓘ	179.776
Vertical Datum: ⓘ	NAVD 88

State, County: ⓘ	IL,SANGAMON
Country: ⓘ	US
Latitude: ⓘ	N 39° 49' 41.85939"
Longitude: ⓘ	W 089° 39' 02.64176"
Ellipsoid Ht.: ⓘ	-147.185

Order/Class:	2/1
Geoid Ht (m).: ⓘ	-32.579
Geoid Model: ⓘ	GEOID18
GNSS Ortho Ht. (m): ⓘ	179.76

Position Source: ⓘ	ADJUSTED
Network Accuracy Hz (cm): ⓘ	0.59
Network Accuracy Ellip (cm): ⓘ	1.37
Ortho Ht. Residual (cm): ⓘ	-1.2

SP 0109, DE9524, 1, 20140910



Nearby Marks ⓘ Hide

PID	Designation	Position Source	Vertical Source	Condition
DP8505	ELLER	HD_HELD1	ADJUSTED	MONUMENTED
KB1487	SPRINGFIELD LINCOLN MONUMENT	ADJUSTED		GOOD

Beta Passive Marks page

Superseded Values

NAD 83(2007)- 39 49 41.85953(N) 089 39 02.64247(W) AD(2002.00) 0
ELLIP H (02/10/07) 147.201 (m) GP(2002.00)
ELLIP H (02/03/05) 147.189 (m) GP( ) 4 2
NAD 83(1997)- 39 49 41.85960(N) 089 39 02.64226(W) AD( ) 1
ELLIP H (01/15/03) 147.204 (m) GP( ) 3 1
NAVD 88 (01/15/03) 179.7 (m) GEOID99 model used GPS OBS

Projects

Leveling Projects

Hide

L28166

Start Date:	01/06/2015	**Order:**	2	**Agency:**	AMESC
End Date:	03/27/2015	**Class:**	1	**BM Count:**	168

GPS Projects

Hide

GPS2183

Start Date:	10/13/2005	**End Date:**	10/13/2005
Agency:	NGS	**Obs. Count:**	13

Descriptive Information

Hide

PID: ⓘ	DE9524	**Designation** ⓘ	SP 0109
Setting Agency: ⓘ	CMT	**Setting Date:** ⓘ	20020611
Marker Type: ⓘ	DD	**Magnetic Code:** ⓘ	B
Stability Code: ⓘ	C	**Setting Class:** ⓘ	7
Setting Phrase: ⓘ		**Logo:** ⓘ	CMT
Stamping: ⓘ	SP 0109	**UDG Mark Type:** ⓘ	
UDG Magnetic Code: ⓘ		**UDG Mark Stability:** ⓘ	
UDG Mark Setting: ⓘ		**UDG Mark Set Date:** ⓘ	
Rod/Pipe Depth: ⓘ		**Sleeve Depth:** ⓘ	
Position Source: ⓘ	A	**Position Quality:** ⓘ	0
Position Technique: ⓘ	G	**Alias:** ⓘ	0109

Descriptive Text

Hide

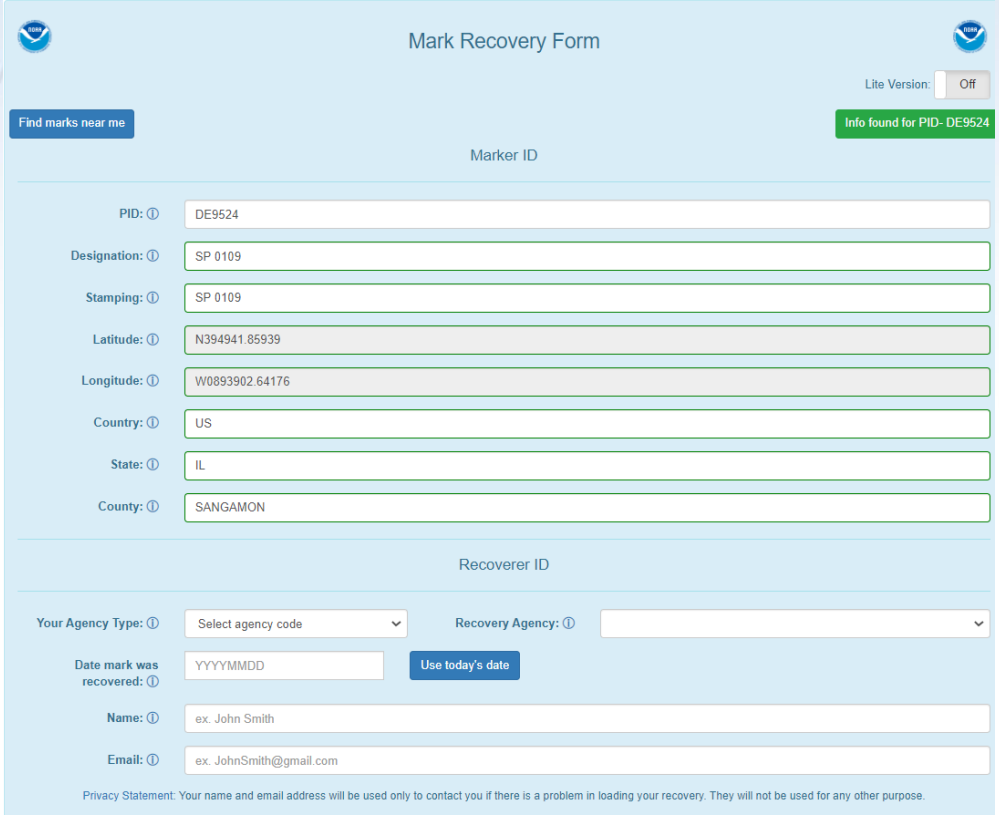
Recovery Date:	08/06/2020	**Cond:**	Recovered in good condition
COP:	DL	**Agency:**	ILDT
*			

