NGS UP-DATES

9/15/2020













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MODERNIZATION OF THE NATIONAL SPATIAL REFERENCE SYSTEM


HUH ?

NSRS MODERINIZATION

- What is the NSRS?
  - A consistent coordinate system that defines:
    - Latitude
    - Longitude
    - Height
    - Scale
    - Orientation
    - Gravity
- Throughout the United States and it’s territories

...and their time variants

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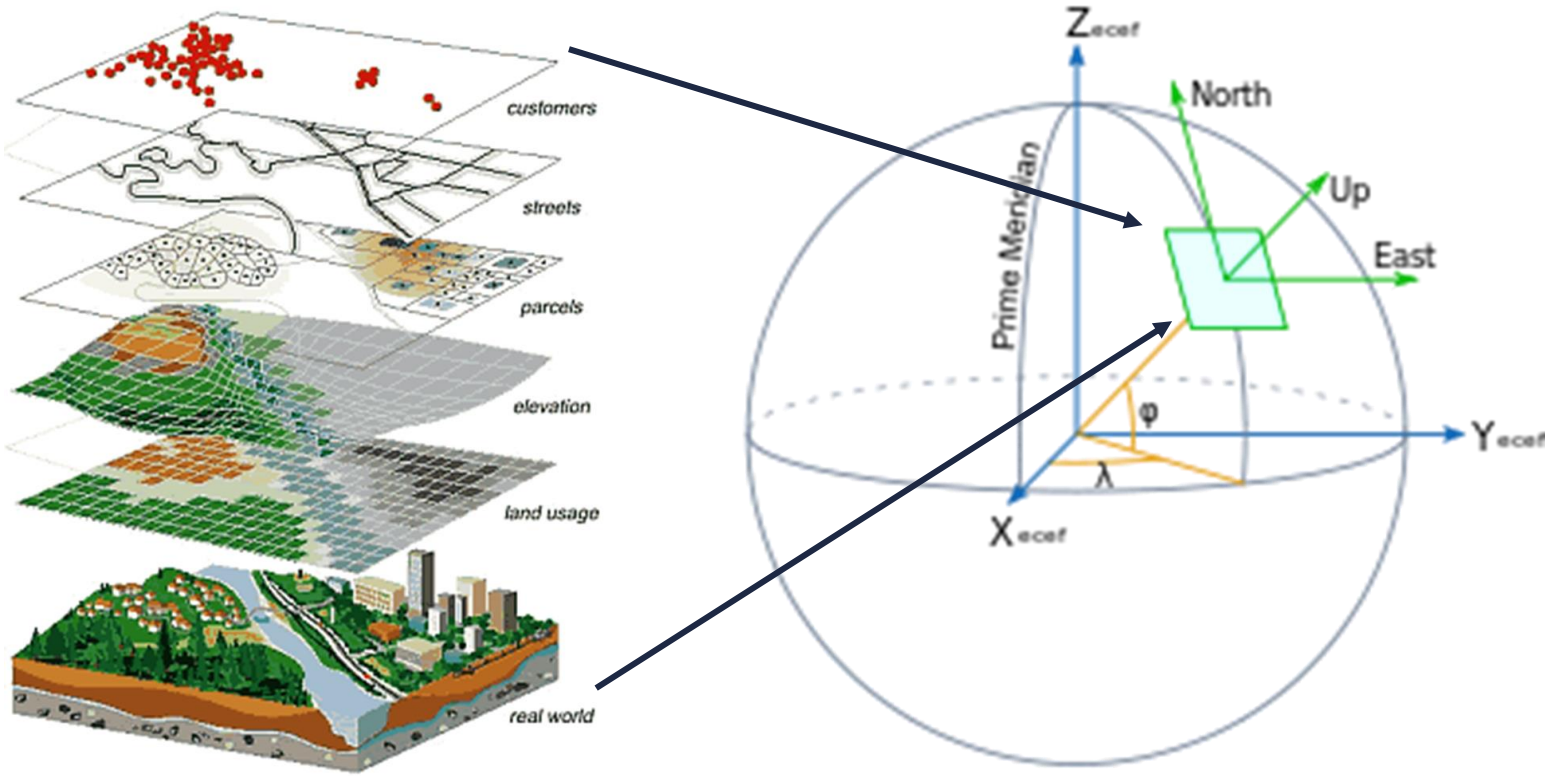
WHAT IS THE NSRS



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	

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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

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Hyperlink to ITRF station map

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NATIONAL SPATIAL REFERENCE SYSTEM

EVOLUTION OF THE NSRS

NAD27 → NAD83 (1986) → NAD83 (2011)

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HORIZONTAL DATUMS

- NAD 27

  - Surveys of the entire continent that started at a common reference point or triangulation station that was near the geographic center of the United States (Meades Ranch Triangulation Station). The Latitudes and Longitudes of every point in North America was based off its direction, angle and distance away from Meade's Ranch and could be measured on the Clarke Ellipsoid of 1866.

  - NAD 27 took all surveys from the USSD and did a least squares adjustment holding Meades Ranch Triangulation Station as fixed.
    - Adjusted 26,000 positions
    - Several hundred measured baselines
    - Several hundred Astronomical Azimuths

odot

Horizontal Datums

- NAD 27
- North American Datum (official release 1913):
  - Canada and Mexico agree to base their triangulation networks on the USSD. The USSD was re-named to North American Datum to reflect their adoption.
    - Origin: Meades Ranch
    - Ellipsoid: Clarke 1866

Relied on triangulation surveys that crisscrossed the United States. Many years of this type of surveying led to many independent surveys from the United States Standard Datum and the North American datum that were not “tied” together. After many surveys were completed started to see overlaps in the surveys.

Horizontal Datums

- Datums
  - Uni

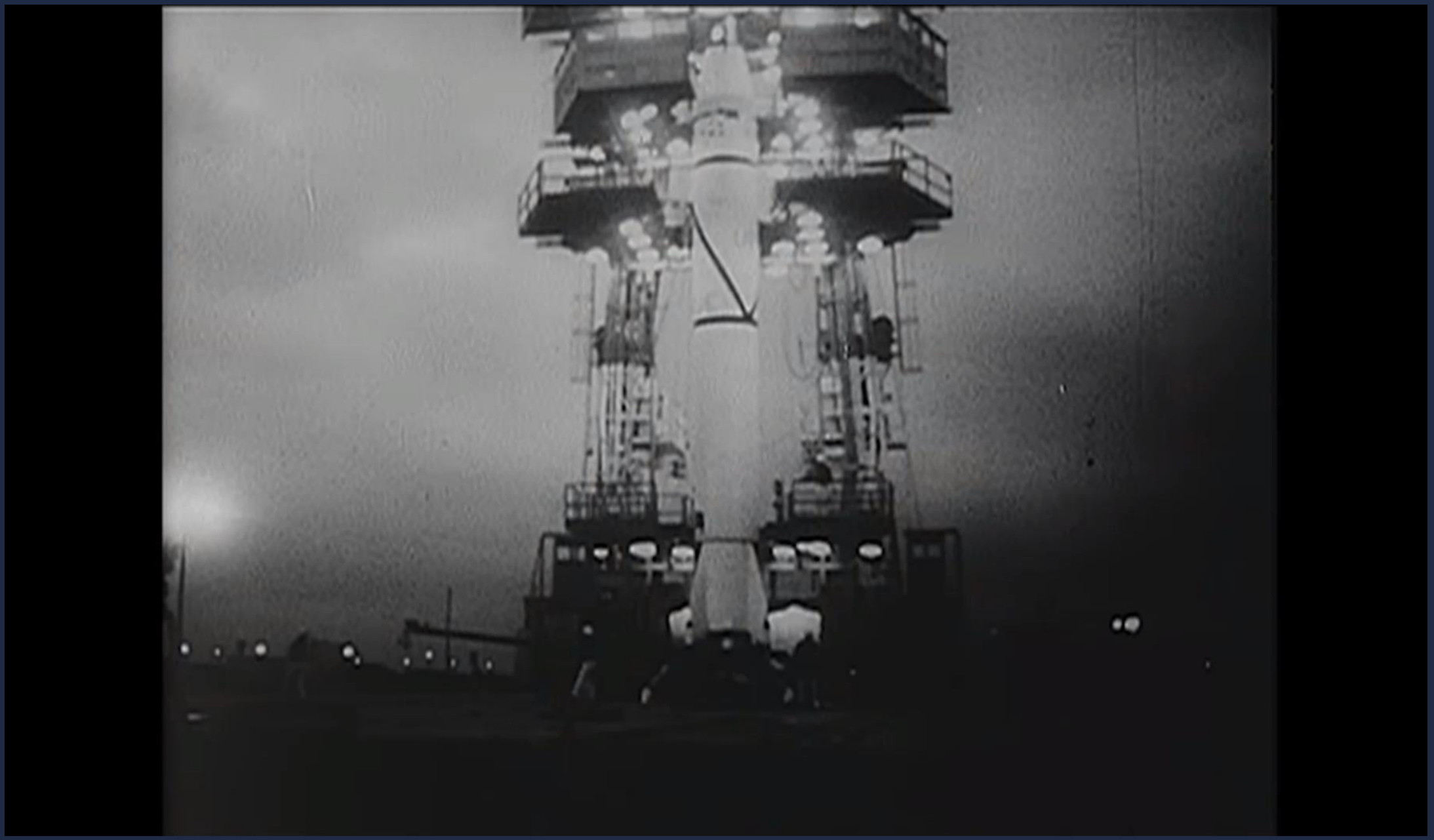
Horizontal Datums

- NAD 27
  - Dr. William Bowie
    - Chief of the Geodesy Division

      United States Coast and Geodetic Survey

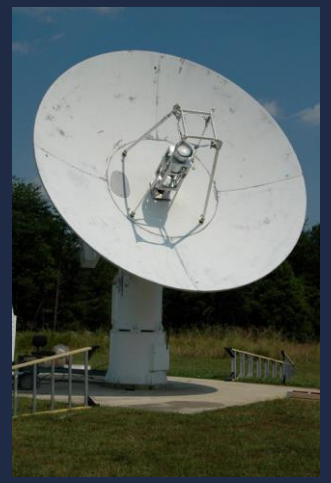
      1909-1936

In 1913 Dr. Bowie persuaded the geodesists of Canada and Mexico to formally connect the surveys of their countries to the existing United States Standard Datum. Dr. Bowie was credited with designing the method of computing the readjustment of the USC&GS geodetic networks which Canada and Mexico later followed creating the North American Datum of 1927



CO-LOCATION SITE

NASA GODDARD SPACE FLIGHT CENTER, GREENBELT MD, USA



- GNSS, SLR, VLBI, DORIS

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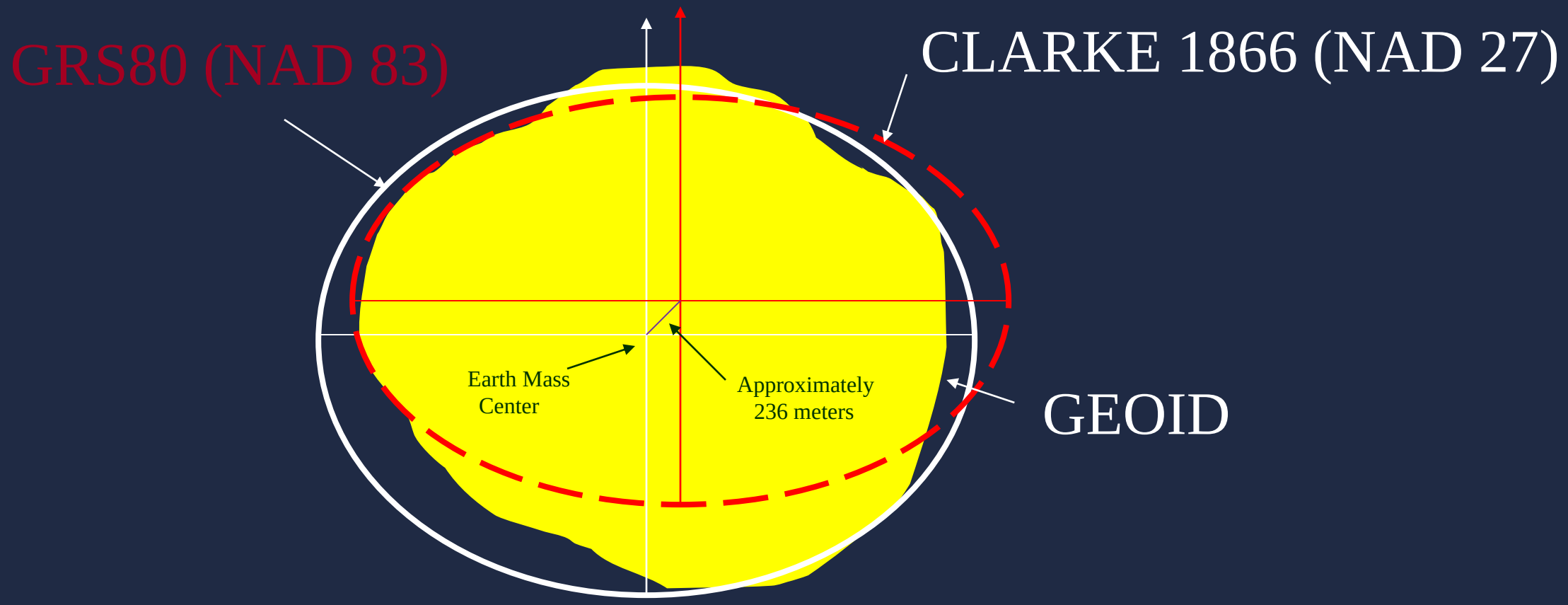
THE GEOID AND TWO ELLIPSOIDS



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EVOLUTION OF THE NSRS

NAD27 → NAD83 (1986) → NAD83 (2011)

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Geocentric Datums

- NAD 83:

NAD 83 computations were processed on an IBM 3081 computer. It processed data at a rate of 5 million instructions per second. Todays i7 processor can handle 180 billion!

Geocentric Datums

- NAD 83:

  - NAD 83 transformed datums from a fixed “assumed” datum to a true global datum or reference frame.

    - NAD 83
      - 1,785,772 Observations
      - Adjusted 266,436 monuments
      - 30,000 EDMI Base Lines
      - 5,000 Astronomical Azimuths
      - Doppler and laser ranging measurements to satellites
      - VBLI measurements to Quasars

dot

Geocentric Datums

- NAD 83:

  - NAD 83 transformed datums from a fixed “assumed” datum to a true global datum or reference frame based on the mass center of the earth.

    - Based on the GRS 80 Ellipsoid
      - Semi Major Axis: 6,378,137 meters
      - 1/f = 298.257222101
    - GRS-80 is positioned to be geocentric and oriented to the Bureau International de l’Heure (BIH) Terrestrial System of 1984 (BTS-84)
    - Similar to other modern global reference systems like WGS-84 (almost!)

Geodesy 101

- NAD 83 adjustment spanned more than a decade
- Involved more than 300 people
- Largest single activity at NGS from 1974 until 1986
- Project Managers:
- John D. Bossler (1974-1983)

  NAD 83 Project Manager, Director of the Center for Mapping at The Ohio State University, Member of PLSO!
- John Gergen (1983-1984)
- Libby Wade (1984-1986)

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NATIONAL SPATIAL REFERENCE SYSTEM

EVOLUTION OF THE NSRS

NAD27 → NAD83 (1986) → NAD83 (2011)

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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 instability; active control via CORS

CONSISTENCY

- Eliminates systematic errors in current datums
- Aligned with global reference frame

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NATIONAL SPATIAL REFERENCE SYSTEM

NATRF 2022

North American Terrestrial Reference Frame 2022

1. develop four "plate-fixed" reference frames
2. **remove non-geocentricity of NAD83**
3. align to ITRF2014 at epoch 2020.00
4. remove most of tectonic plate rotation from ITRF2014 via Euler Pole Parameters

Shift and Drift…

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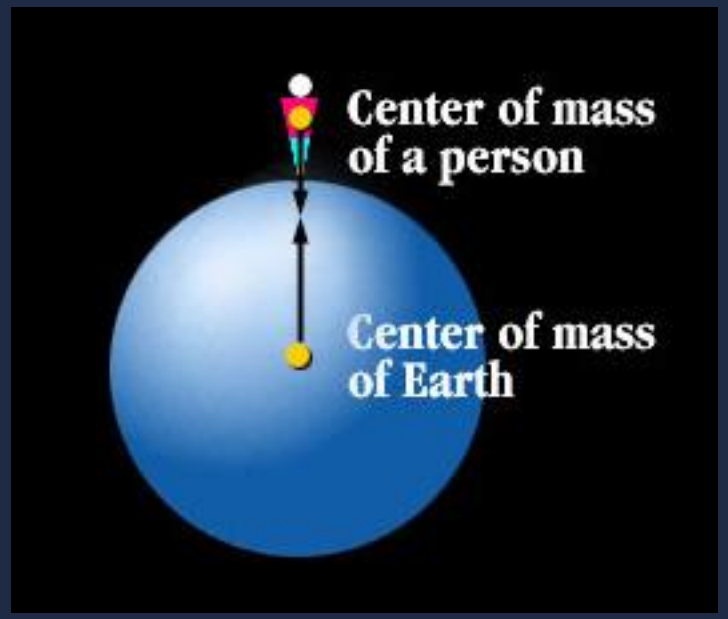
FIRST…THE SHIFT

Non-geocentricity?

