Datums: The Foundation of Geospatial Data

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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: 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

Overview

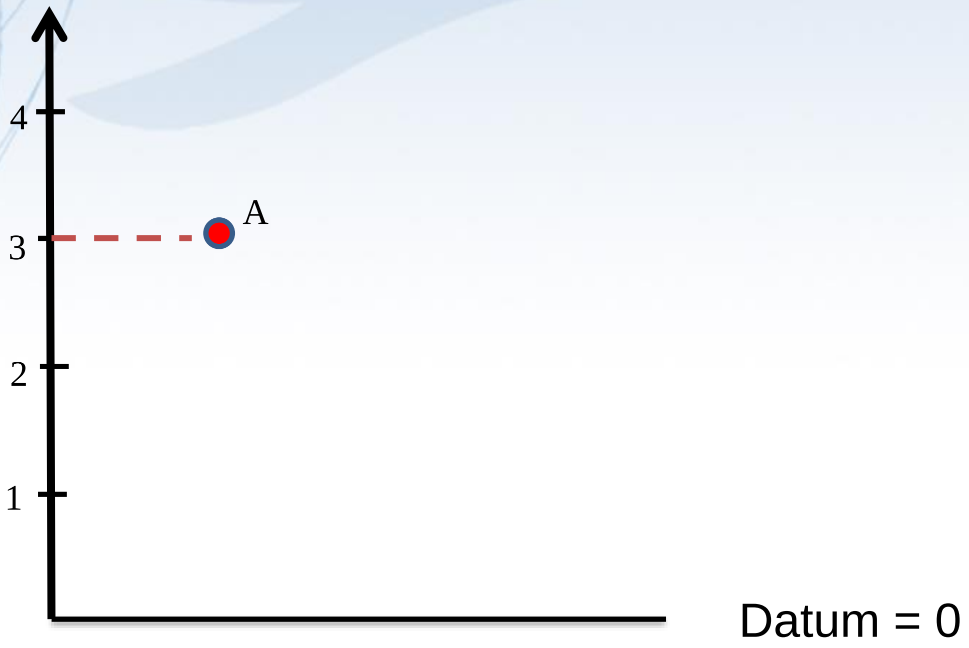
- Background on coordinate systems
- International geodetic efforts
- Datum access
- Horizontal datums
- Geometric reference frames
- Vertical datums