Recovery Date:	09/10/2014	**Cond:**	Recovered in good condition
COP:	THH	**Agency:**	AMESC

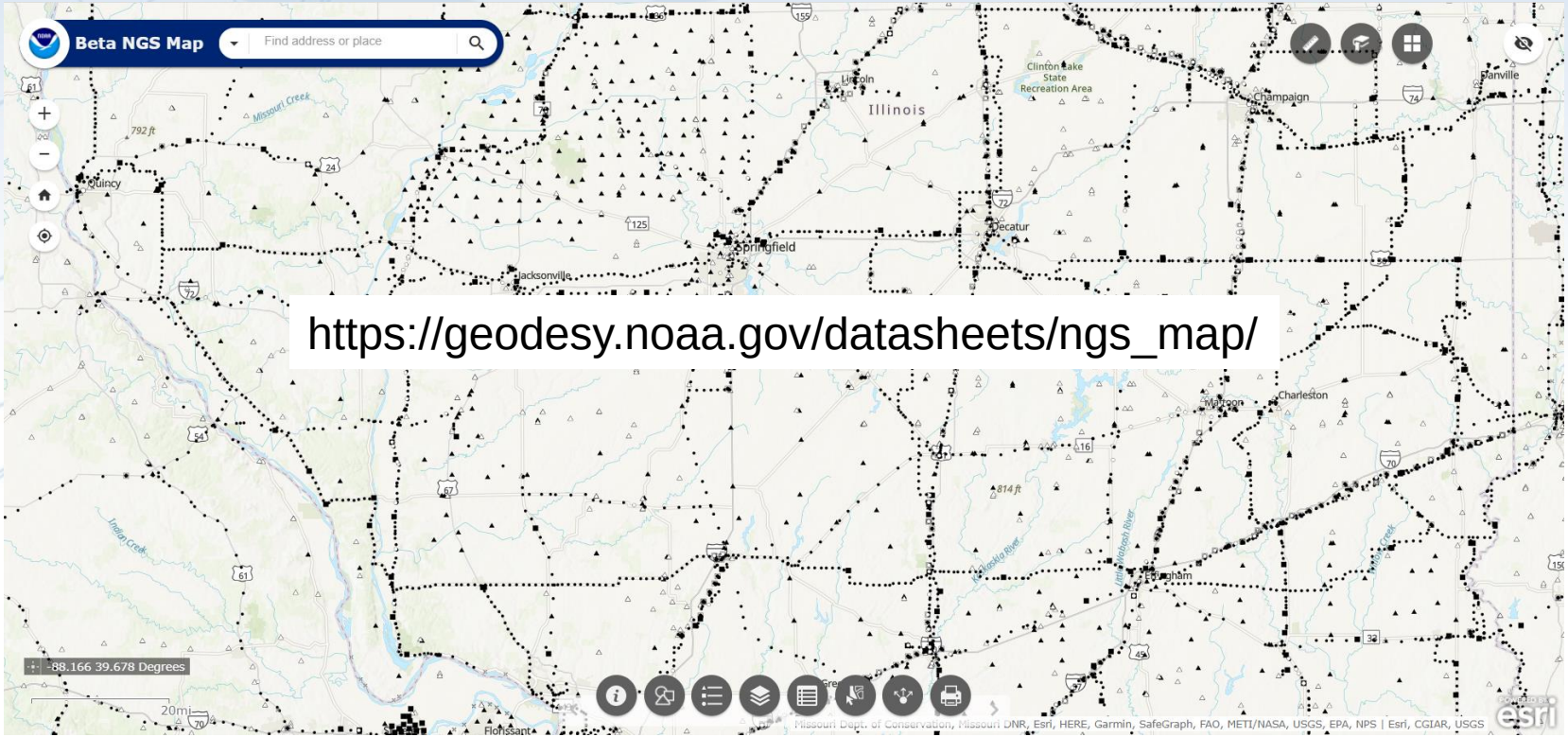
RECOVERED IN GOOD CONDITION. NOTE-ADD-THE STATION IS 84.3 FT (25.7 M) NORTHWEST OF THE NORTHEAST CORNER OF THE BUILDING, 65.3 FT (19.9 M) WEST-NORTHWEST OF A FIRE HYDRANT, 64.9 FT (19.8 M) NORTH OF THE NORTH FACE OF THE