- Geocentric:
  - relating to, measured from, or as if observed from the earth's center of mass



- The goal was to accomplish that in NAD 83… but didn't.

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NON-GEOCENTRICITY OF NAD83

GRS = Geodetic Reference System

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NON-GEOCENTRICITY OF NAD83

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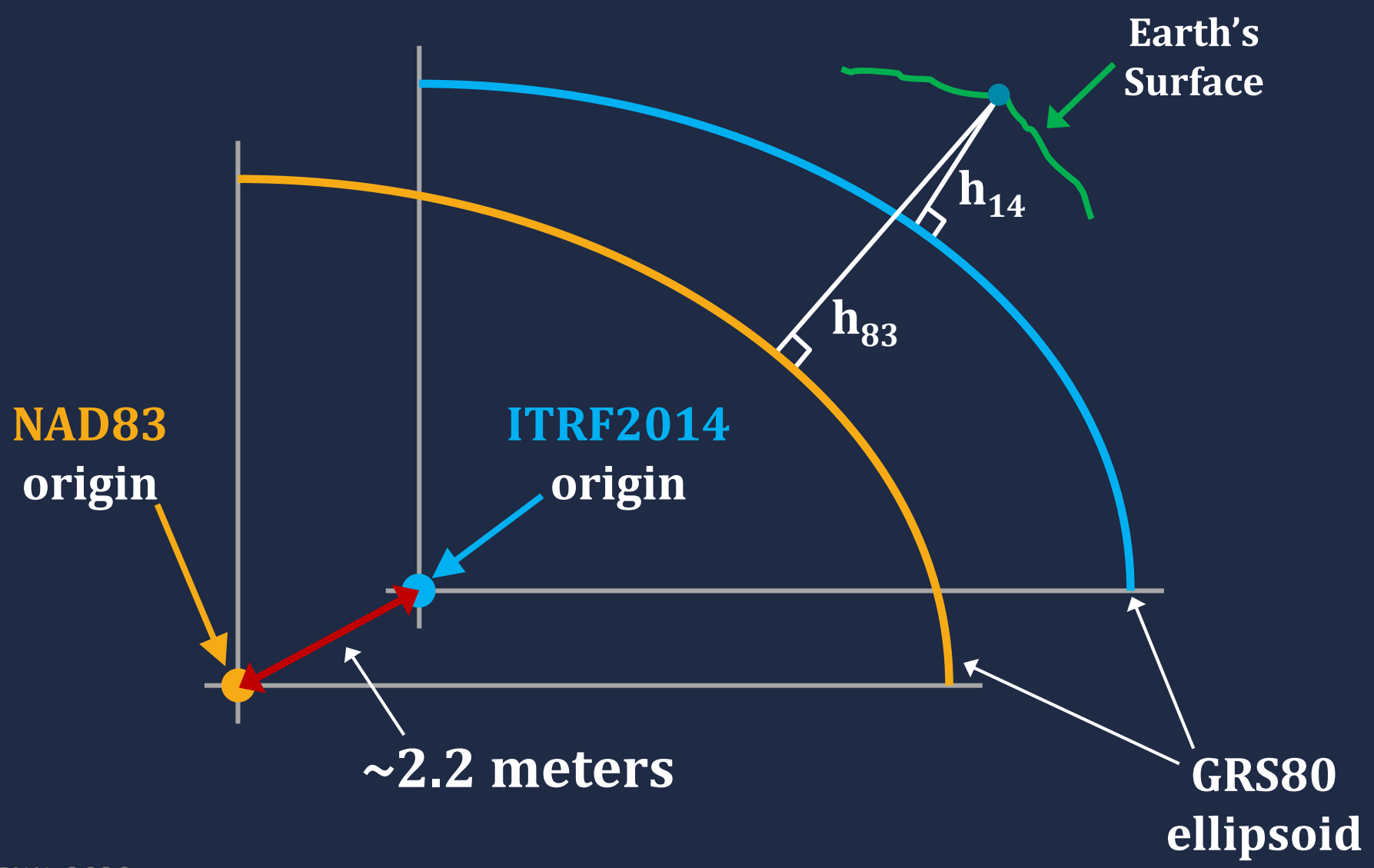
NON-GEOCENTRICITY OF NAD83



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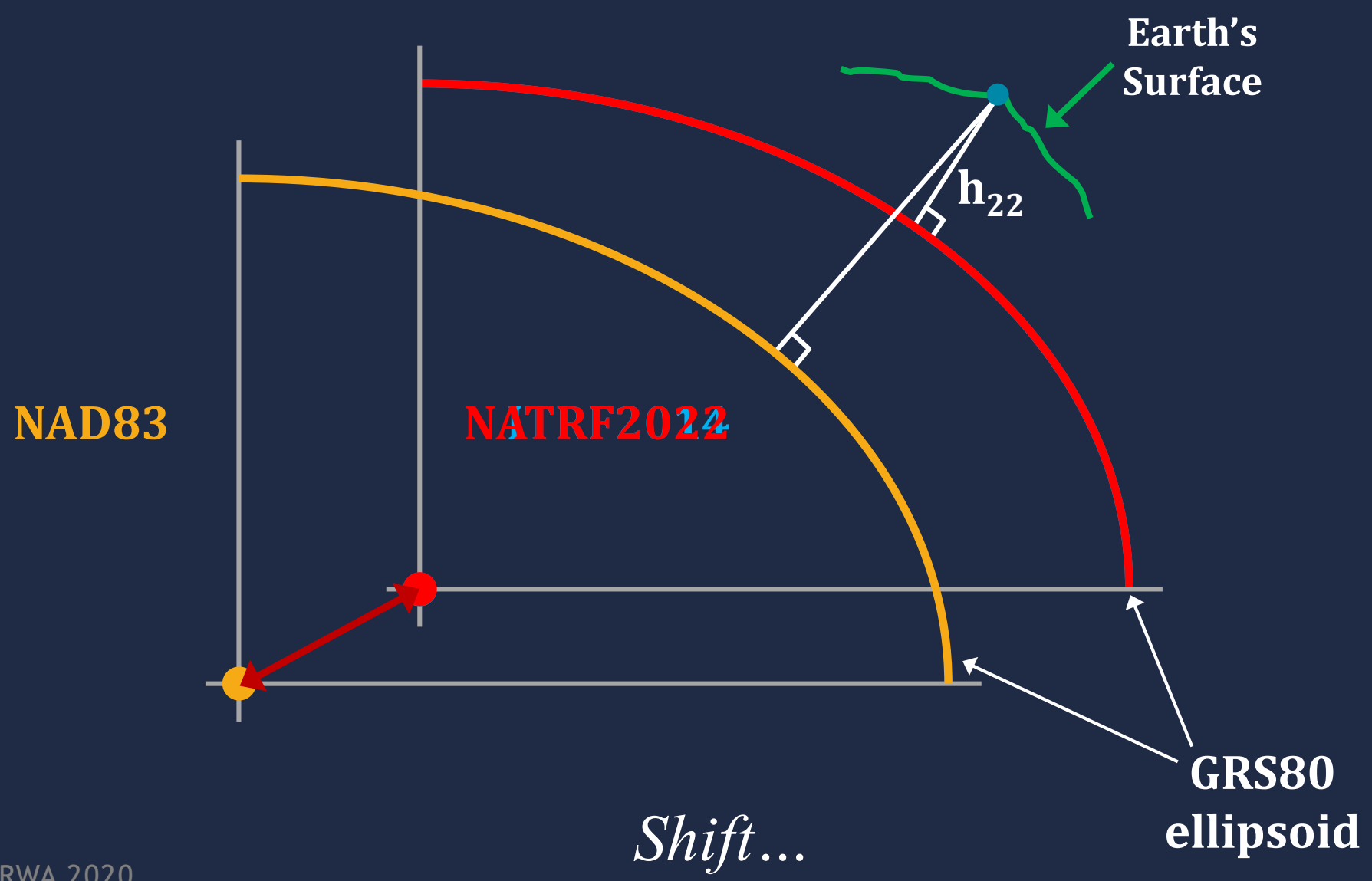
NON-GEOCENTRICITY OF NAD83



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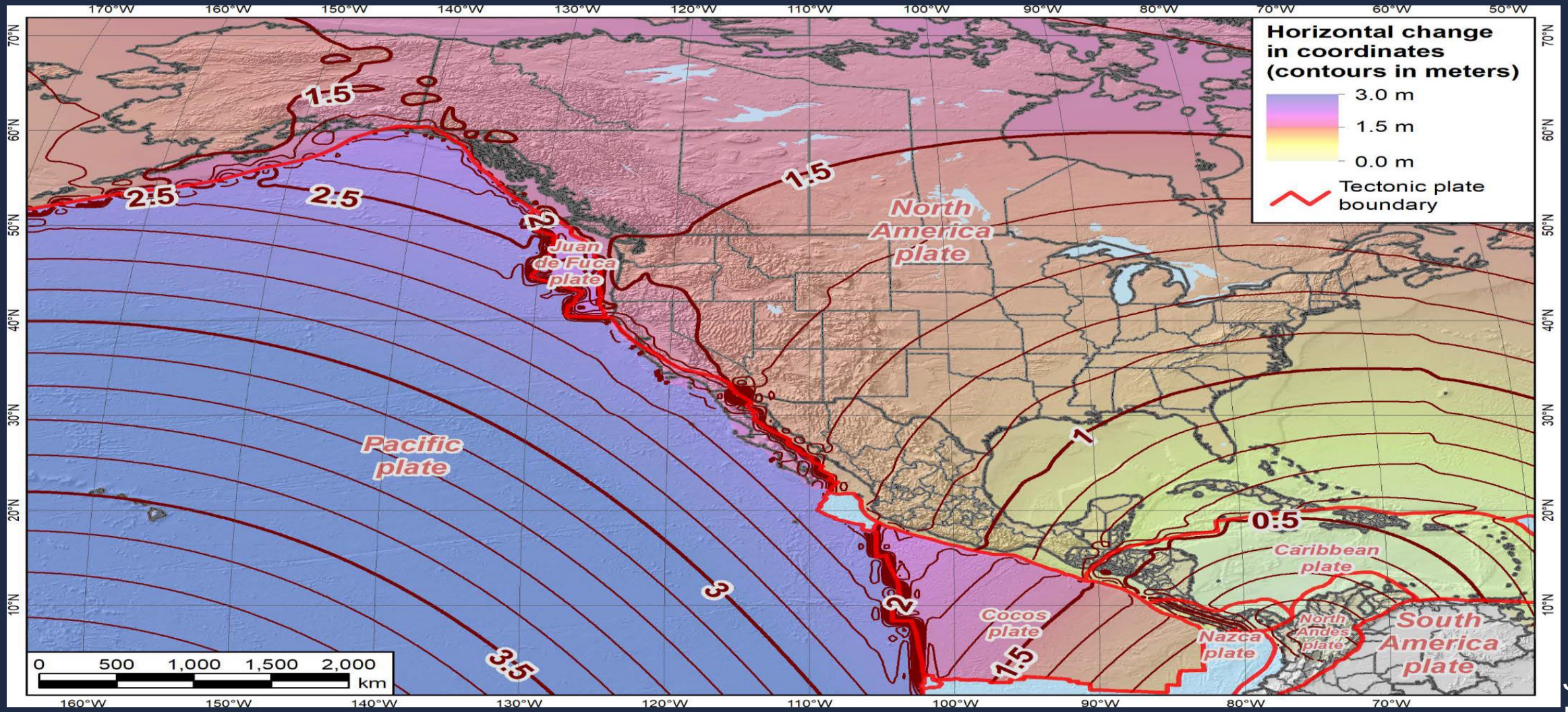
NATIONAL SPATIAL REFERENCE SYSTEM



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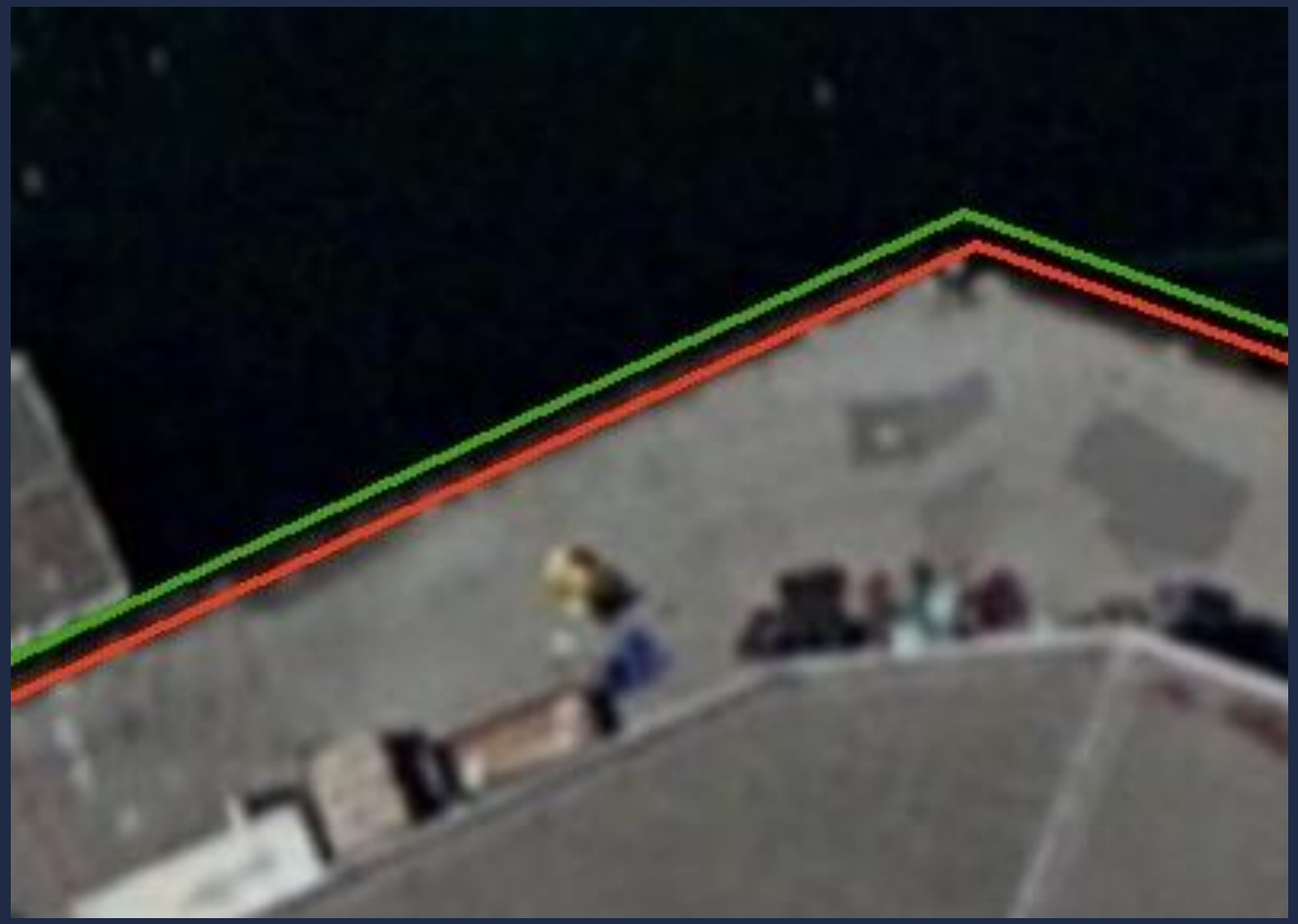
What's that going to look like?