BACKGROUND ON COORDINATE SYSTEMS

Datum Fundamentals

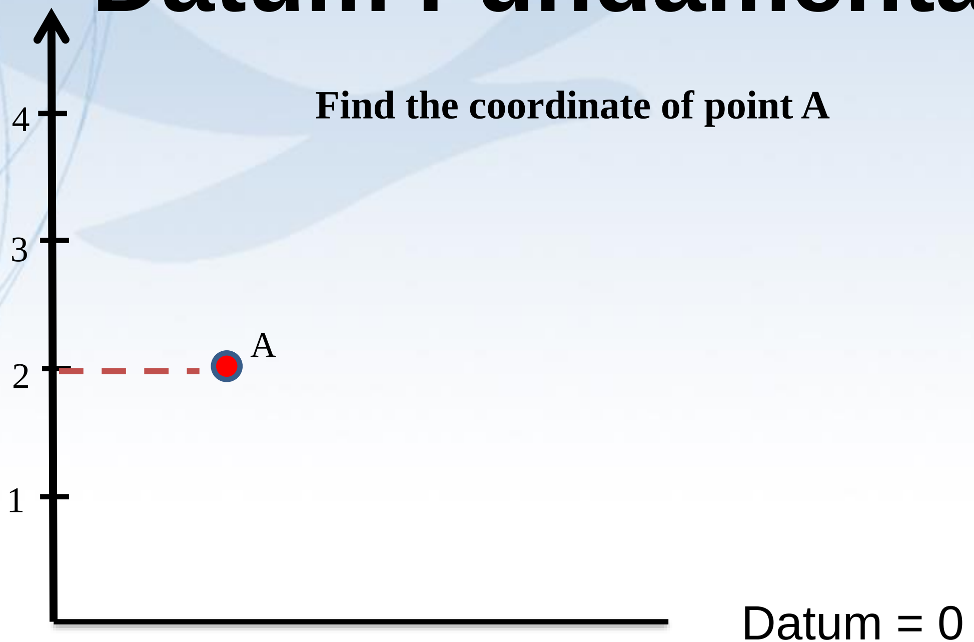
Find the coordinate of point A

Datum Fundamentals



Datum Fundamentals

Find the coordinate of point A



Geodetic Control Primer

Find the coordinates of point A

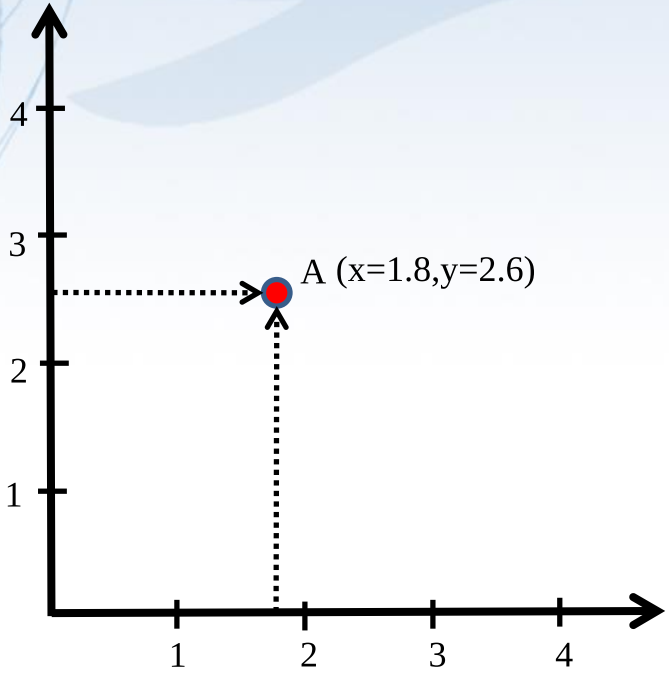
Somewhere on Earth…

You are presented with this problem…

Without any other information, the problem is unsolvable.

Geodetic Control Primer

Find the coordinates of point A



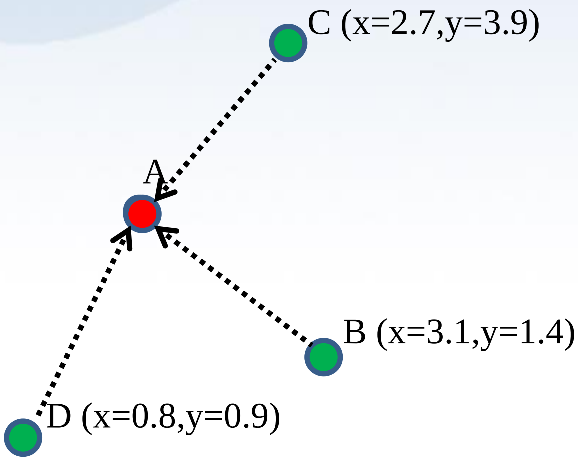
Wouldn't it be fantastic if someone just provided you with a coordinate system?

Unfortunately, the Earth doesn't come with lines of latitude and longitude just drawn all over it…

"The Earth is not a globe"

Geodetic Control Primer

Find the coordinates of point A



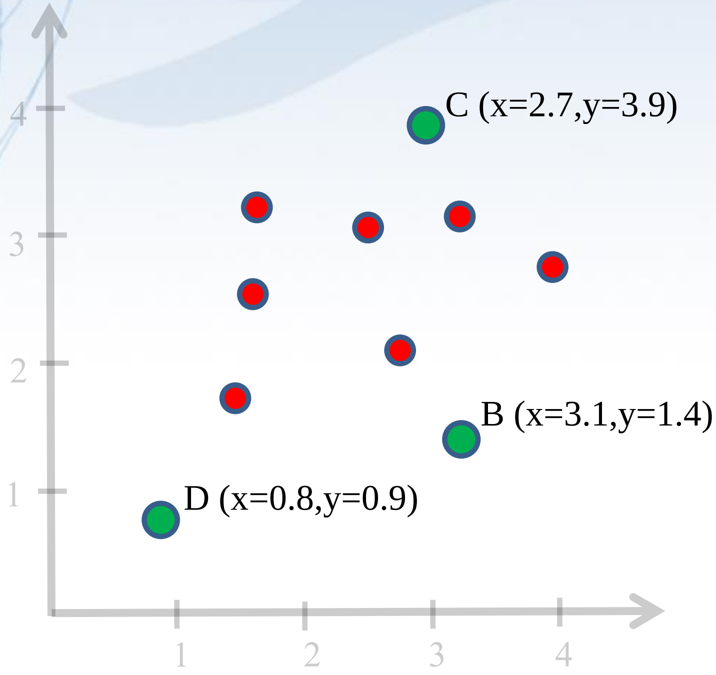
But what if someone gave you enough other points with pre-determined coordinates?

With a little measuring and trigonometry, you could certainly determine the coordinates of point A!

These “other points with pre-determined coordinates” are “**geodetic control**”

Geodetic Control Primer

Find the coordinates of point A



Although the coordinate axes are not visible, their location and scale are *implied* by the given coordinates of the points B, C, and D.

It is often the job of surveyors, mappers and other geospatial professionals to determine the coordinates of many points on Earth.

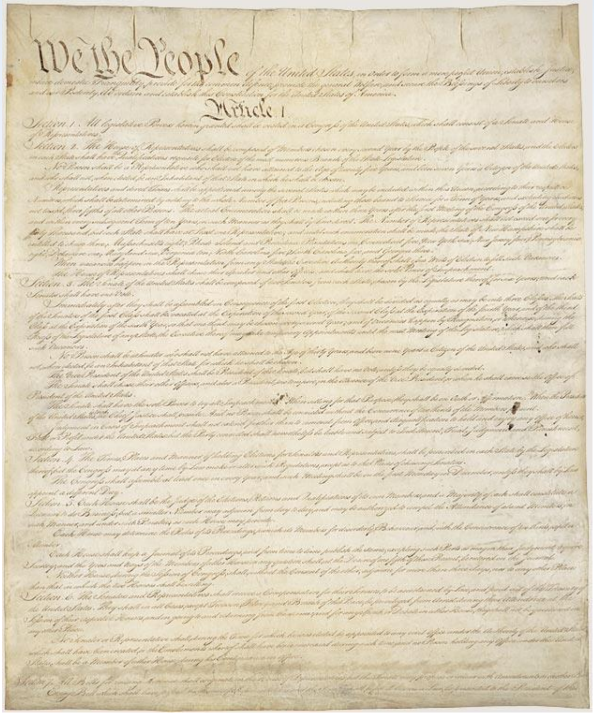
It is the job of NGS to provide the geodetic control to the nation to make those jobs possible.