Easy to use mark recovery tool

https://geodesy.noaa.gov/cgi-bin/mark_recovery_form.prl

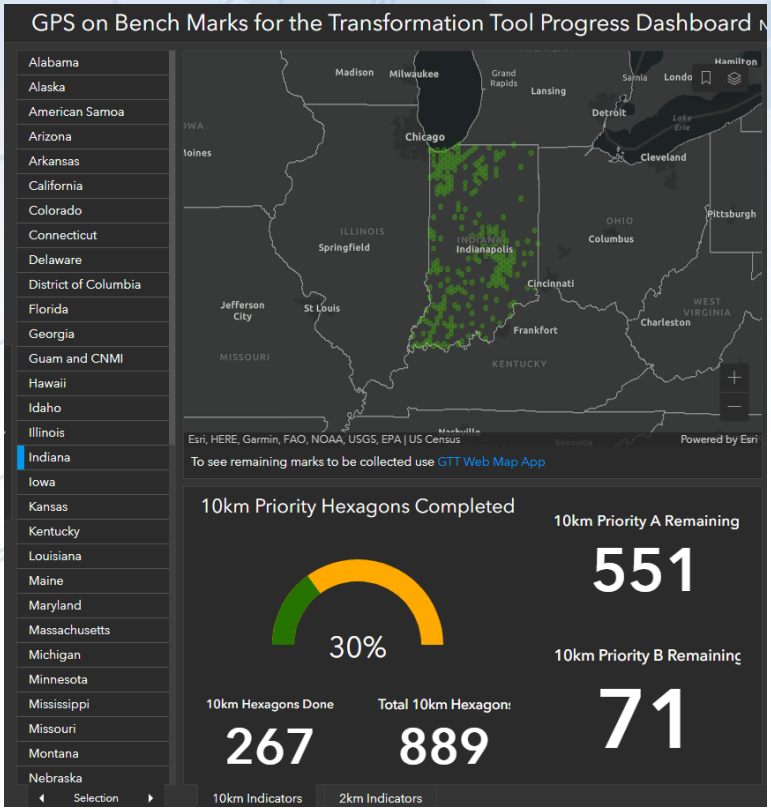


NGS Map


Beta NGS Map
Find address or place
https://geodesy.noaa.gov/datasheets/ngs_map/
-88.166 39.678 Degrees
20mi
Illinois
Quincy
Springfield
Decatur
Champaign
Charleston
Jacksonville
Lincoln
Clinton Lake State Recreation Area
Missouri Creek
Indian Creek
Kaskaskia River
Little Wabash River
792 ft
814 ft
esri

GPS ON BENCH MARKS

GPS on Bench Marks



- Priority Map:

https://noaa.maps.arcgis.com/apps/webappviewer/index.html?id=6093dd81e9e94f7a9062e2fe5fb2f7f5

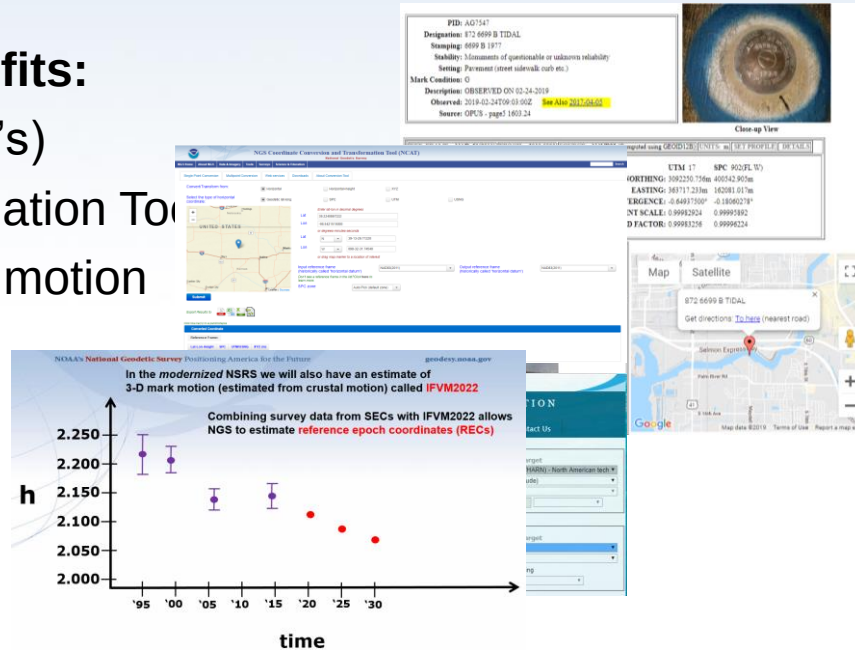
https://geodesy.noaa.gov/GPSonBM/

GPS on Bench Marks - What & Why?

GPS on Bench Marks is about preparing the country and our communities to take full advantage of the benefits of the Modernized NSRS, by collecting new GPS observations on bench marks with published NAVD 88 heights.

Primary GPSonBM Campaign Benefits:

- 2020.0 Reference Epoch Coordinates (REC's)
- Data for NAVD 88 – NAPGD2022 Transformation To
- Build time series of observations in areas of motion



Added benefits:

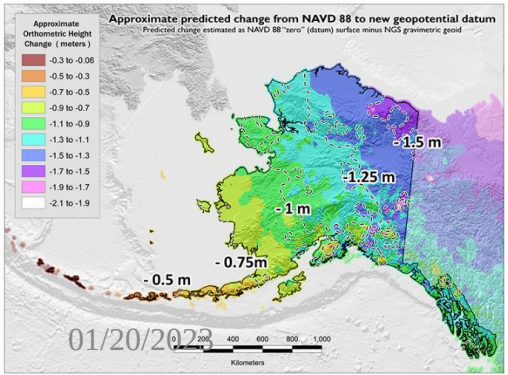
- Evaluate gravimetric geoid models
- Check your RTN results
- Update and maintain passive control marks
- Identify marks suspected of movement