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



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NOW…THE DRIFT

TWO TYPES OF DRIFT

Tectonic Plate Rotation

- horizontal

simple to model

Everything Else

- residual motions left after rotation
- regional linear motions
- localized subsidence or uplift

complex

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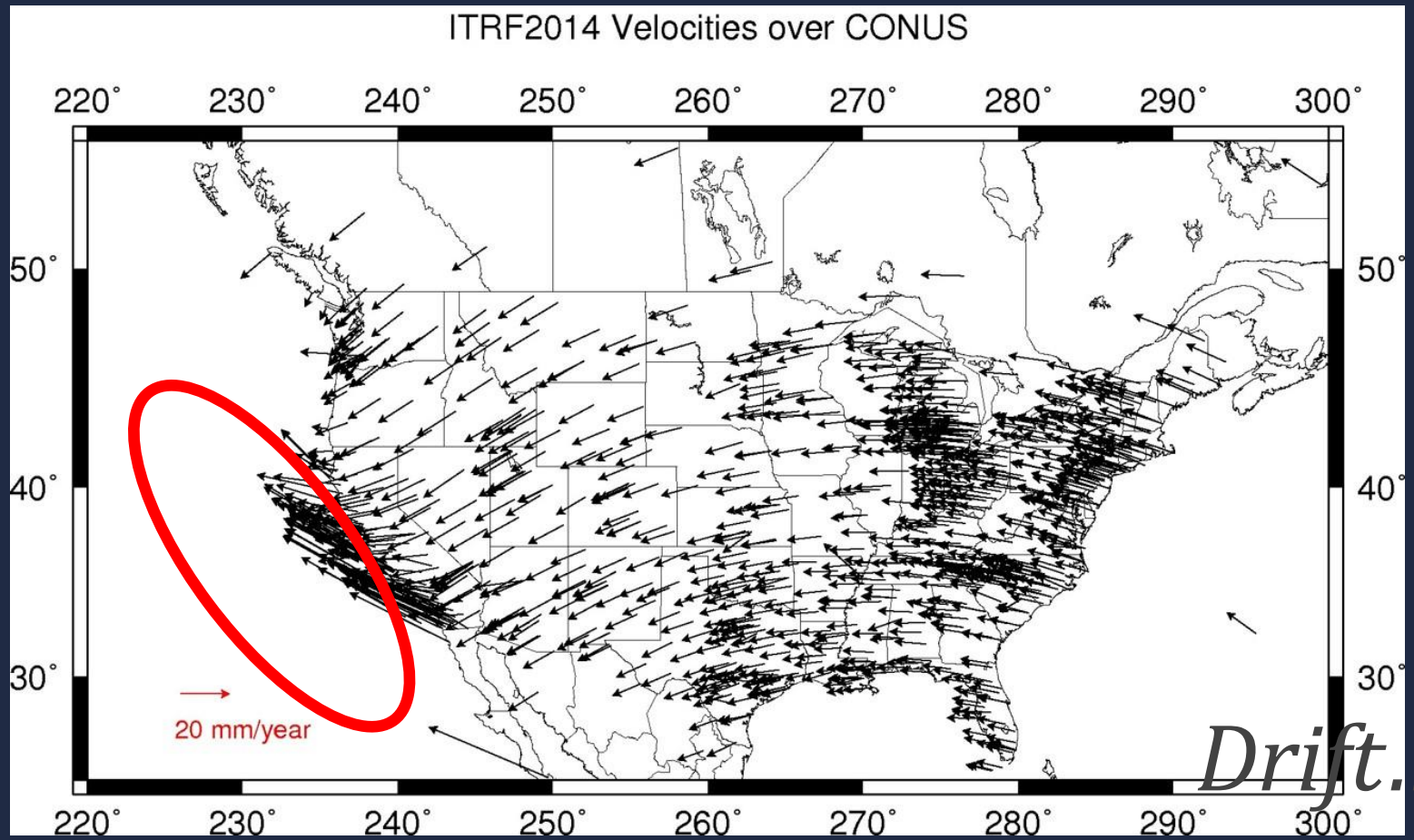
PLATE ROTATION VISUALIZED



Drift…

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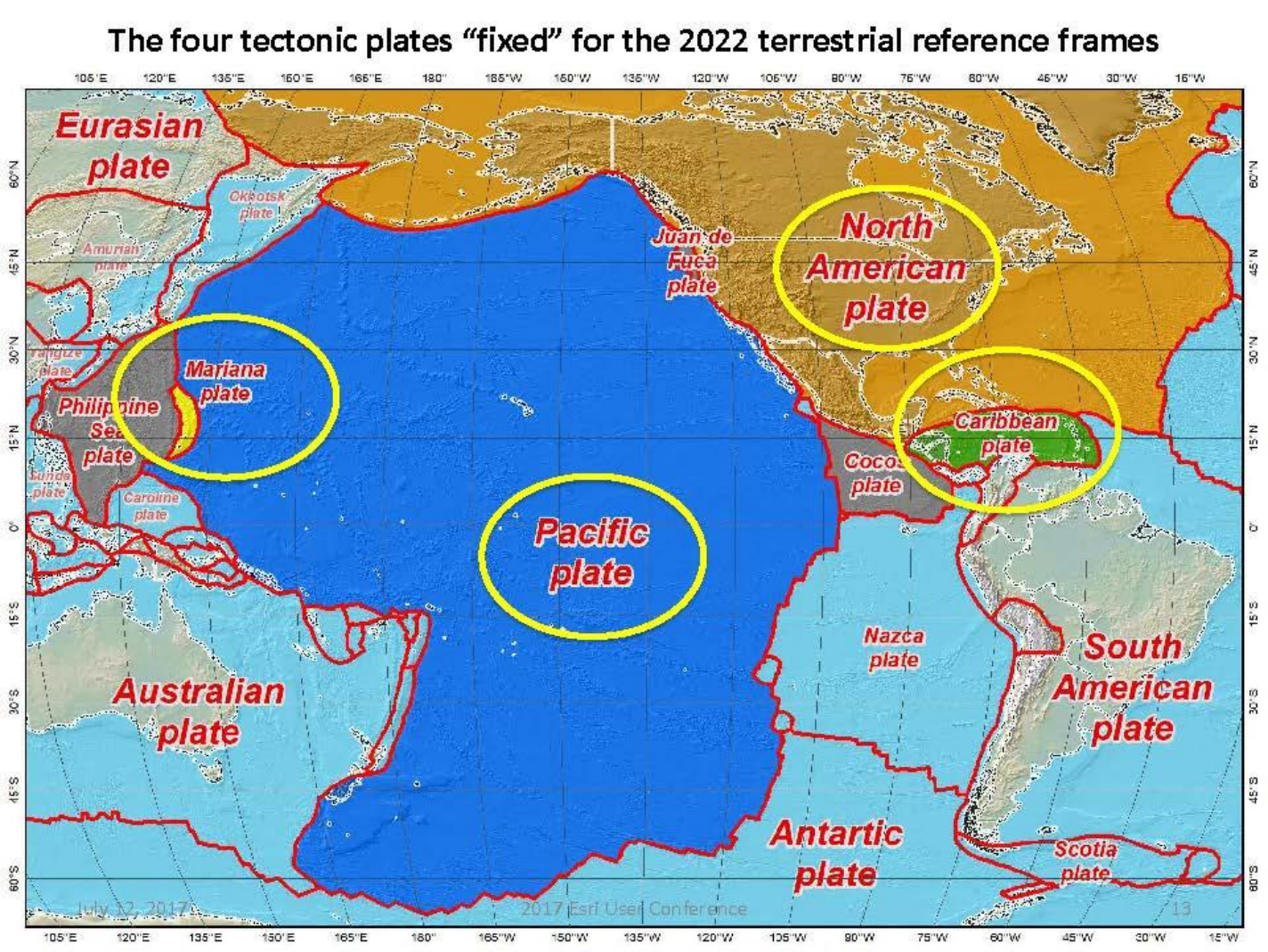
PLATE ROTATION VISUALIZED



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EPP – EULER POLE PARAMETERS

Latitude
Longitude
Rotation Speed

yellow star off west coast of S. America

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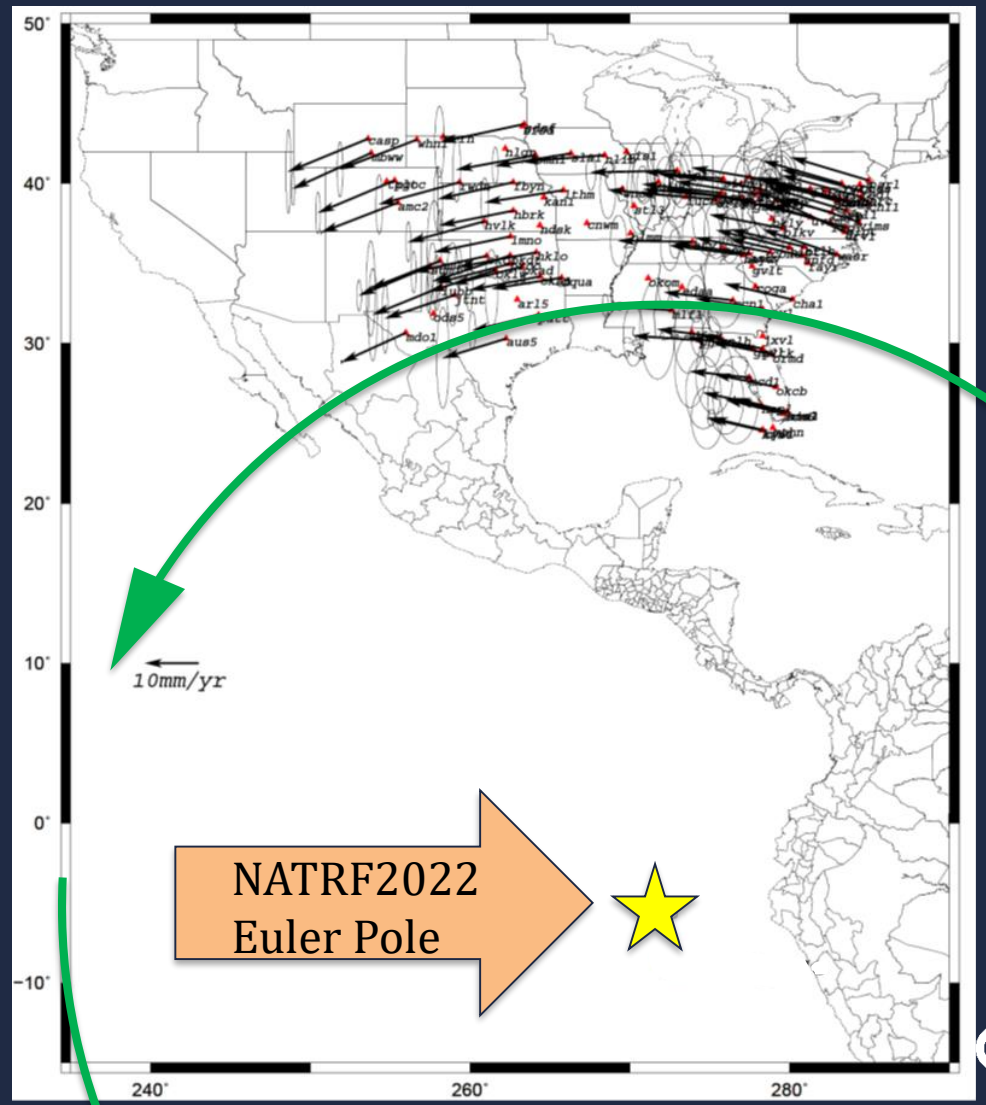
EULER POLES AND "PLATE-FIXED"

- In the ITRF, many tectonic plates have a *dominant* motion: **rotation**
- **Euler Pole** - point about which a plate rotates (yellow star)



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EULER POLES AND "PLATE-FIXED"

ITRF	NATRF
Frame = constant	Frame = rotating
NA Plate = rotating	NA Plate = constant

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EULER POLES AND "PLATE-FIXED"

ITRF

Frame = constant

NA Plate = rotating

NATRF

Frame = rotating

(*relative to ITRF*)

NA Plate = constant

(*relative to NATRF2022*)

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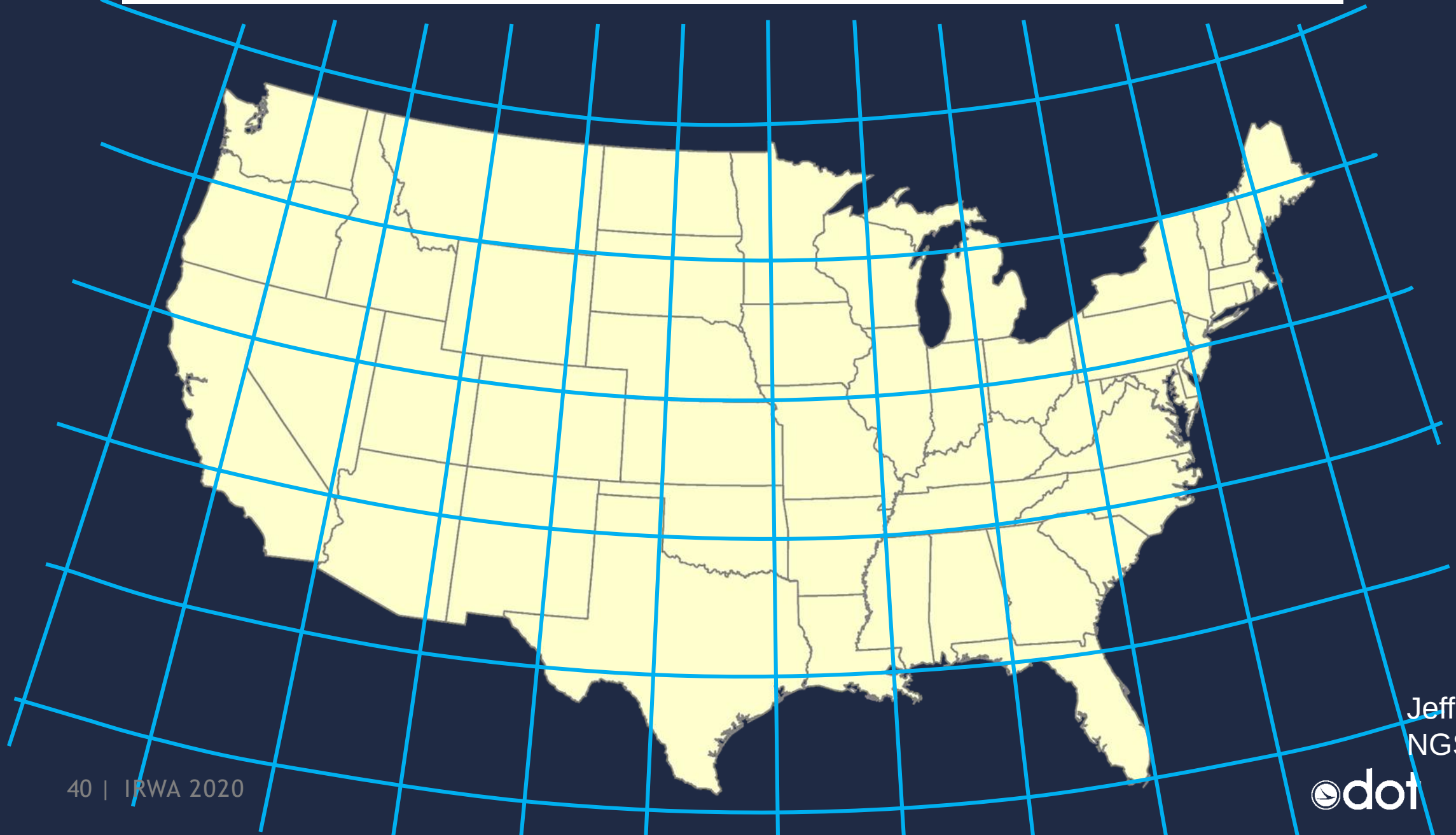
ITRF – constant frame, rotating plate