Article 1, Section 8:

"The Congress shall have Power To lay and collect Taxes, Duties, Imposts and Excises, to pay the Debts and provide for the common Defence and general Welfare of the United States; but all Duties, Imposts and Excises shall be uniform throughout the United States;

…

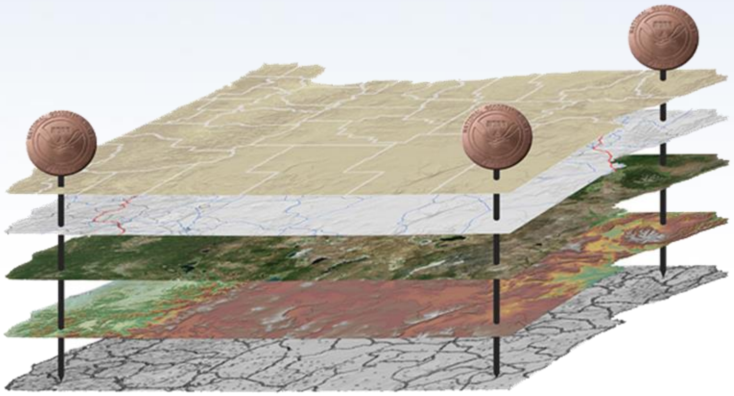
To coin Money, regulate the Value thereof, and of foreign Coin, ***and fix the Standard of Weights and Measures***; ..."



The National Spatial Reference System

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

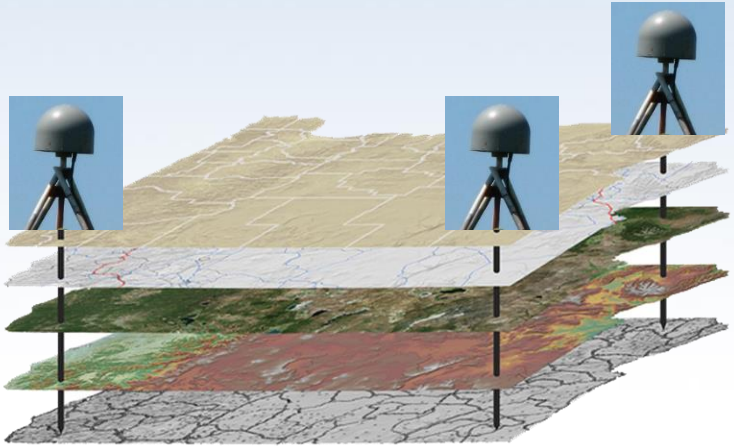


- North American Datum of 1983 **(NAD 83)**
- North American Vertical Datum of 1988 **(NAVD 88)**

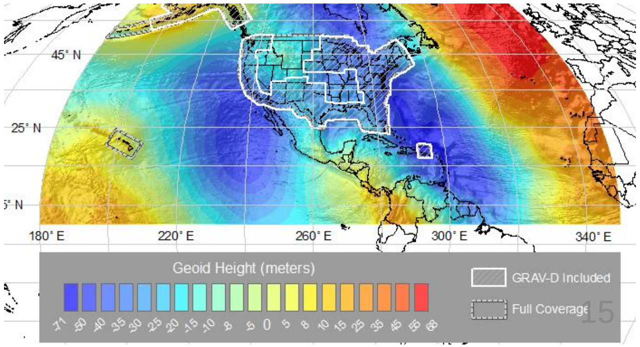
Today's NSRS

The National Spatial Reference System

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



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)

National Spatial Reference System (NSRS)

Geometric Geodesy

- Horizontal Datums/Geometric Reference Frames
- Latitude
- Longitude
- Ellipsoid Height
- State Plane Coordinates

Physical Geodesy

- Geopotential Datums
- Orthometric Height
- Dynamic Height
- Surface Gravity
- Leveling

Main Components: latitude, longitude, height, origin, scale, gravity, and orientation

Passive Control

- Any geodetic control point that is infrequently or intermittently observed.
- 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.
- CORS

Geodetic Stations

Common geodetic stations:

- Continuously Operating GNSS Reference **Station** (CORS)
- Satellite Laser Ranging (SLR) **Station**
- Very Long Baseline Interferometry (VLBI) **Station**
- Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) **Station**
- Continuously Operating Relative Gravimeter **Station**

Geodetic Stations

Global Geodetic Control

- Geodetic control is inherently global.
- NGS works with international groups to improve the global geodetic framework.
- The UN Global Geodetic Reference Frame (UN-GGRF) was adopted by the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM). The NSRS ties to the UN-GGRF.