GPSonBM Measurements Connect Current and Future Datums

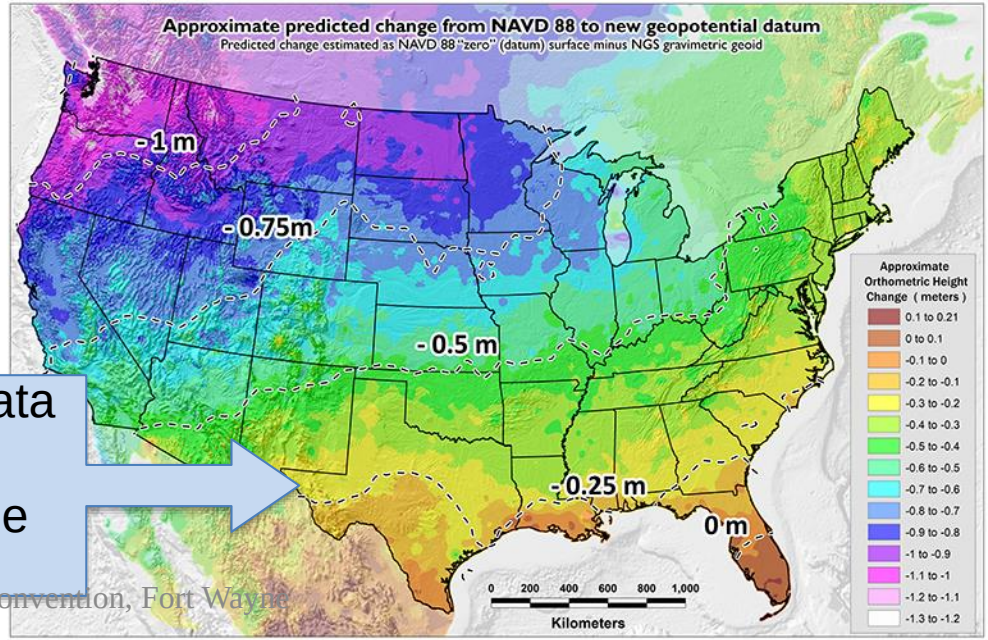
The relationship between the old and new datums vary by location. GPSonBM data is used to measure that relationship. The accuracy of the transformations in any particular place will be directly related to the density of GPSonBM data available in that area.

In moving from NAVD 88 to NAPGD2022, there will be a Shift: A one-time 0 to 2 meter jump in orthometric heights

-From fixing biases and/or tilts in NAVD 88



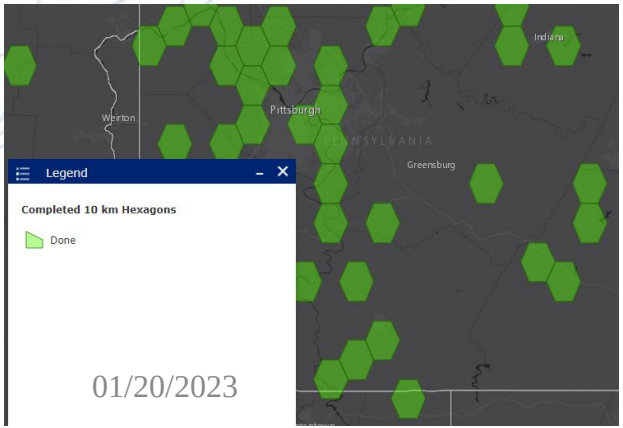
GPSonBM data is used to measure the Shift

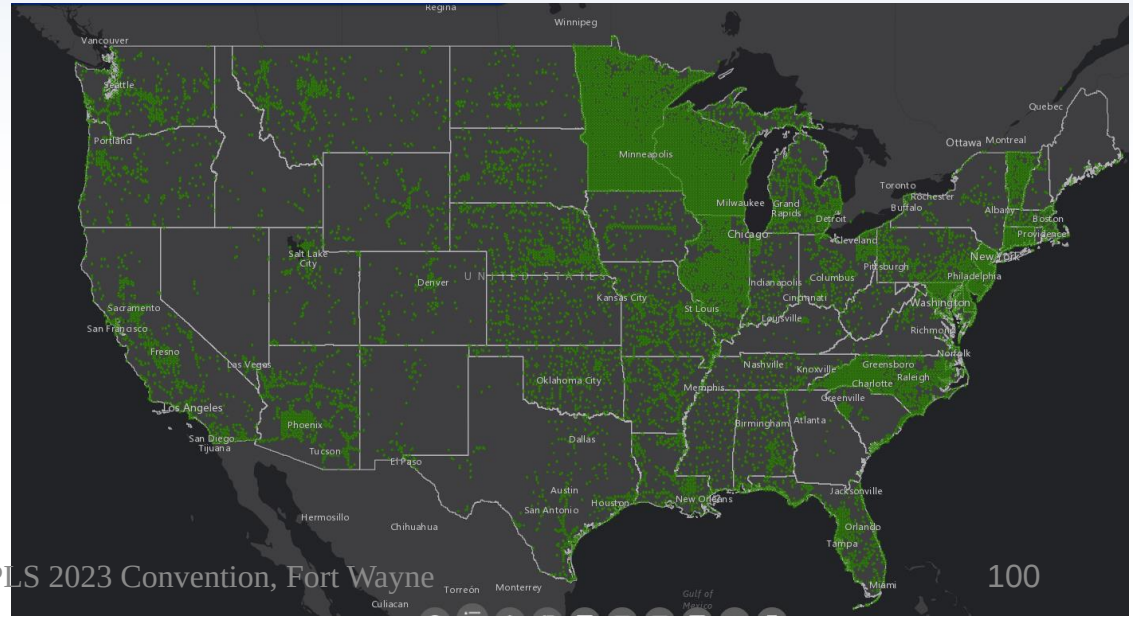


2022 Transformation Tool Campaign

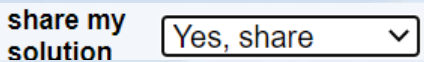
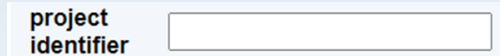
NGS will make a **national scale**, **mapping grade** transformation tool with the data we have in the NGS Database and Shared through OPUS. We must interpolate over areas with data gaps.

Uncertainties in the transformed coordinates will grow larger as the distance from a GPSonBM data point increases.