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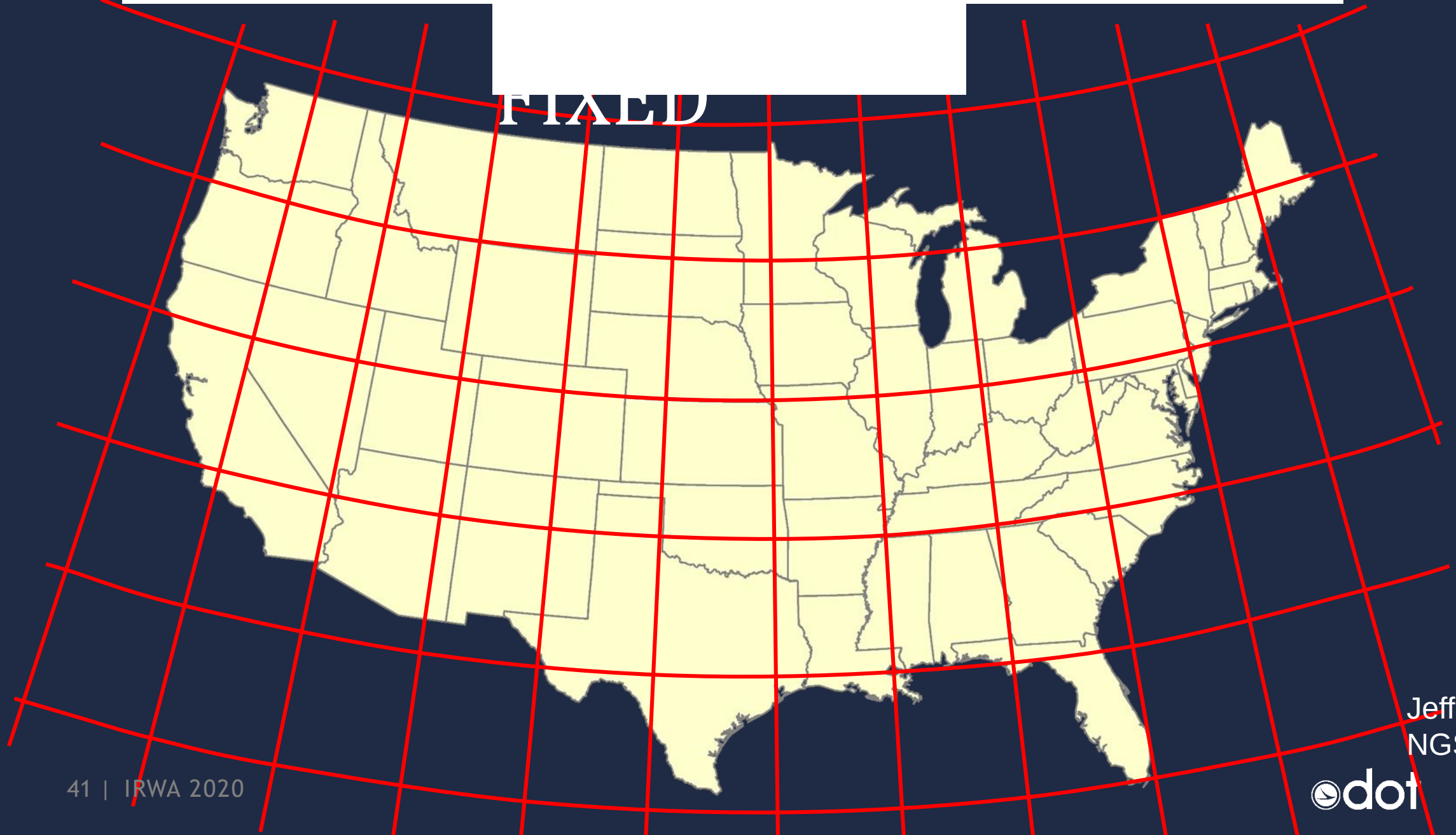
NATRF – rotating frame, constant with plate



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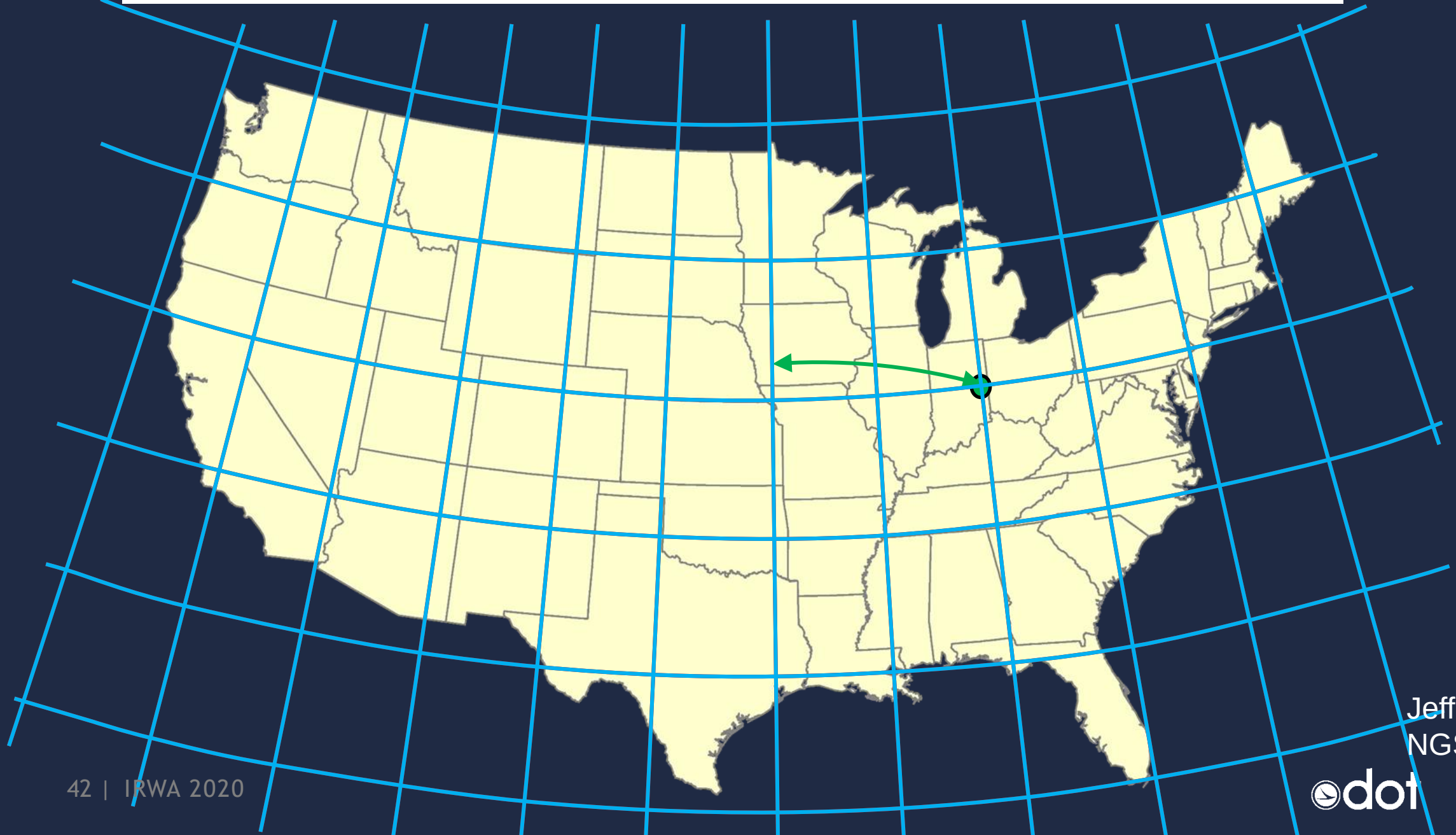
ITRF or NATRF – your choice, just use EPP



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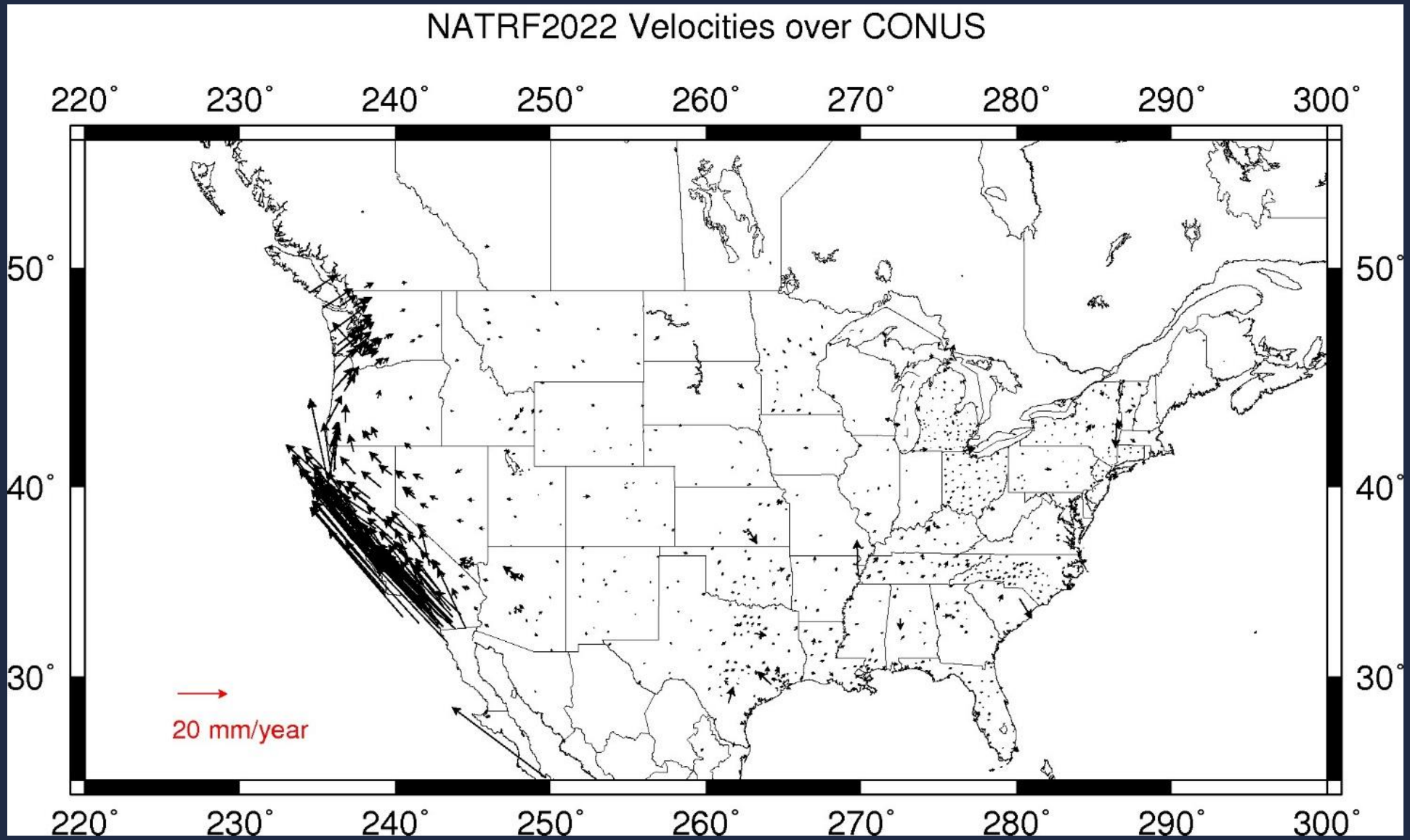
IFVM goal = model all velocities



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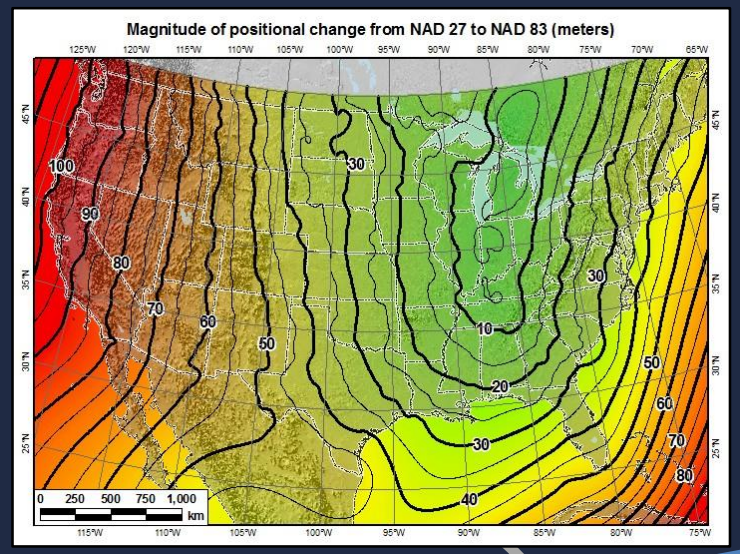
HISTORY OF U.S. HORIZONTAL & GEOMETRIC DATUMS



triangulation

GNSS

US Standard Datum

NAD27

NAD83(1986)

NAD83(HARN/199#)

NAD83(2007)

NAD83(2011)

NATRF2022

time

<10 m	tens of meters	few 0.1m	few 0.01m	few 0.01m	~2m

shift dot

NEW VERTICAL DATUM:

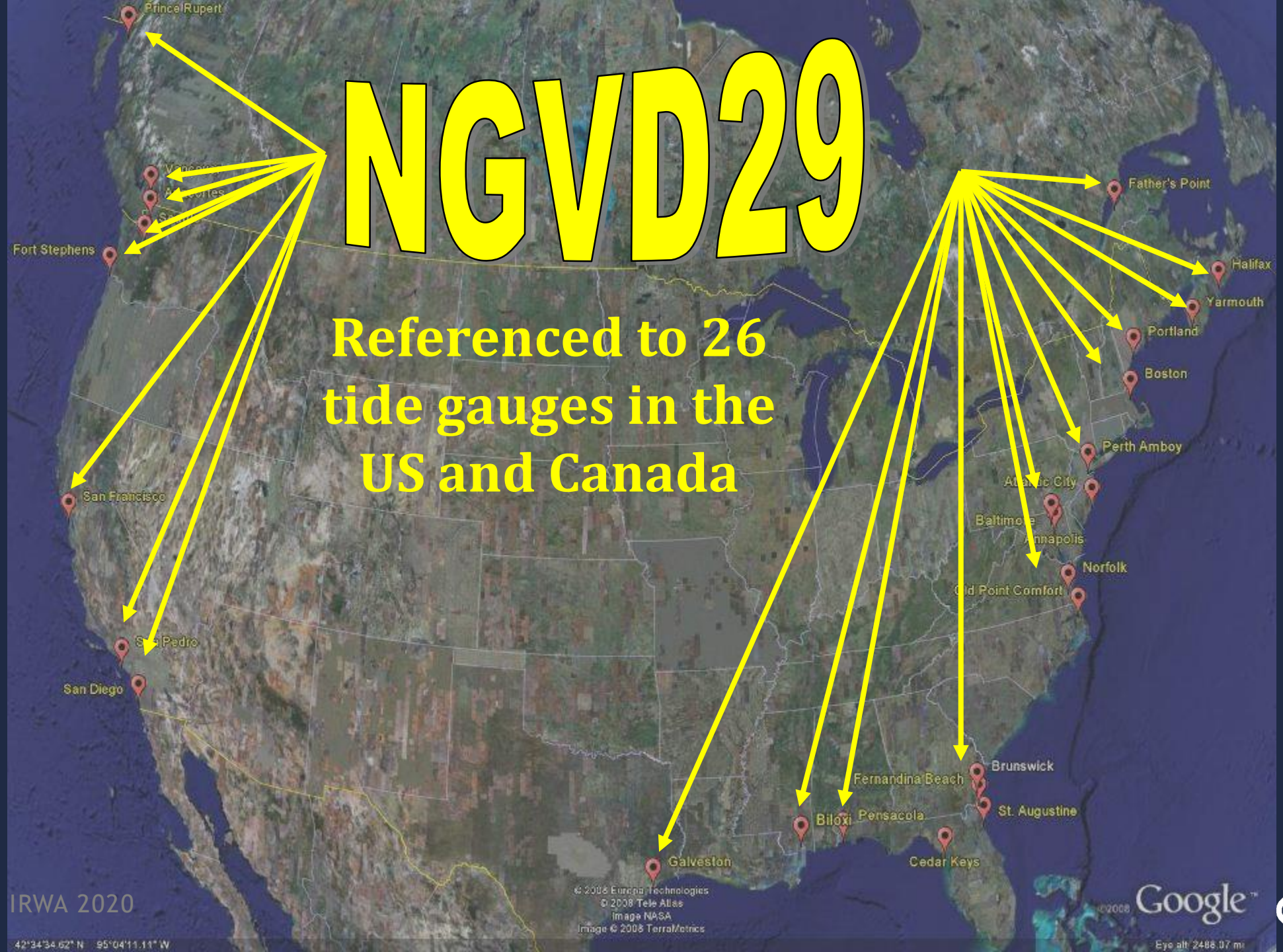
North American-Pacific Geopotential Datum of 2022

SOMEBODY MAKE HIM STOP!

odot

NGVD29

Referenced to 26 tide gauges in the US and Canada



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NAVD88

Referenced to a single tide gauge in Canada

Why one gage fixed this time?
–removed local sea level variation problem of NGVD29

But it did introduce possibility of cross-continent error build-up…

Father Point Lighthouse, Quebec

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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**)

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NAPGD 2022

- New Vertical datum based on Gravity models (New Geoid Model)
- **NOT** a Hybrid Geoid Model like Geoid 09, GEOID 12B, Geoid 18, etc.
- Will see significant differences in elevation at any given location.