UN-GGIM

United Nations

Department of Economic and Social Affairs (ECOSOC)

Statistics Division

United Nations Global Geospatial Information Management (UN-GGIM)

UN-GGIM Asia-Pacific	UN-GGIM Americas	UN-GGIM Arab States	UN-GGIM Europe	UN-GGIM Africa

SubCommittee on Geodesy (UN SCoG)

- EG on Land Administration and Management
- EG on the Integration of Statistical and Geospatial Information
- WG on Development of a Statement of Shared Principles for the Management of Geospatial Information
- WG on Trends in National Institutional Arrangements in Geospatial Information Management
- WG on Geospatial Information and Services for Disasters
- WG on Global Fundamental Geospatial Data Themes
- WG on Legal and Policy Frameworks for Geospatial Information Management
- WG on Marine Geospatial Information

- UN-GGIM adopted the GGRF – that is, all Nations (including USA) have agreed to use a common reference frame based on the ITRS
- The UN-SCoG is tasked with implementing the GGRF globally
- That agreement and the obligation to adopt the GGRF was also passed through to the Regional Committees (RCs).

UN Global Geodetic Reference Frame

- GGRF encompasses all aspects of a modernized reference frame including:
  - Geodetic infrastructure (GI)
  - Education Training and Capacity Building (ETCB)
  - Governance (GOV)
  - Outreach and Communication (OC)
  - Policies Standards and Conventions (PSC)
- Includes both International Terrestrial Reference System (**ITRS**) and the International Height Reference System (**IHRS**)
  - Determined and maintained by the International Association of Geodesy (IAG)

Structure of the International Association of Geodesy

International Council for Science (ICSU): 142 Countries, 31 Unions

IAU | IGU | ISPRS | **IUGG** | IUGS | ICA | other Unions

International Union of Geodesy and Geophysics (IUGG)

IACS | **IAG** | IAHS | IAGA | IAMAS | IAPSO | IASPEI | IAVCEI

International Association of Geodesy (IAG)

Commissions

- 1 Reference Frames
- 2 Gravity Field
- 3 Earth Rotation and Geodynamics
- 4 Positioning and Applications

Inter-Commission Committee on Theory

Scientific Services

ITRF models

IHRF models (eventually)

Geometry: IERS, IDS, IGS, ILRS, IVS

Gravity: IGFS, BGI, ICGEM, IDEMS, ISG, IGETS

Combining: BIPM, PSMSL

Global Geodetic Observing System (GGOS)

ACCESSING DATUMS

Traditional Access: Passive Control

Horizontal

The NGS Data Sheet

See file dsdata.pdf for more information about the datasheet.

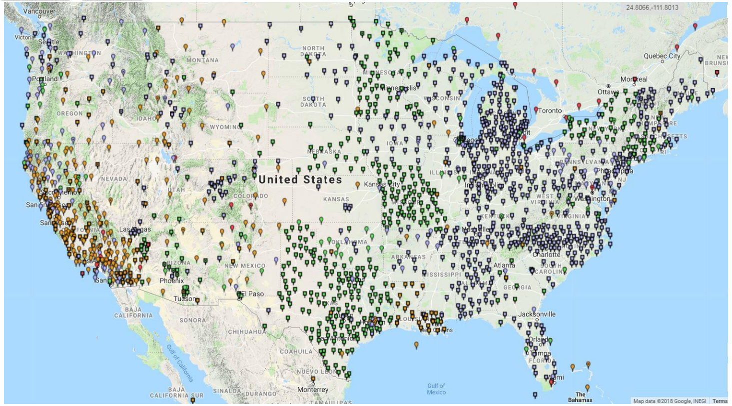
```
PROGRAM = datasheet95, VERSION = 8.12.5.12
Starting Datasheet Retrieval...
1          National Geodetic Survey,   Retrieval Date = JUNE 25, 2021
 AJ8317 ***********************************************************************
 AJ8317  SACS       -  This is a Secondary Airport Control Station.
 AJ8317  DESIGNATION -  SPI B
 AJ8317  PID        -  AJ8317
 AJ8317  STATE/COUNTY-  IL/SANGAMON
 AJ8317  COUNTRY    -  US
 AJ8317  USGS QUAD   -  SPRINGFIELD WEST (2018)
 AJ8317
 AJ8317                        *CURRENT SURVEY CONTROL
 AJ8317
 AJ8317* NAD 83(2011) POSITION- 39 50 22.48941(N) 089 39 57.06655(W)   ADJUSTED
 AJ8317* NAD 83(2011) ELLIP HT-   144.479 (meters)        (06/27/12)   ADJUSTED
 AJ8317* NAD 83(2011) EPOCH   -  2010.00
 AJ8317* NAVD 88 ORTHO HEIGHT -   177.097 (meters)      581.03  (feet) ADJUSTED
 AJ8317
 AJ8317  GEOID HEIGHT    -        -32.599 (meters)                     GEOID18
 AJ8317  NAD 83(2011) X  -      28,601.347 (meters)                    COMP
 AJ8317  NAD 83(2011) Y  - -4,904,165.278 (meters)                     COMP
 AJ8317  NAD 83(2011) Z  -  4,064,417.425 (meters)                     COMP
 AJ8317  LAPLACE CORR    -          0.92  (seconds)                    DEFLEC18
 AJ8317  DYNAMIC HEIGHT  -        177.000 (meters)      580.71  (feet) COMP
 AJ8317  MODELED GRAVITY -    980,078.4   (mgal)                       NAVD 88
 AJ8317
 AJ8317  VERT ORDER      -  SECOND    CLASS I
```

Vertical

Modernized Access: Through the CORS and OPUS

NGS provides data and coordinate functions with NOAA CORS Network

- And one definitive coordinate function for each one
- And the software (M-PAGES / OPUS / OPUS Projects) to differentially position your GPS receiver to each station



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.