Data Contribution Routes

	 via OPUS option "share my solution" 	 via OPUS option "project ID" 
WHAT DATA?	minimal one receiver, one 4+ hour observation	more; many receivers, redundant sessions, network adjusted by project manager
USE, in transformation tool	Will be used in modeling, existing BMs only (with published ortho heights)	Will be used in modeling, all marks, as projects publish new NGS datasheets with ortho heights
USE, in *current* generation datasheets	for all marks, results appear as 'shared solutions' = not published geodetic control *for existing BM datasheets only, updates "SCALED">"HD_HELD2" coordinates*	for all marks, results appear as NGS datasheets = published geodetic control
USE, in *next* generation datasheets	will be published with 2020.00 RECs in the modernized NSRS	

see also, mark recovery to update mark descriptions and add photos

GPSonBM Q&A

Q: What is the deadline to submit GPSonBM for the Transformation Tool?

A: **September 30, 2023**– so that observations can be used to create 2020.0 Reference Epoch Coordinates (See Blueprint 3 -Working in the Modernized NSRS)

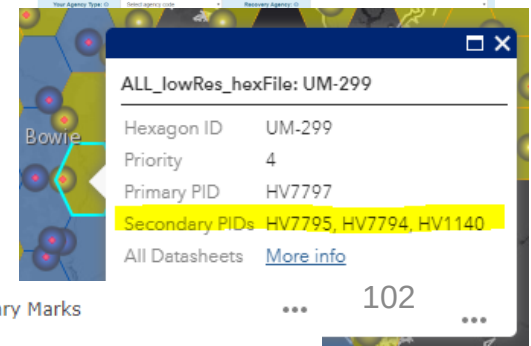
Q: Can we submit previous observations?

A: Yes! Observations made within the past 3 years may be submitted <u>if you have the required metadata and pictures</u>.

Q: What do we do if we can't find the priority mark or if it not observable with GPS?

A: 1) Submit a Mark Recovery with the new Mark Recovery Form.

2) Find and observe an secondary mark listed in the hexagon layer on the web map.



GPSonBM Q&A

Q: Can we submit offset observations for marks that are not GPS-able?

A: Not for now, unless you follow the NGS Mark Reset Procedures. In the future, OPUS 6.0 will enable you to process and adjust GPS, leveling, and total station observations together, and submit them to NGS.

Q: Can we submit less than 4 hours of data?

A: Yes, but only by using OPUS Projects to Bluebook the data.

Q: Can we submit RTK observations?

A: YES! The recently released BETA version of OPUS Projects 5.1 enables processing of Hybrid Survey Networks that include both static and real-time observations uploaded in the new GVX vector exchange file format.

Required Metadata for GVXonBM

- WinDesc Files → *1 each* of .dsc, .des, .err, .dis, .nbr
  - Yes, for the foreseeable future you will need to download, install, and learn how to use WinDesc
- 3 photos per mark → uploaded to Marks Pages
  1. close-up
  2. downward from eye-level
  3. horizon/setup
- Project Report (PDF)
- Observation Logs (single PDF)

Resources

- Survey Project Proposal Page
- WinDesc Tutorial Video
- OPUS Projects User Guide (HTML version)
- OPUS Projects User Guide (PDF version)
- Requirements for Using OPUS-Projects 5 in the 2023 GPSonBM Campaign

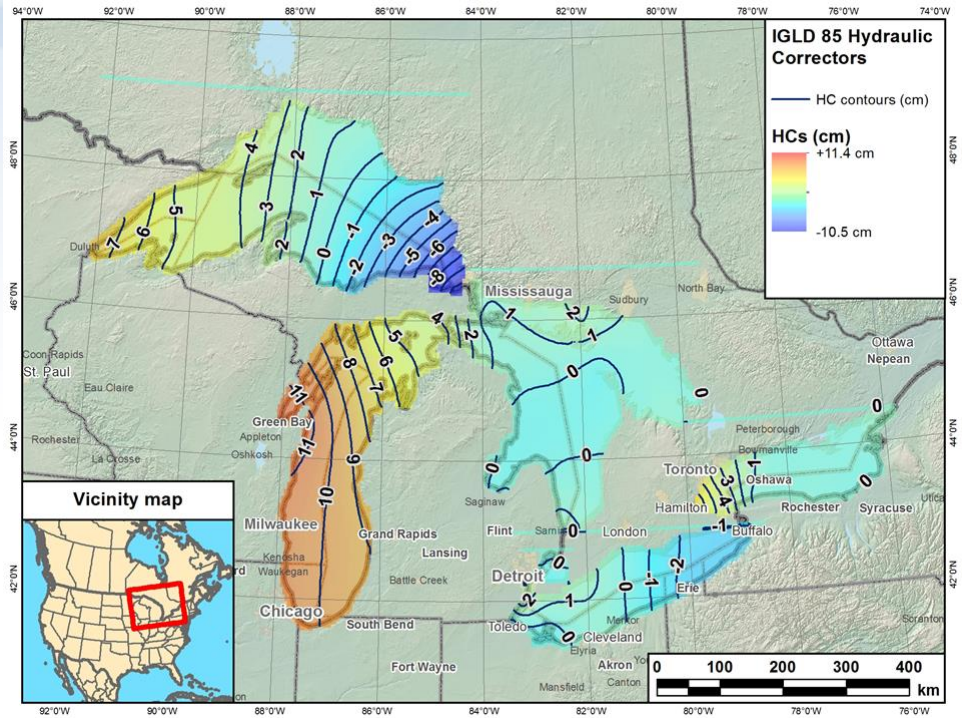
IGLD UPDATE

What is IGLD?