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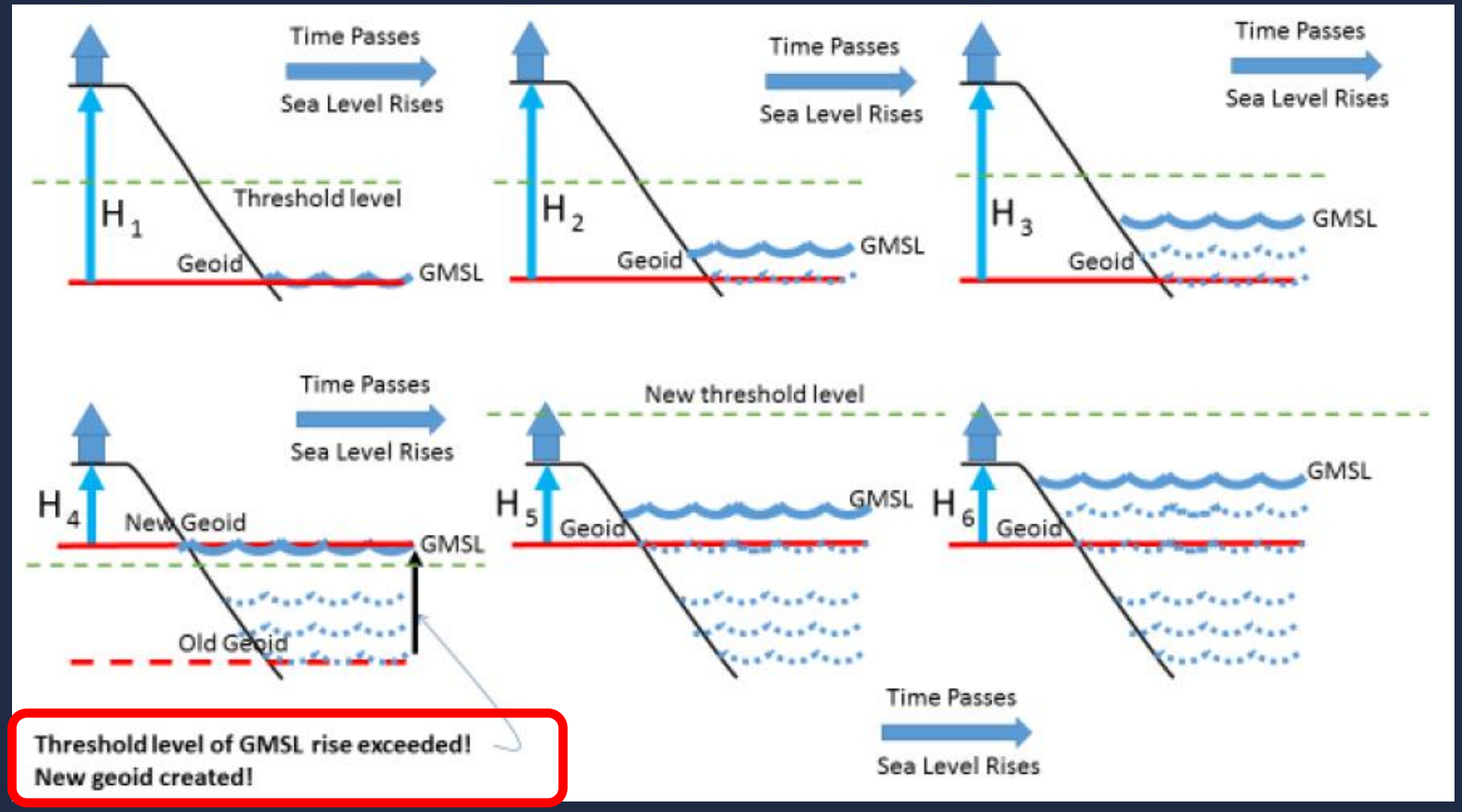
NAPGD 2022



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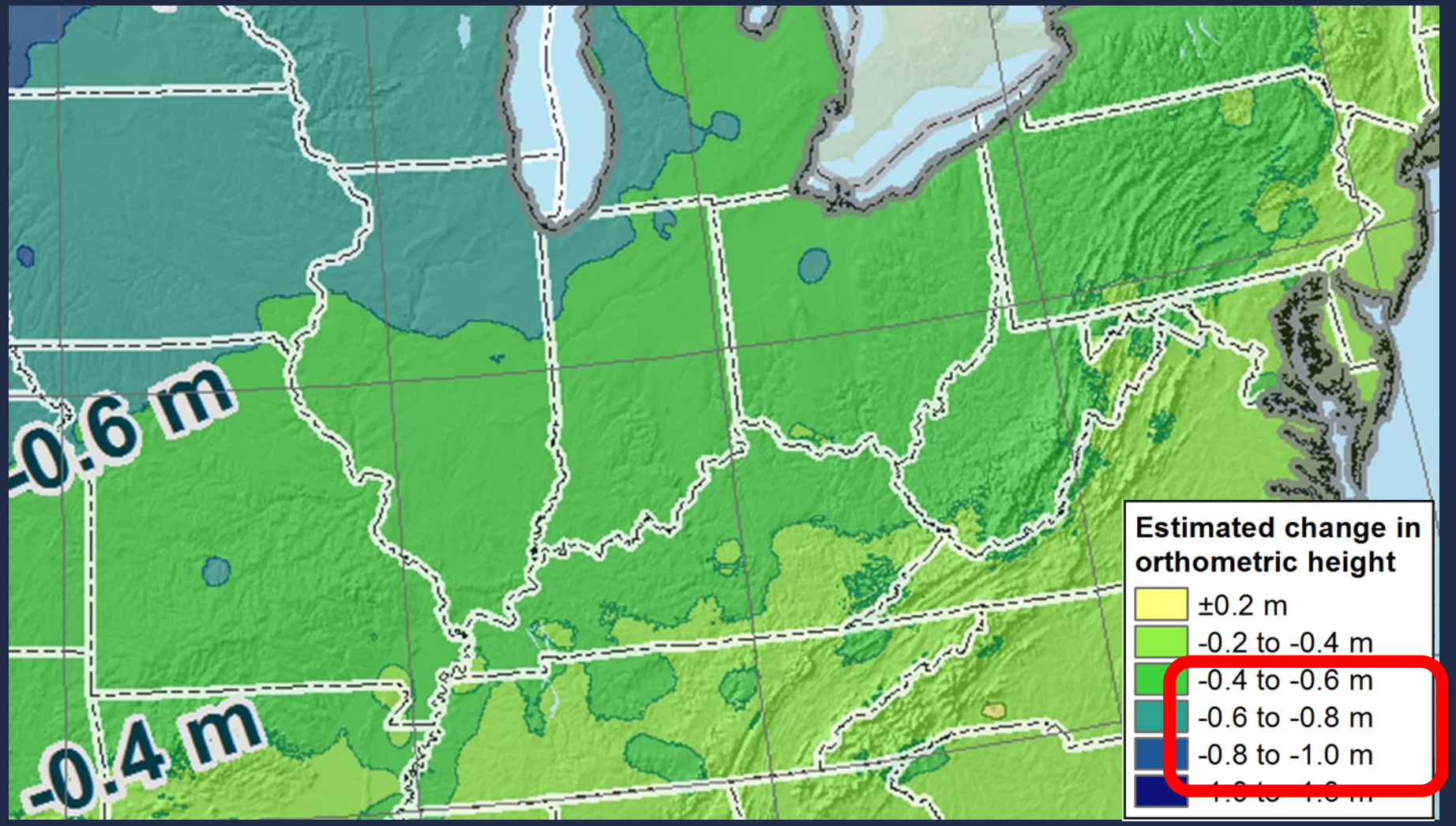
-0.6 m
-0.4 m
Estimated change in orthometric height
±0.2 m
-0.2 to -0.4 m
-0.4 to -0.6 m
-0.6 to -0.8 m
-0.8 to -1.0 m

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SAYING GOODBYE TO THE US SURVEY FOOT…

dot

US SURVEY FOOT

- **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

odot

US SURVEY FOOT

2 parts per million (ppm)

- 1,000,000.00 sft = 999,998.00 ift
- 10,000,000.00 sft = 9,999,980.00 ift

- International → 1 ft = .3048 m
- US → 1 ft = .30480061 m (approx.)
  - frequently calculated by $\frac{1200}{3937}$

odot

- **When does this matter?**
  - ***Not*** typically in lengths/distances but in published planar coordinate systems
- **Like what?**
  - SPCS and UTM are very popular and both fall victim to mix-ups
- **Why?**
  - Large false eastings and northings

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ODOT UP-DATES

9/15/2020














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ODOT'S LOW DISTORTION MAP PROJECTIONS

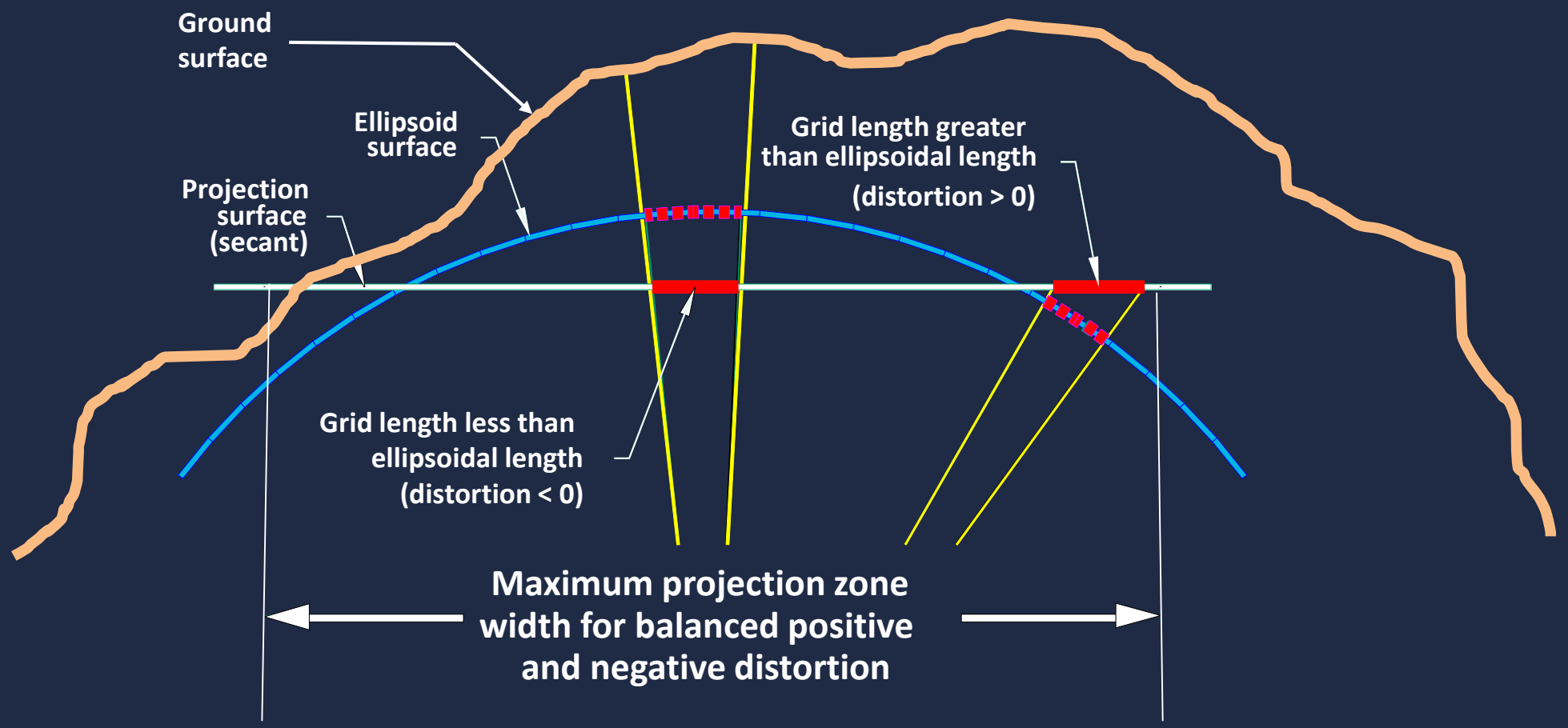
LDP

YEA!

Mapping Projections

- Projections convert spherical coordinates (latitude-longitude) to planar coordinates.
- Three fundamental types of projections:
  - –Azimuthal: projection onto a planar surface
  - –Cylindrical: projection onto a cylinder, which is then ‘unrolled’ to a plane.
  - –Conic: projection onto a cone, which can be unrolled to a plane.
- All projections create distortions of either shape, area, distance, or more than one of these.