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

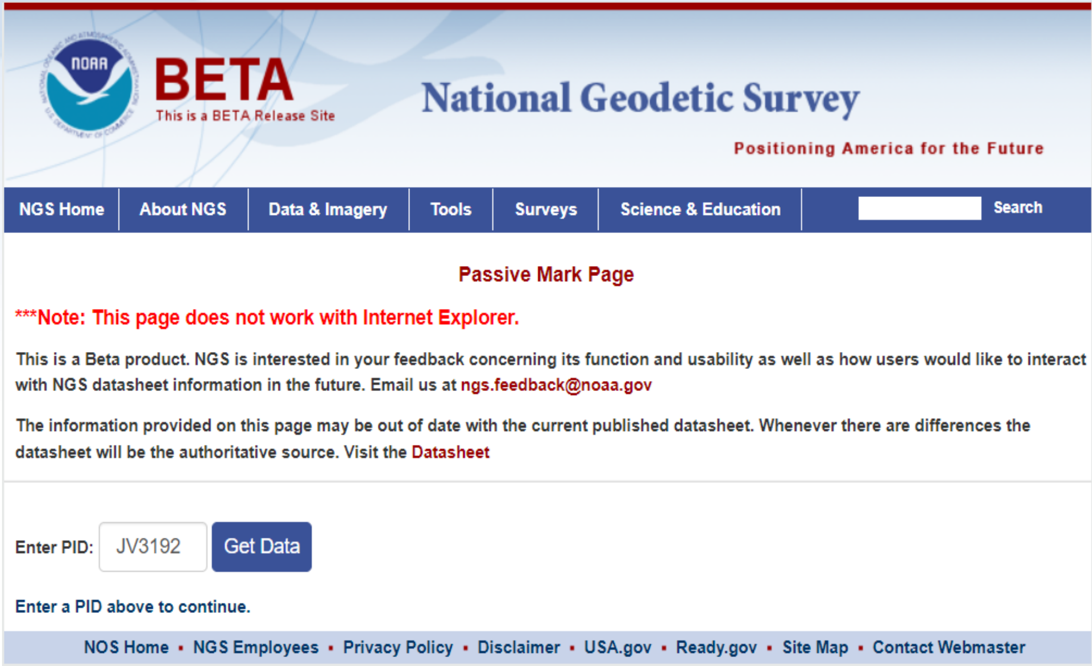

```
{"datasheet":
   {
      "datasheetHeading":"National Geodetic Survey",
      "datasheetRetrievalDate":"JULY  1, 2022",
      "htMod":"This is a Height Modernization Survey Station.",
      "pacs":"This is a Primary Airport Control Station.",
      "determinedProjects":[

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

...
   }
}
```