- International Great Lakes Datum (IGLD) is a common height reference system by which water levels can be measured and meaningfully related to each other
- Joint effort between the United States and Canada
- Maintained by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data
- Due primarily to Glacial Isostatic Adjustment, IGLD is updated every 25-35 years
- The next update will be IGLD (2020)

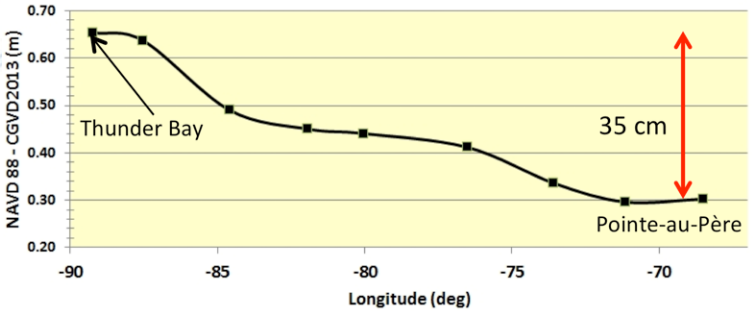
Current IGLD

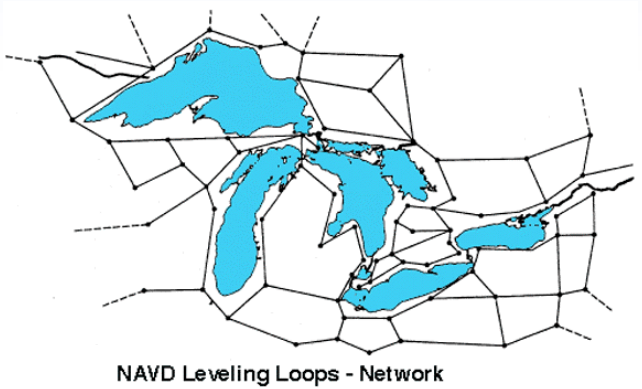
- IGLD (1985) replaced IGLD (1955) in 1992
- Same reference zero as NAVD 88 (at Pointe au Père, Québec)
- Surface determined by leveling
- Dynamic heights
- Hydraulic correctors



IGLD (1985) Reference Surface

- Reference surface is each lake (equipotential surface) to which heights are referenced
- IGLD 1955 & 1985 used 1000's miles of geodetic leveling to indirectly define the reference surface
  - Very time consuming & cost prohibitive
  - Datum accessible only where leveling exists (benchmarks)
  - Susceptible to accumulation of systematic errors
- Extends the reference zero inland



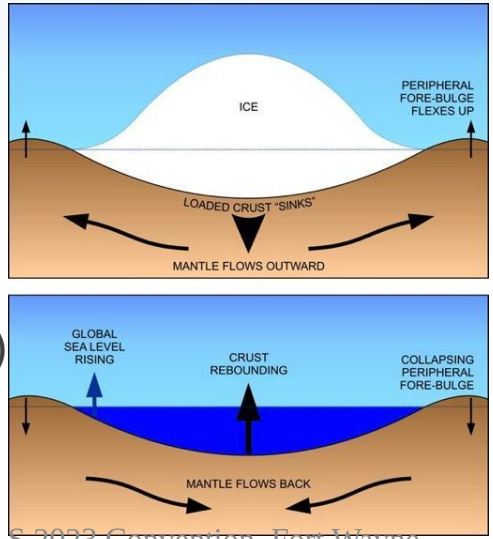


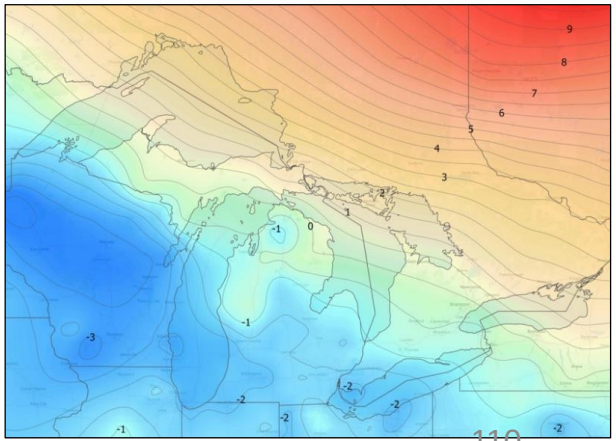
Why a new IGLD?: Glacial Isostatic Adjustment – (GIA)

Process of Glacial Isostatic Adjustment (left) and the resulting tilting of the entire Great Lakes region (right) as determined by high accuracy GPS measurements in units of mm/year. M. Craymer and C. Wisotzkey, 2021.

Entire basin is:

- Uplifting in north
- Subsiding in south
- Overall tilting ~7 mm/year
  (21cm or 0.7' over 30 year)
- Need to update IGLD
  every 25-30 years