Linear distortion due to Elevation

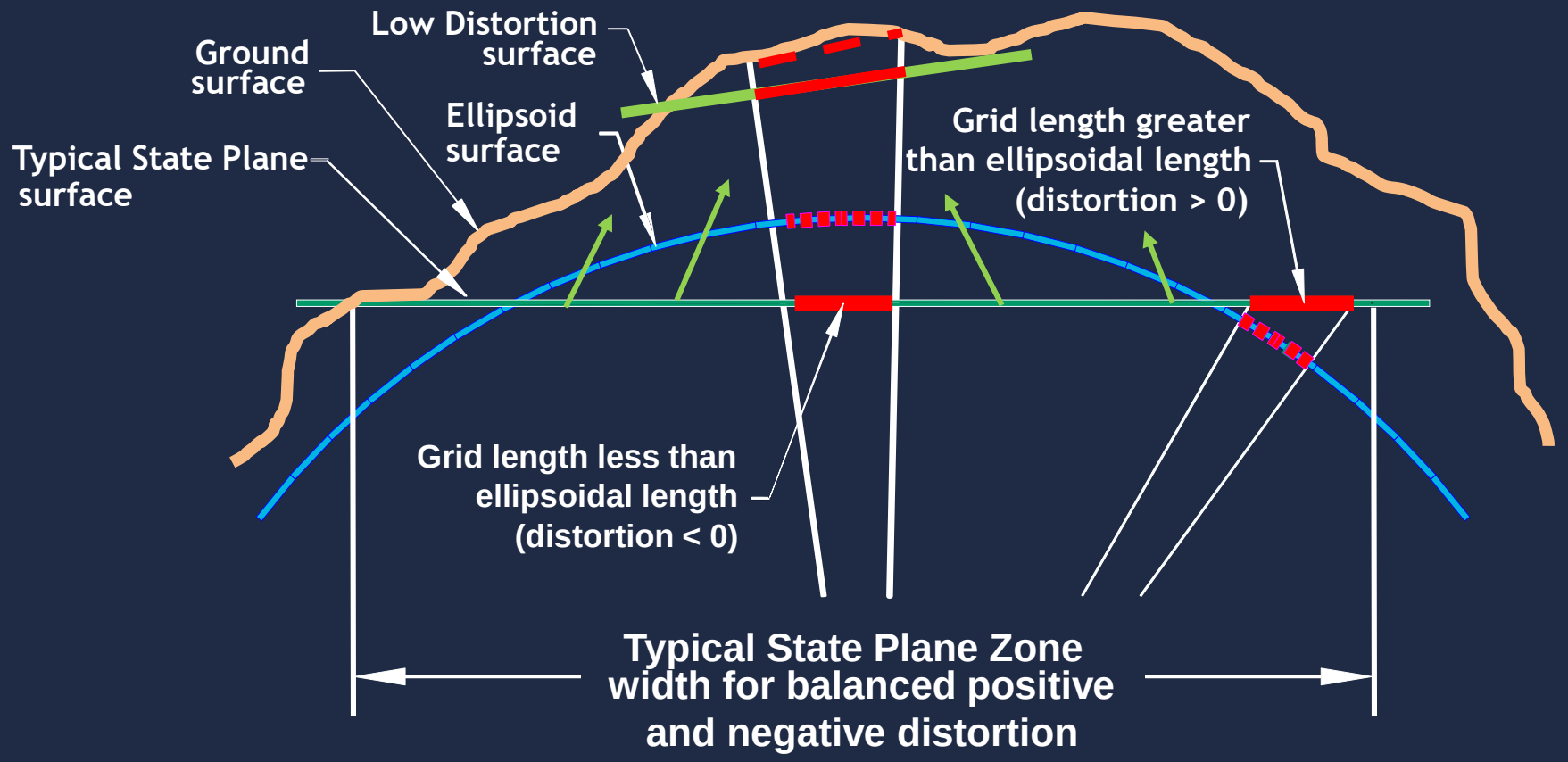


ISSUES WITH THE USE OF CURRENT STATE PLANE COORDINATE SYSTEM:

- CURRENT STATE PLANE COORDINATE SYSTEM DESIGNED AT 1 : 10,000 ACCURACY
  TODAYS EQUIPMENT IS MUCH MORE ACCURATE THAN THIS
  - OAC 4733-37-04: SETS THE MINIMUM STANDARD FOR BOUNDARY SURVEYS AT 1 : 10,000 MINIMUM ACCURACY.
    THIS EATS UP YOUR "ERROR BUDGET" RATHER QUICKLY

- GRID DISTANCES DO NOT REFLECT "TRUE" GROUND DISTANCES
- NEED TO SCALE PROJECTS TO MINIMIZE DISTORTION BETWEEN GRID AND GROUND
- THIS SCALING IS DONE ON A PROJECT BY PROJECT BASIS
  - NO STANDARD SCALE FACTOR USED FOR MULTIPLE PROJECTS
  - PROJECTS IN CLOSE PROXIMITRY TO EACH OTHER HAVE DIFFERENT SCALE FACTORS AND DO NOT "FIT" EACH OTHER
- DOES NOT WORK SEAMLESSLY WITH OTHER PRODUCTS
  (GOOGLE EARTH, ESRI, OSIP IMAGERY, CADD PLATFORMS)

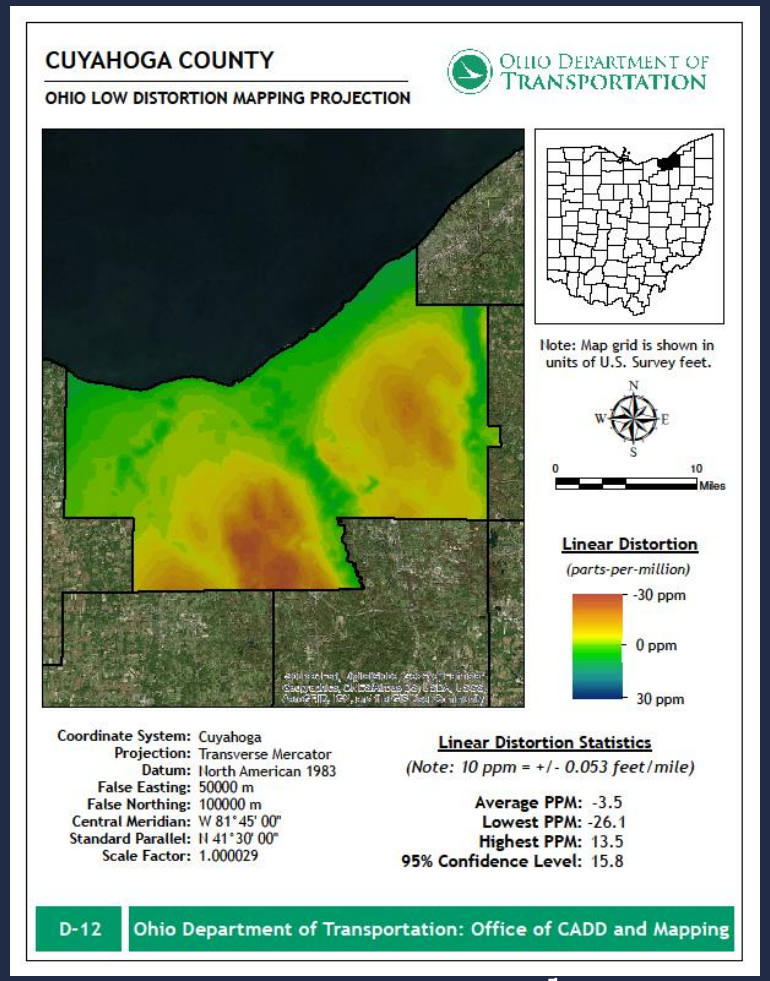
LDP



Dave Minkel and Michael Dennis
NGS/NOAA

Cuyahoga County I-480 Valley View Bridge

I-480 BRIDGE SPAN						
	Grid	Ground	Diff.	feet per mile	parts per million	1/
STATE PLANE	4191.688	4192.004	-0.316	-0.398	-75	13266
20 PPM	4191.920	4192.004	-0.084	-0.106	-20	49905
LDP	4191.995	4192.004	-0.009	-0.011	-2	465778



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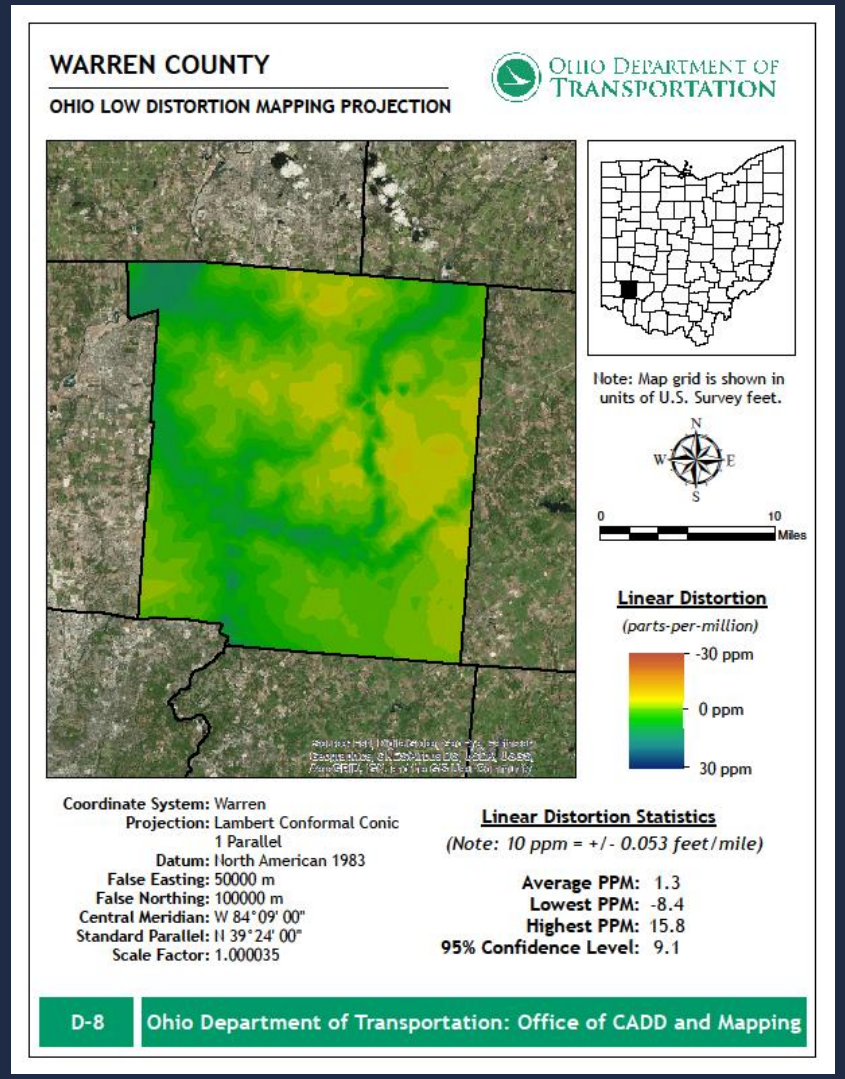
Warren County Jerimiah-Morrow Bridge

JERIMIAH MORROW BRIDGE						
	Grid	Ground	Diff.	feet per mile	parts per million	1/
STATE PLANE	2224.093	2224.317	-0.224	-0.532	-101	9930
20 PPM	2224.272	2224.317	-0.045	-0.107	-20	49429
LDP	2224.313	2224.317	-0.004	-0.009	-2	556079



ODOT'S REAL TIME NETWORK

CORS

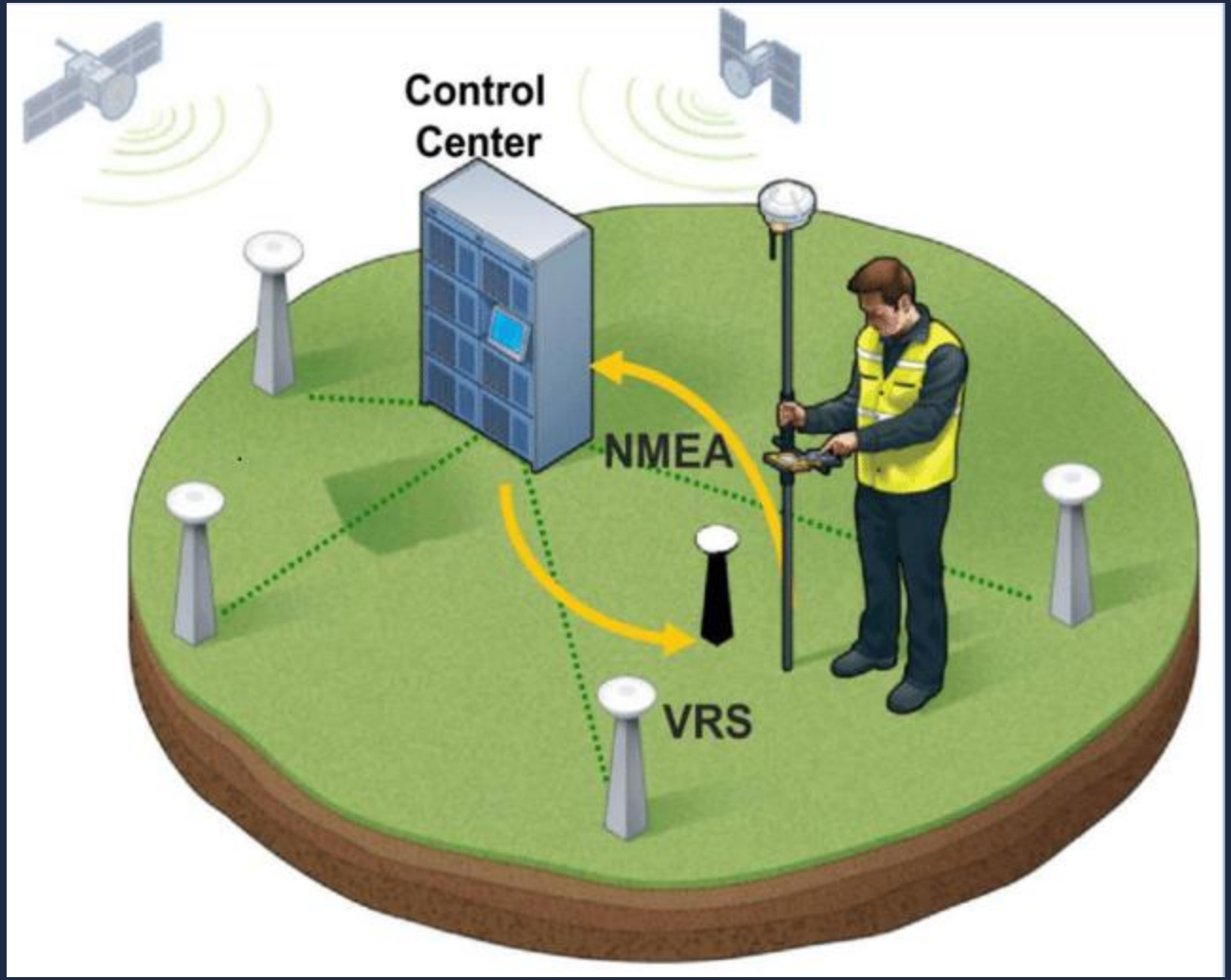
- CORS/VRS/RTN What's the difference?
  - CORS = Continuously Operating Reference Station
    - GNSS antennas and Receivers that collect positional data 24/7/365
    - Provides our network with the data needed to determine atmospheric corrections to provide users with accurate positional data.

VRS

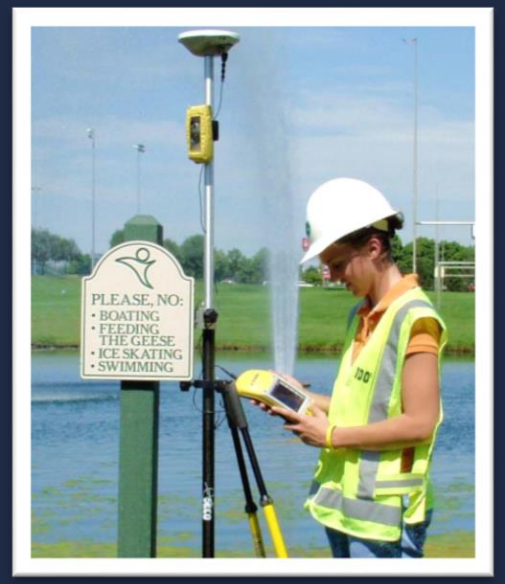
VRS (Virtual Reference Station) is a Trimble trademarked software solution that runs on high performance servers that takes GNSS data from CORS and produces a Real Time corrected solution for precise GNSS positioning.

Network solution. The software uses the 6 nearest CORS to your position to model and compute atmospheric corrections to stream to your field device (a **V**irtual **R**eference **S**tation), you are NOT tied to a single base station like you are in other "Real Time Network" systems.