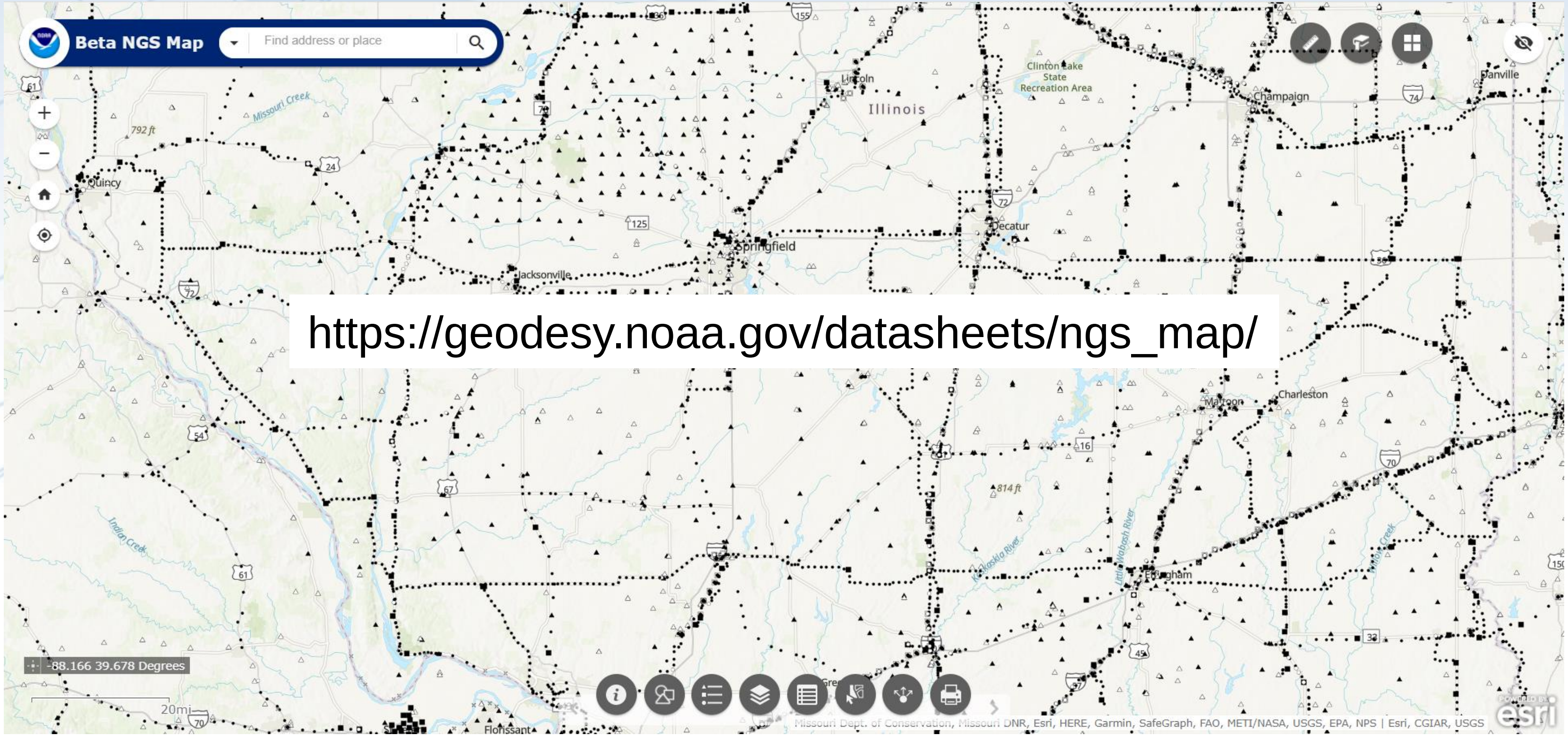
Beta Passive Marks page

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



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

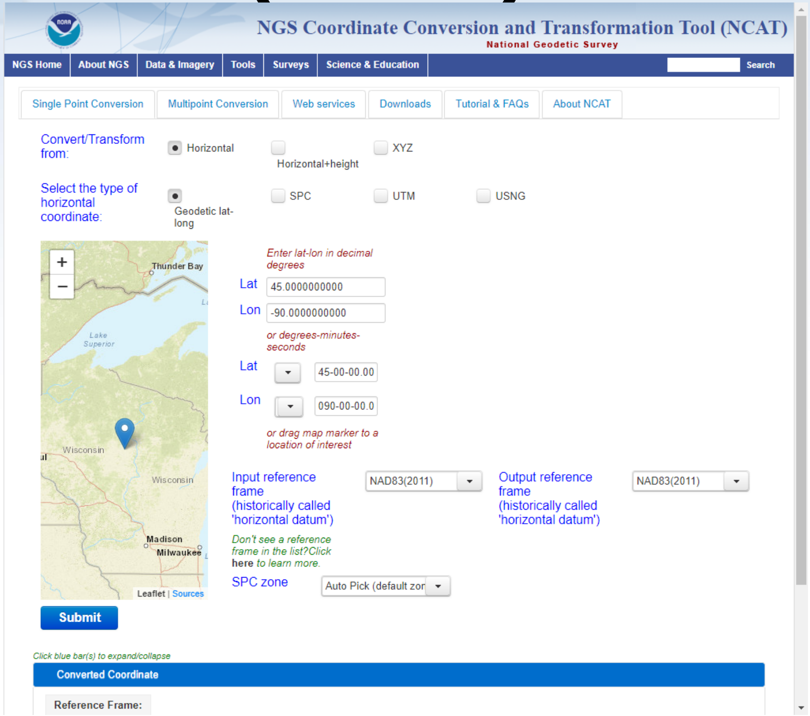
NGS Map



https://geodesy.noaa.gov/datasheets/ngs_map/

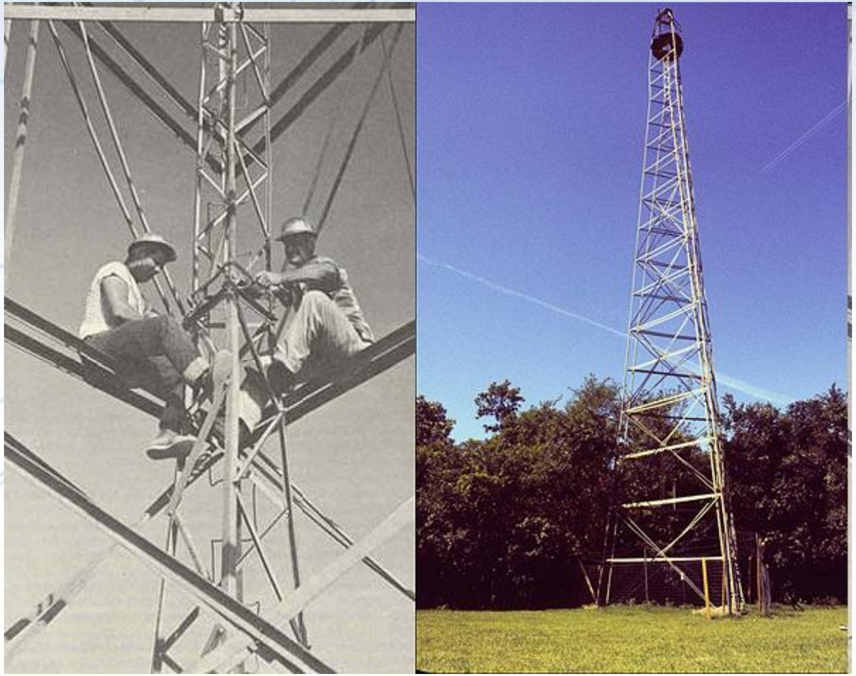
NGS Coordinate Conversion and Transformation Tool (NCAT)