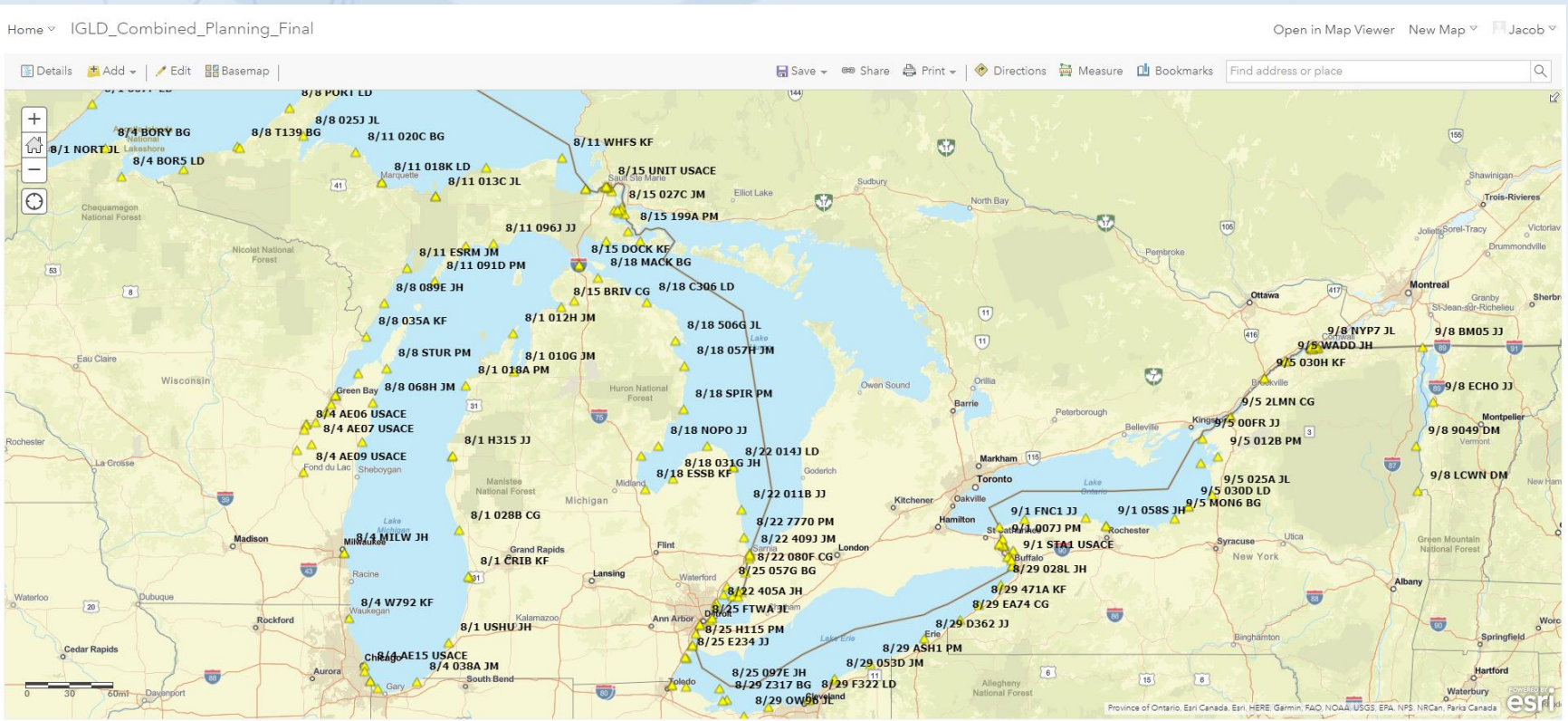
Definition of IGLD (2020)

- Reference Zero
  - W_0 = 62,636,856.00 m^2/s^2 that the U.S. and Canada have adopted for the new geoid-based North American-Pacific Geopotential Datum of 2022 (NAPGD2022) & Canada has already adopted for the Canadian Geodetic Vertical Datum of 2013 (CGVD2013)
- Realization of the Reference Surface
  - NAPGD2022 geoid model representing the reference zero everywhere over the Great Lakes – St. Lawrence River system, not only where leveling and bench marks exist
- Reference Epoch
  - 2020.0, the central epoch of the 7-year water level observation period of 2017–2023
- Dynamic Height
  - IGLD (2020) will use dynamic heights derived from GNSS occupations
  - The dynamic height represents the difference in potential above the reference surface and is the same at all points on a level surface

Status of IGLD Update

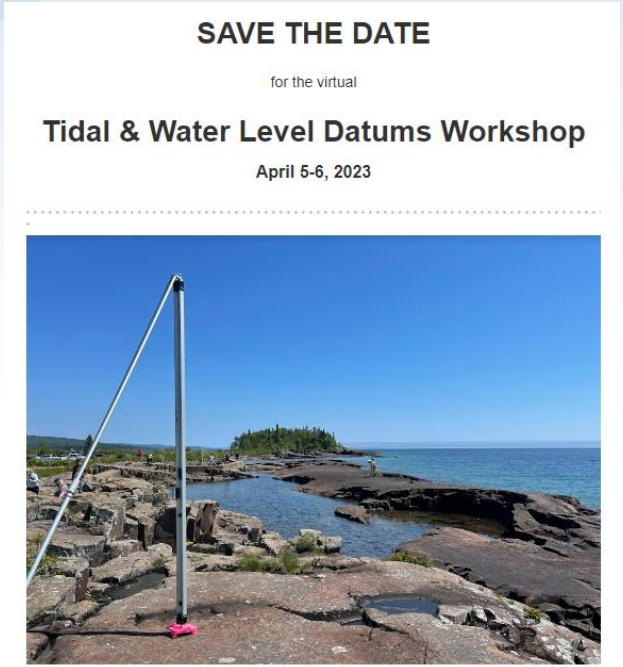
- GNSS field campaign took place in 2022 – data processing continues
- Seasonal gauging continues
- Hydraulic corrector working group is investigating the need for HCs in IGLD (2020)
- IGLD (2020) is planned for release about one year after the release of the NAPGD2022 vertical datum (around 2026)

2022 IGLD GNSS Campaign



Save the Date! Water Level Datum Workshop

- NOAA, the Canadian Hydrographic Service (CHS), and the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data would like to invite you to a virtual workshop on Tidal and Water Level Datums. Participants will have the opportunity to learn more about the datums and impacts on the coastal, navigation and shipping communities and industries.
- ***April 5****: National Tidal Datum Epoch (NTDE)*
- ***April 6****: International Great Lakes Datum (IGLD) and the Low Water Datum (LWD)*
- The workshop will feature presentations and discussions from NOAA's Center for Operational Oceanographic Products and Services, the National Geodetic Survey, and the Office of Coast Survey, as well as U.S. Army Corps of Engineers, CHS, Natural Resources Canada, Environment and Climate Change Canada, and others.