VRS

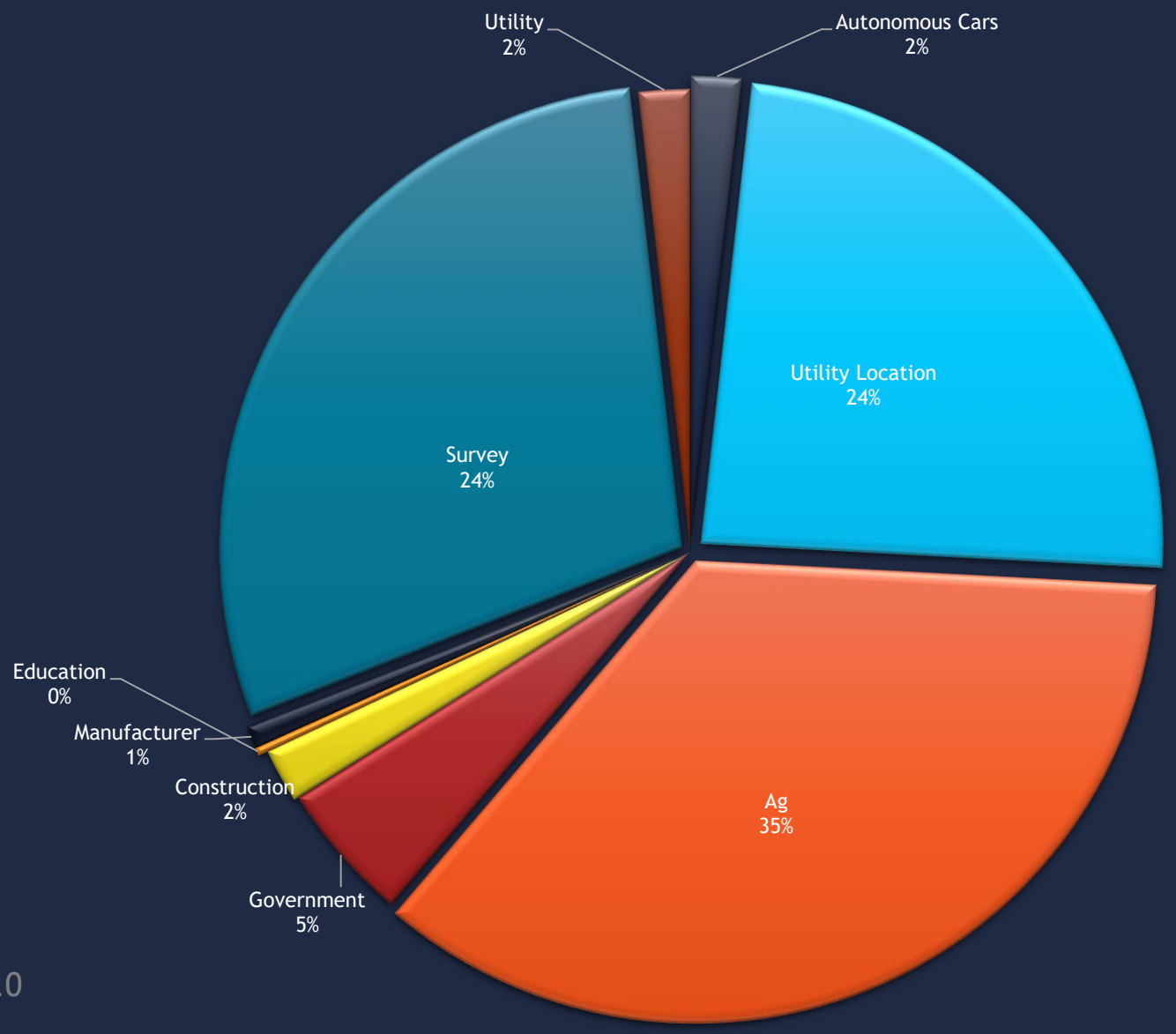


VRS APPLICATIONS



2019 HOURS BY CLASSIFICATION

TTOTAL USAGE: OVER 564,000 HRS



Coming soon to a Network Near You!!!

Trimble RTX is a software enhancement to the existing Trimble Pivot software that allows us to process data from Galileo (European Union) and Beidou (China) constellations, as well as the GPS L5 signal on the newer United States GPS Block IIF and Block IIIF satellites.

Our surveyors (and those that use our system in the private sector will now have almost double the number of satellites to calculate their positions as they did in the past.

Preliminary tests indicate we are now getting accurate positions in places we have never gotten data before (eg. under trees, near buildings…)

FULL GNSS UPGRADE

Current Satellite Availability

- GPS: 31 Satellites
- GLONASS: 23 Satellites
- Total potential: 54 Satellites

Upcoming Satellite Availability

- GPS: 31 Satellites
- GLONASS: 23 Satellites
- Galileo: 21 Satellites
- Beidou: 17 Satellites
- Total potential: 92 Satellites

SURVEY AND MAPPING SPECIFICATIONS

History of Mapping Control at ODOT

SECTION 300: DATUMS, COORDINATE SYSTEMS AND POSITIONING PARAMETERS

As of the publication date of this specification all project control and mapping will be surveyed and mapped on NAD83 (2011) & Geoid 18.

Ensure all project control and mapping performed for ODOT meets the following positioning parameters unless otherwise directed by the District Survey Operations Manager.

301 Vertical Positioning

- Furnish vertical positions using the following:

- Orthometric Height Datum – NAVD88
- Geoid Model – Geoid 18

- For purposes of this document, the term “elevation” refers to the orthometric height.

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302 Horizontal Positioning

Furnish horizontal positions using the following:

- Coordinate System – Ohio State Plane:
  - North or South Zone as appropriate
  - Project Adjustment Factor (1/Combined Scale Factor) from grid to ground as appropriate (Refer to Section 502.2k)
    - Use 0,0 for the origin of the coordinate system
    - North Zone Latitude/Longitude origin point: Lat,Long = 0,0
      - N 39º 27’ 01.76097”/W 89º 28’ 32.98476”
    - South Zone Lat/Long origin point: Lat,Long = 0,0
      - N 37º 47’ 45.30621”/W 89º 19’ 00.02517”
- Map Projection – Lambert Conformal Conic 2 Standard Parallel
- Reference Frame – NAD83(2011) (epoch 2010.0)
- Ellipsoid – GRS80

502 Control Surveys

502.1 General

Control Surveys consist of establishing positions (e.g. northings, eastings, and elevations) on strategically located monuments to govern all survey work that follows.

502.2 Project Control

502.2a General

Project Control, the purpose of a geodetic/primary control survey is to establish a network of physically monumented coordinate points in and along a highway corridor that provide a common horizontal and vertical datum for the entire project. The geodetic control survey provides the means for tying all the geographic features and design elements of a project to one common horizontal and vertical reference system. The geodetic/primary control survey is performed at a higher level of accuracy than the aerial control survey, as such the aerial control survey shall be considered secondary control.

SECTION 500: TYPES OF SURVEYS

502.2b Geodetic Control (for path 4 or 5 projects)

Geodetic Control will govern the positioning for all ODOT path 4 or 5 projects that require aerial mapping tying them to the National Spatial Reference System (NSRS). Geodetic Control monuments should be set prior to the establishment of any aerial photo or lidar control. All ODOT projects will be positioned based on the most current horizontal and vertical datums established by the National Geodetic Survey (NGS) or as scoped. Path 4 & 5 projects greater than 1 mile in length but less than 5 miles in length shall have a minimum of 5 Geodetic Control monuments that are separate of the Primary Project Control. Additional Geodetic Control monuments will be required for projects greater than 5 miles long. All Path 1 thru 3 projects and Path 4 & 5 projects less than 1 mile in length will not require Geodetic Control monuments.

SECTION 500: TYPES OF SURVEYS

502.2b Geodetic Control (for path 4 or 5 projects)(continued)

Geodetic Control monuments shall be set approximately ½ mile outside of and encompassing the project limits. One Geodetic Control monument will be set near the center of, but outside of, the area where construction activity is expected to take place. This monument will be used to calculate the Project Adjustment Factor as well as serve as the primary benchmark for all leveling (see following diagram for example).

Geodetic Control monuments should be of sufficient design, material, and construction to maintain their horizontal and vertical position throughout the life span of the project. The project surveyor may use existing monuments (e.g. NGS horizontal control or benchmarks, County Geodetic Control monuments or PLSS monuments) or set their own type A monuments if no other options are available.

SECTION 500: TYPES OF SURVEYS

Geodetic/Primary Project Control Monument Placement Criteria

Project Category**	Type of Control	Monument Type*	Monument Controls	Horizontal Positioning Methods***	Vertical Positioning Methods
Path 4 & 5	Geodetic > 1 mile Primary	A	Horizontal &Vertical	Static GNSS, PPK, Conventional Traverse	+Differential Leveling
Path 1-3++	Primary Only	A or B	Horizontal only on type B Separate Vertical	Static GNSS, PPK, ODOT VRS, RTK Conventional Traverse	+Differential Leveling

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SECTION 500: TYPES OF SURVEYS

Primary Project Control Monument Placement

Project Length	Beginning & End of Project Limits (Excluding MOT)	Approx. Interval Distance along Alignment	At locations Specified by District	Minimum # of Monuments Required
< 1mile	X	0.5 Miles	X	3
≥1mile	X	0.5 Miles	X	4
*See diagrams below for examples of project control monument placement				

If site geology or site conditions do not permit placement of the monument, contact the District Survey Operations Manager.

** Project Category is defined in the Project Development Process Manual.

*** Contact the District Survey Operations Manager if GNSS positioning is not feasible. See 502.2d for positioning methods.

+ See Section 502.3

++Consider using type A monuments for Path 1-3 projects that may expect to be delayed in project development.

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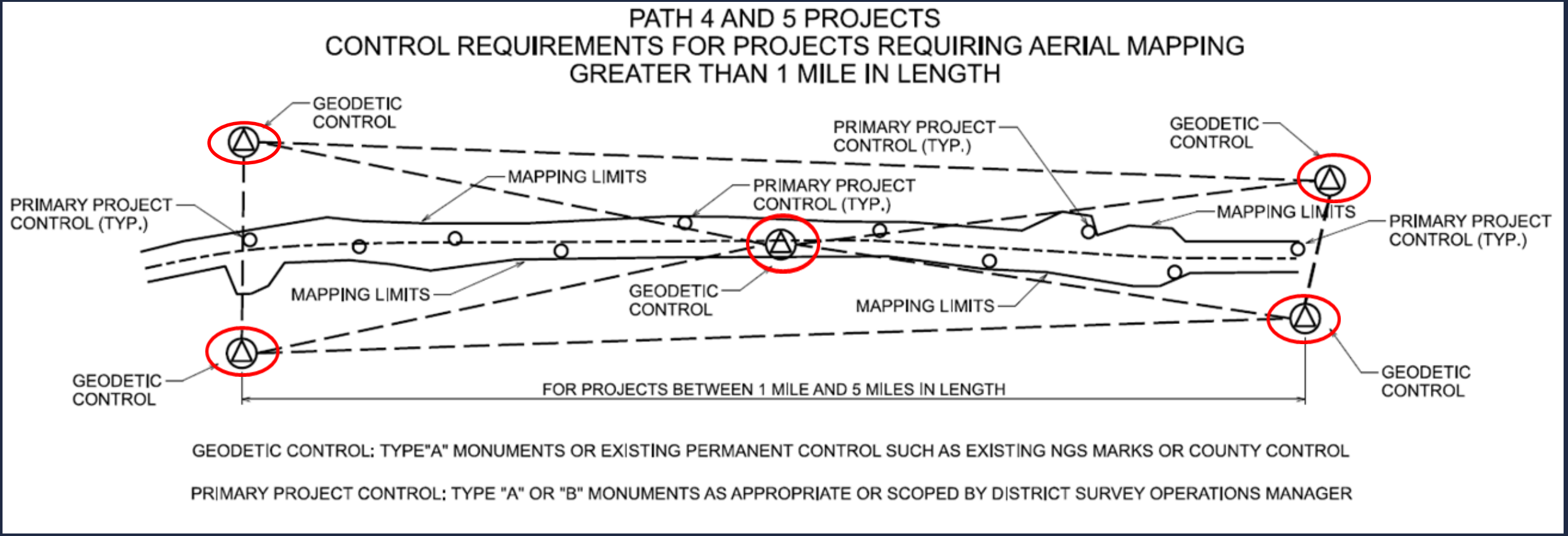
SECTION 500: TYPES OF SURVEYS



SECTION 500: TYPES OF SURVEYS

502.2d Observation Methods to Establish Geodetic Control on Path 4 and 5 projects

- Static GNSS Surveys [Required on Path 4 and 5 projects, Recommended on Path 3 projects]

  All control points need a minimum of 3 GNSS sessions observed on 3 separate days within a 4-week period. Use survey grade GNSS receivers and antennas in accordance with Section 600. Use one of the following methods:

  - OPUS Solution for all Control Points
    - Collect a minimum of 3 sessions of static GNSS data following NGS requirements for an OPUS static session for each Geodetic Control Monument. Ensure the survey equipment is removed and reinstalled over the monument between sessions. Ensure proper GNSS survey planning to achieve the required data quality as outlined in this specification. Consider the following when planning the GNSS survey: positional dilution of precision (PDOP), number of satellites, mask angle, collection rate, multipath, solar activity, etc.
  - Base Receiver Setup/CORS with Rover unit collecting PPK data
    - Establish a base receiver by collecting the Geodetic Control Monument near the center of the project using a minimum of 3 static GNSS sessions as described above or use a nearby CORS as a base. Simultaneously collect the remaining Geodetic Control and/or Primary Control points using a GNSS rover collecting fast-static data. Collect 3 individual sessions on each Geodetic Control and/or Primary Control point using fast-static data for a minimum of 20 minutes plus 1 minute per kilometer over 15 kilometers of baseline between the occupied control points.

SECTION 500: TYPES OF SURVEYS

502.2d Observation Methods to Establish Geodetic Control on Path 4 and 5 projects (continued)

- Traversing
  - Conduct a conventional survey traverse using an Electronic Total Station defined in 602.2. A minimum of 2 direct/2 reverse angles and 5 distance measurements shall be observed and averaged for the final observation of each control point.
  - Closed loop traverses or ties to known control points at the beginning and end of each project should be used to adjust the traverse for errors.

    Note: at least two monuments need to be tied to the NSRS and the traverse transformed and adjusted to their positions.

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SECTION 500: TYPES OF SURVEYS

502.2e Observation Methods to Establish Control on Path 1 thru 3 projects

- ODOT VRS Surveys [For use on Path 1-3 projects only, not to be used on Path 4 or 5 projects]
  - For use on Path 1-3 projects only collect the Northing, Easting, and Elevation coordinates using 5 second observations at a 1 second epoch rate. Collect a minimum of 12 observations for each project control monument. *Note: If more than 20 observations are needed to meet the minimum RMSE requirements consider changing location of control and contact district Survey Operations Manager.* Collect 4 observations rotating the rod 90 degrees between each observation, remove the rod and break initialization, repeat observation procedures until 12 positions have been recorded. Consider the following when planning and performing VRS surveys: positional dilution of precision (PDOP), number of satellites, mask angle, multipath, solar activity, etc. A minimum of 9 observations are required to be included in the RMSE calculations that meet the required accuracy.

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SECTION 500: TYPES OF SURVEYS

502.2e Observation Methods to Establish Control on Path 1 thru 3 projects

- RTK Surveys [For use on Path 1-3 projects only, not to be used on Path 4 or 5 projects]
  - Establish a base receiver by collecting 3, 4-hour static sessions on one control point. While the receiver is collecting static data perform an RTK survey on the remaining control points. Repeat with each static data collection session so every control point has a minimum of 3 RTK/static positions.

- Traversing
  - Conduct a conventional survey traverse using an Electronic Total Station defined in section 602.2. A minimum of 2 direct/2 reverse angles and 5 distant measurements shall be observed and averaged for the final observation of each control point.
  - Closed loop traverses or ties to known control points at the beginning and end of each project should be used to adjust the traverse for errors.

    Note: at least two monuments need to be tied to the NSRS and the traverse transformed and adjusted to their positions.

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SECTION 500: TYPES OF SURVEYS

502.2f Static GNSS Data Processing

- OPUS Solution for all Control Points
  - Process the collected data to determine the Northing, Easting, and Elevation (Orthometric Height) for each session using National Geodetic Survey's OPUS (Online Positioning User Service). Use the rapid or precise ephemeris only. Ensure the correct antenna height, make, and model are utilized. Use the same three nearest CORS base stations and standard logging rates when processing a primary project control point in OPUS. The user must manually select the CORSs to be used in the OPUS processing.
- Base Receiver Setup with Rover unit collecting PPK data
  - Establish the base station coordinates to post process GNSS baselines by submitting the GNSS data RINEX files to OPUS as described for OPUS Static solutions. Process the collected GNSS data by importing into a GNSS post processing software such as Trimble Business Center, Leica Infinity, or MAGNET, post process the GNSS baselines thru the appropriate post processing software. Calculate the positions of three observations per point and calculate the RMSE value to insure the control point meets the ODOT Survey and Mapping Specifications for a type A monument.