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



HORIZONTAL DATUMS

Developing previous horizontal datums



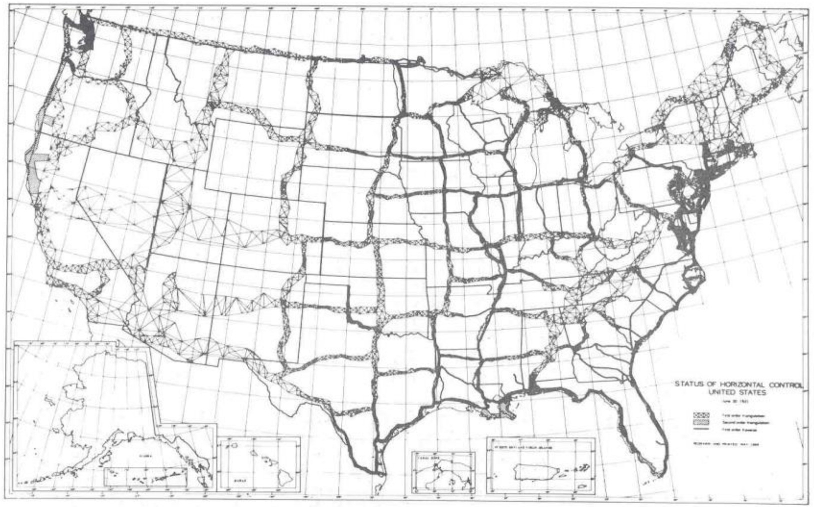
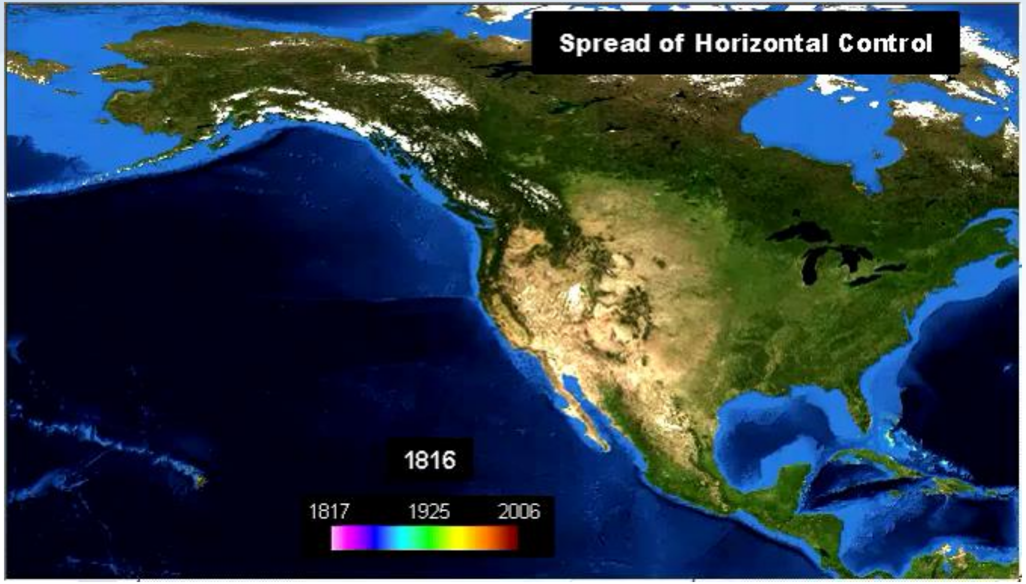


Figure 3

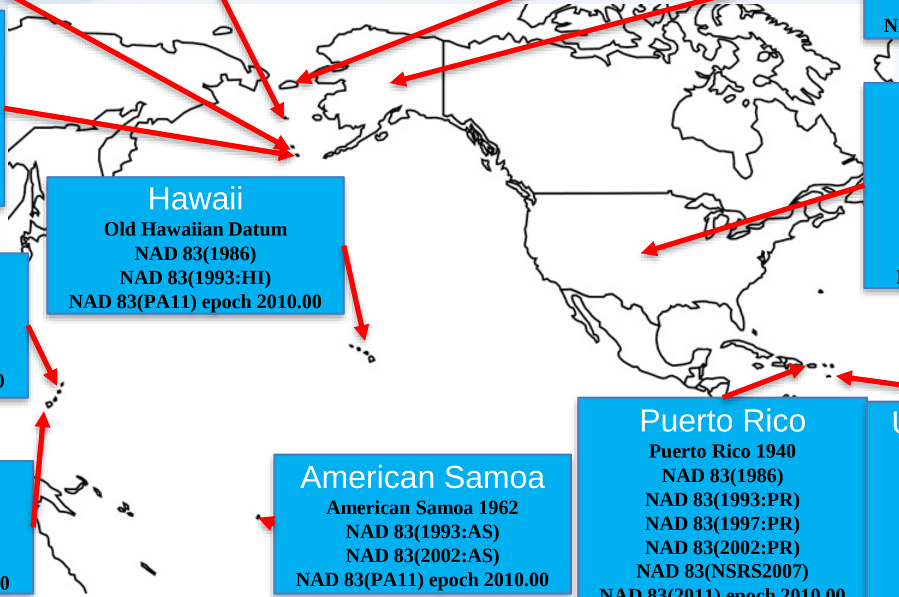
Horizontal Control Network of the United States June 1931