Save the Date! NGS day at FIG 2023

NGS will present a full day's worth of content at the 2023 FIG Working Week in Orlando, FL on May 31, 2023

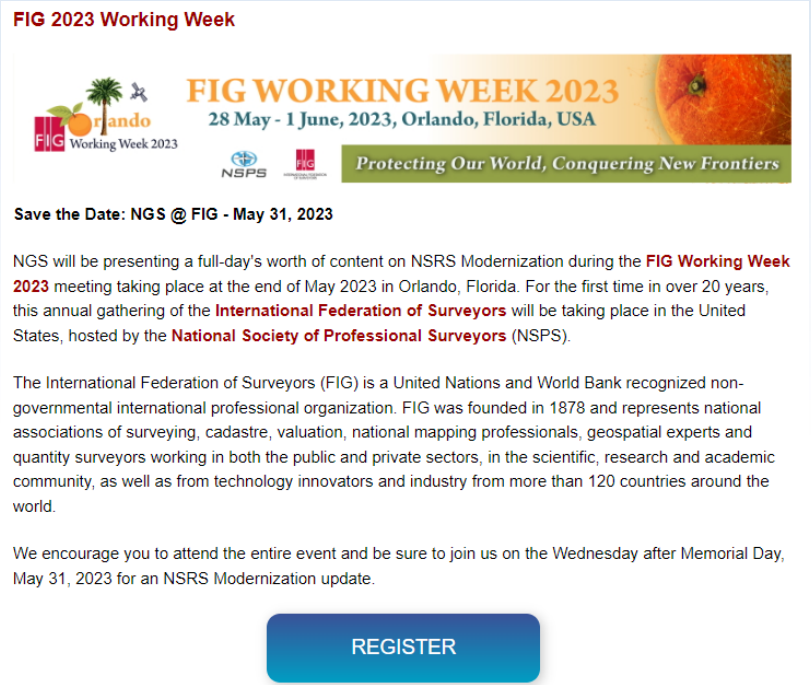


FIG 2023 Working Week

FIG Working Week 2023 Orlando

FIG WORKING WEEK 2023

28 May - 1 June, 2023, Orlando, Florida, USA

Protecting Our World, Conquering New Frontiers

Save the Date: NGS @ FIG - May 31, 2023

NGS will be presenting a full-day's worth of content on NSRS Modernization during the **FIG Working Week 2023** meeting taking place at the end of May 2023 in Orlando, Florida. For the first time in over 20 years, this annual gathering of the **International Federation of Surveyors** will be taking place in the United States, hosted by the **National Society of Professional Surveyors** (NSPS).

The International Federation of Surveyors (FIG) is a United Nations and World Bank recognized non-governmental international professional organization. FIG was founded in 1878 and represents national associations of surveying, cadastre, valuation, national mapping professionals, geospatial experts and quantity surveyors working in both the public and private sectors, in the scientific, research and academic community, as well as from technology innovators and industry from more than 120 countries around the world.

We encourage you to attend the entire event and be sure to join us on the Wednesday after Memorial Day, May 31, 2023 for an NSRS Modernization update.

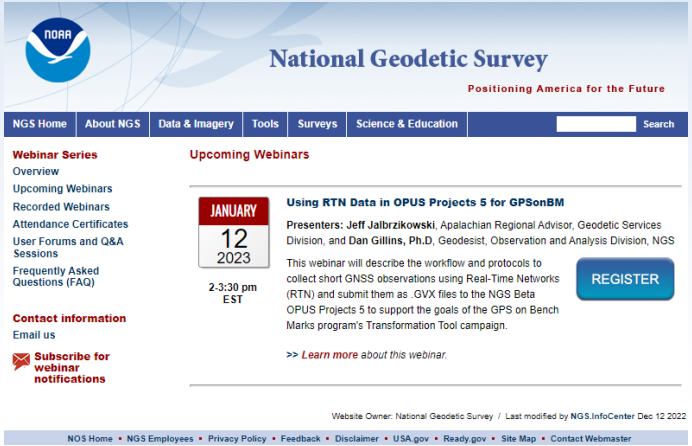
REGISTER

https://fig.net/fig2023/

https://geodesy.noaa.gov/datums/newdatums/fig-2023.shtml

NGS Webinar Series

- Monthly webinars highlight geodesy and coastal mapping programs, products, and research
- Each webinar features an NGS employee delving into a topic of interest, and generally includes a moderated question and answer session
- Registration is free and video recordings are made available for later viewing
- Certificates of attendance are available



https://geodesy.noaa.gov/web/science_edu/webinar_series/

https://geodesy.noaa.gov/

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

Process GPS Data (OPUS) | NGS Data Explorer | Looking for Bench Marks | Conversion & Transformation (NCAT) | NOAA CORS Network | New Datums

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Storm Imagery | State Plane Coordinates | News Bulletins

Thank You!

Jacob M. Heck, Ph.D., P.S.
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U.S. National Geodetic Survey, NOAA
jacob.heck@noaa.gov

c/o NOAA Great Lakes Environmental Research Laboratory
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Ann Arbor, MI 48108

For more information, visit https://geodesy.noaa.gov