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502.2f Static GNSS Data Processing

- CORS with Rover unit collecting PPK data
  - Use the published coordinate values of the nearest CORS to post process GNSS baselines from. Process the collected GNSS data by importing into a GNSS post processing software such as Trimble Business Center, Leica Infinity, or MAGNET. Post process the GNSS baselines thru the appropriate post processing software. Calculate the positions of three observations per point and calculate the RMSE value to insure the control point meets the ODOT Survey and Mapping Specifications for a type A monument.

SECTION 500: TYPES OF SURVEYS

502.2g Coordinate Statistical Analysis

Calculate the Root Mean Square Error (RMSE) for each coordinate component (Northing, Easting, and Elevation) at each Primary Project Control Monument as shown in Appendix D:

Ensure the RMSE for the Northing, Easting, and Elevation components do not exceed the maximum allowable RMSE for all project control monuments according to the following:

Coordinate Component	Maximum Allowable RMSE
Northing	0.029 feet [0.0088 meters]
Easting	0.029 feet [0.0088 meters]
Elevation	0.039 feet [0.0119 meters]

SECTION 500: TYPES OF SURVEYS

502.2h Geodetic/Primary Project Control Monument Horizontal Coordinates

The Northing and Easting of the Geodetic/Primary Project Control Monument coordinates are determined by taking the average of each coordinate component from the solutions that meet the RMSE requirements as specified in Section 502.2g.

502.2i Geodetic/Primary Project Control Monument Vertical Coordinates

Establish the elevations of Geodetic/Primary Project Control Monuments or their associated project benchmarks by differential leveling. Refer to section 502.5 for leveling procedures. Differential leveling for Geodetic/Primary Project Control Monuments and project benchmarks will originate from, and close on, the Geodetic Control Monument (Path 4 or 5) at the center of the project or the Primary Project Control Monument (Path 1-3) with the lowest Elevation RMSE value nearest to the center of the project. Level through all Geodetic and/or Primary Project Control Monuments as well as project benchmarks. Hold the elevation values established by differential leveling for all Geodetic and Primary Project Control Monuments. As a check, compare the leveled elevations to the GNSS determined elevations from Section 502.2g. Highlight any differences that exceed 0.10 U.S. Survey Foot.

SECTION 500: TYPES OF SURVEYS

502.2j Intermediate Project Control

Intermediate project control for surveying purposes are to be positioned relative to the Geodetic/Primary Project Control.

502.2k Project Adjustment Factor (Grid to Ground multiplier)

- The Project Adjustment Factor shall be documented and used for all work on the project. The Project Adjustment Factor shall be calculated by taking the inverse of the combined scale factor (1/(coordinate scale factor x ellipsoid height scale factor)). Scale the project about the origin of the Zone of the State Plane Coordinate system (0, 0). Provide Project Adjustment Factor to the 8th decimal place. If a Project Adjustment Factor is required, use one of the following methods for establishing the combined scale factor:
  - The Latitude of the center Geodetic Control Monument or Primary Project Control Monument closest to the center of the project shall be used to calculate the Project Adjustment Factor for all projects regardless of the method used to locate the monument or method used to determine the Project Adjustment Factor. An ellipsoid height that is a good representation of the average height of the project site shall be used to calculate the ellipsoid height scale factor.
  - Project Adjustment Factor may be derived by other means with approval of the District Survey Operations Manager (i.e. Data Collector solution, TBC, Infinity, Magnet tools) based on GNSS data collected for any individual point. The control point used should meet the RMSE requirements.
  - As reported by OPUS or OPUS-RS

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504 Mapping Surveys

504.1 General

A mapping survey is the collection of points to define the features (natural, man-made, or both) of a physical surface. Examples may include topographic surveys, hydrographic surveys, Aerial mapping surveys, Mobile mapping surveys, etc.

Any mapping survey must be accurately tied to ground control and meet the DTM accuracy as set forth in this document. All ground control work shall be directly supervised and certified by a professional surveyor licensed in the State of Ohio.

504.2 Accuracies

All mapping surveys are required to abide by the following accuracy classes outlined in the sections below:

504.2a DTM Accuracy

Check points to verify remotely sensed mapping products should be dispersed throughout the entire project. To determine the minimum amount of check points, use the following formula:

SECTION 500: TYPES OF SURVEYS

Minimum Number of Class A points = 20+2*x at 5 foot spacing in two or more locations

AND

Minimum Number of Class B, C or D points = 20+2*x at 5 foot spacing in two or more locations

Note: X is equal to the distance of project in miles

DTM Accuracy Class	Classification Area	Maximum Allowable Average Dz (feet)	Maximum Allowable RMSE (feet)
Class A	Paved areas	± 0.07	0.16
Class B	Vegetated areas outside of pavement that are maintained at a minimum biannual frequency (i.e.: farm fields, residential yards, roadside R/W, etcetera)	± 0.25	0.32
Class C	Vegetated areas that are not maintained	± 0.50	0.50
Class D	Areas where vertical accuracy is not critical or warranted	± 1.00	1.00

SECTION 500: TYPES OF SURVEYS

504.2b Horizontal Planimetric Accuracy

This specification covers collection of existing planimetric features and all known underground utilities. Remote sensing products are included with this specification and may be required in the scope of services. Ensure positioning is performed relative to geodetic/primary project control.
Collect planimetric Check Points along well defined planimetric features shown in the delivered mapping. Check points collected for the vertical DTM accuracy test may be utilized if they are on a planimetric feature (example: painted edge line). Check points should be dispersed throughout the entire project. To determine the minimum amount of check points, use the following formula and table:
Number of Planimetric check points = 20+2*x, where x is equal to the distance of project in miles

Planimetric Features	Maximum Allowable Horizontal RMSE (ft.)
Planimetric features listed in Appendix A	0.30

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SECTION 500: TYPES OF SURVEYS

504.3 Ground Control

Collect coordinates and elevations at the center of the aerial target or selected picture point. All ground control (Targets and Photo Points) shall be furnished with a survey nail except on private property. Ensure all photo control is positioned relative to the Geodetic Control and meets the RMSE tolerances as set forth in 502.2g. A professional surveyor licensed in the State of Ohio will document the accuracies, survey procedures and methods used.

If a geodetic/primary control survey will not be performed, all aerial control horizontal surveys shall be referenced to and tied into the National Spatial Reference System (NSRS) as defined by the National Geodetic Survey (NGS) or through the project scoping process.

SECTION 500: TYPES OF SURVEYS

504.4a Surveyor's Certification Statement

Any control established and verification of a mapping survey must be done under the direct supervision of a professional surveyor licensed in the State of Ohio (i.e. Primary Control, Ground Control Points etc.).

504.4b Quality Control Report

When applicable the following is required:

- DTM Accuracy Report
- Horizontal Planimetric Accuracy Report
- Aero Triangulation Report
- Control Report (Survey Master Sheet)

504.4c Equipment Calibration/Certifications

Any equipment used in the creation of project deliverables must meet the calibration requirements as specified in section 600. Include the following as applicable:

- Boresight alignment calibration parameters for any airborne sensors utilized for mapping
- Camera calibration certificate
- GNSS/INS system lever arms for any airborne sensors
- Documentation confirming the calibration of all survey equipment used
- Any calibration/certificates for equipment required to adjust the data set

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1. Get Survey involved EARLY!
   Control needs done before mapping can begin. This will take some time…plan for it.

2. Determine a clear project Scope.
   Plan for the worst…hope for the best. It is better to have data you don’t need then not have data you DO need.

3. Keep Survey involved through out the project.

OHROW

http://gis3.dot.state.oh.us/ohrow_viewer/

OHROW

- OhROW is the ODOT web page featuring the District Right-of-Way plans and ODOT monument inventory.
- OhROW allows individuals not associated with ODOT to find Right-of-Way plans and other documentation used to establish ODOT road Right-of-Way
- OhROW is GIS based and searchable by District, County, PID, or NLFID.
- When fully functional (meaning all District data has been added) it should save Districts countless hours researching public information requests for Right-of-Way.

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OHROW

- Right-of-Way Plans are stored in ProjectWise:

  pw:\\Ohio DOT Archive\Documents\Archive Projects\ROW
- CMS converts tiffs from the district plan vault to multi=page pdf's and stores them in ProjectWise.
- Each R/W plan gets assigned a unique identifier called a GUID that stays with the plan wherever it may end up residing in ProjecWise.
- When someone wants to download a plan they simply click on the "download plan" link and a token gets passed through to the ProjectWise server allowing access.

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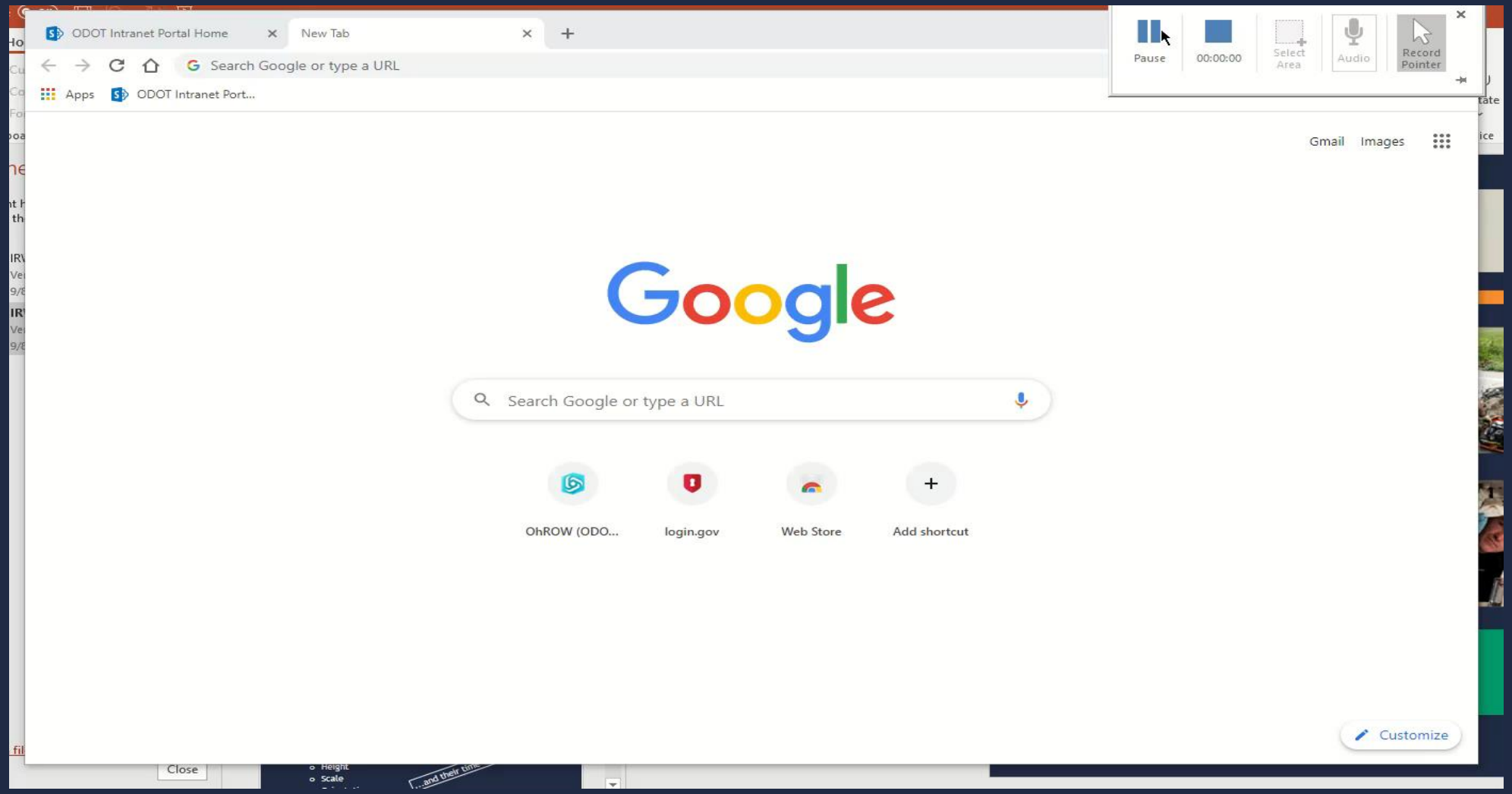
OHROW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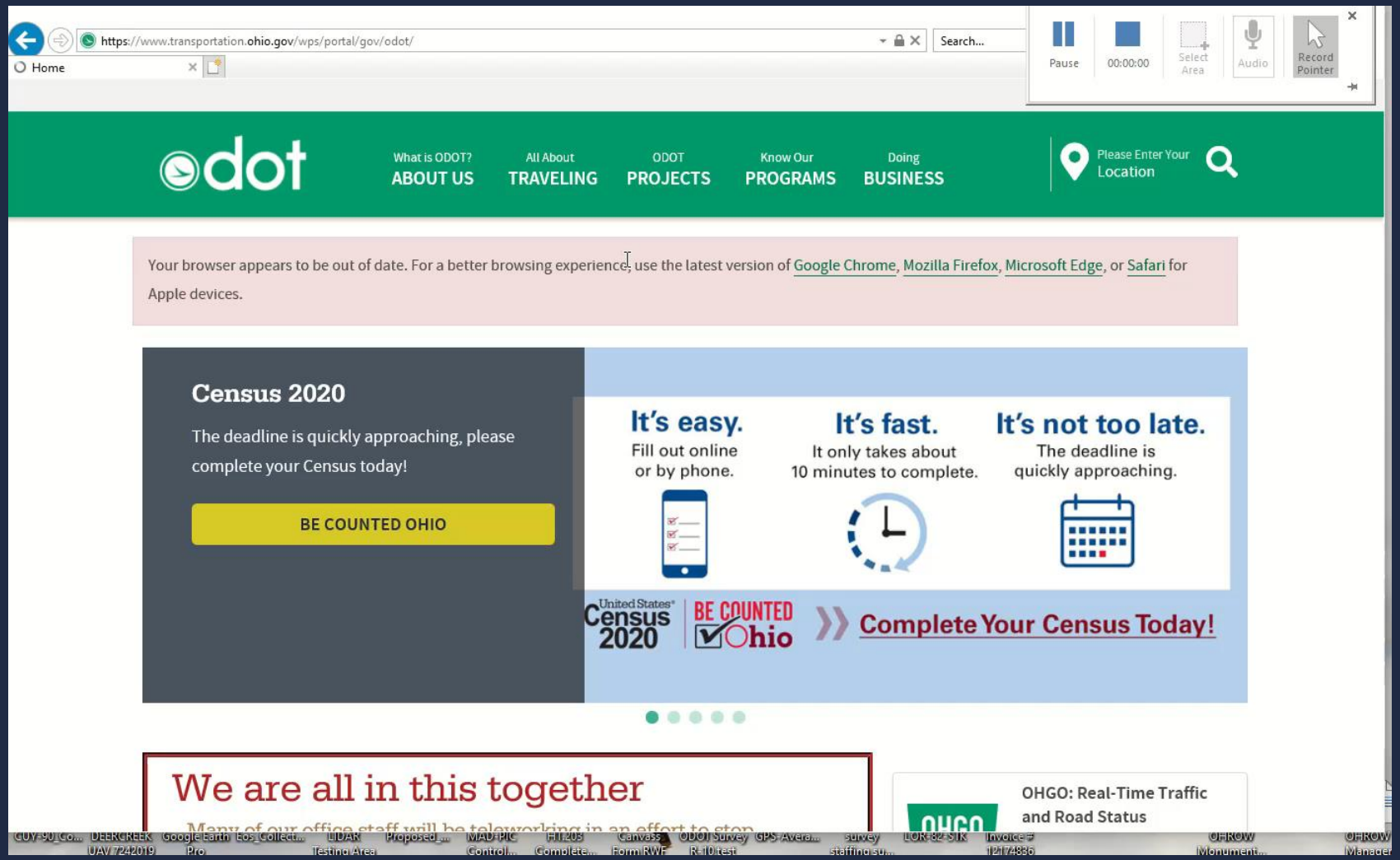

QUESTIONS

Last updated 9/17/2020