Marks in the NSRS 1816–2006

- Watch for:
  1849 CA Gold Rush
  1895 Systematic Mapping of Seward's Folly
  1896 Transcontinental Arc of Triangulation (39th Parallel)
  1901 Transcontinental Arc of Triangulation (98th Meridian)
  1933 Public Works Administration
  1950–1980 NAD 83
- Project
  1990s Statewide HARN and FBN Projects



Horizontal Datums of the NSRS



St. Paul I.
St. Paul 1897
St. Paul 1952
NAD 83(1986)
NAD 83(2002:AK)
NAD 83(NSRS2007)
NAD 83(2011) epoch 2010.00

St. Matthew I.
St. Matthew 1952

St. Lawrence I.
St. Lawrence 1952
NAD 83(1986)
NAD 83(2002:AK)
NAD 83(NSRS2007)
NAD 83(2011) epoch 2010.00

Alaska
NAD 27
NAD 83(1986)
NAD 83(2002:AK)
NAD 83(NSRS2007)
NAD 83(2011) epoch 2010.00

St. George I.
St. George 1897
St. George 1952
NAD 83(1986)
NAD 83(2002:AK)
NAD 83(NSRS2007)
NAD 83(2011) epoch 2010.00

Hawaii
Old Hawaiian Datum
NAD 83(1986)
NAD 83(1993:HI)
NAD 83(PA11) epoch 2010.00

CONUS
U.S. Standard Datum
NAD 27
NAD 83(1986)
NAD 83("HARN")
NAD 83("FBN")
NAD 83(NSRS2007)
NAD 83(2011) epoch 2010.00

CNMI
Guam 1963
NAD 83(1993:GU)
NAD 83(2002:GU)
NAD 83(MA11) epoch 2010.00

Guam
Guam 1963
NAD 83(1993:GU)
NAD 83(2002:GU)
NAD 83(MA11) epoch 2010.00

American Samoa
American Samoa 1962
NAD 83(1993:AS)
NAD 83(2002:AS)
NAD 83(PA11) epoch 2010.00

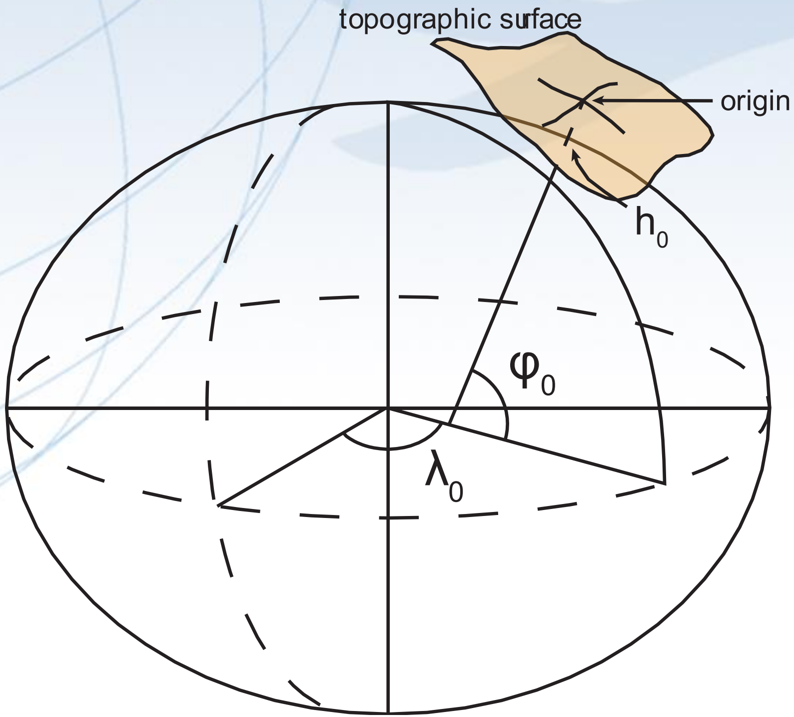
Puerto Rico
Puerto Rico 1940
NAD 83(1986)
NAD 83(1993:PR)
NAD 83(1997:PR)
NAD 83(2002:PR)
NAD 83(NSRS2007)
NAD 83(2011) epoch 2010.00

U.S. Virgin Islands
Puerto Rico 1940
NAD 83(1986)
NAD 83(1993:PR)
NAD 83(1997:PR)
NAD 83(2002:PR)
NAD 83(NSRS2007)
NAD 83(2011) epoch 2010.00

Replacing the NAD 83s

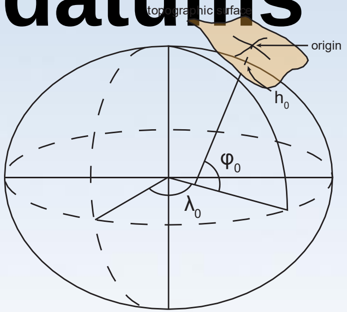
The Old	The New
NAD 83 (2011)	NATRF2022 - The North American Terrestrial Reference Frame of 2022
NAD 83 (2011)	CATRF2022 - The Caribbean Terrestrial Reference Frame of 2022
NAD 83 (PA11)	PATRF2022 - The Pacific Terrestrial Reference Frame of 2022
NAD 83 (MA11)	MATRF2022 - The Mariana Terrestrial Reference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

Traditional horizontal geodetic datums



- Positions of points on Earth's surface are reduced to the surface of a reference ellipsoid
- The reference ellipsoid roughly matches the shape of the Earth
- A reference point is selected as the origin, all other positions are given with respect to that point

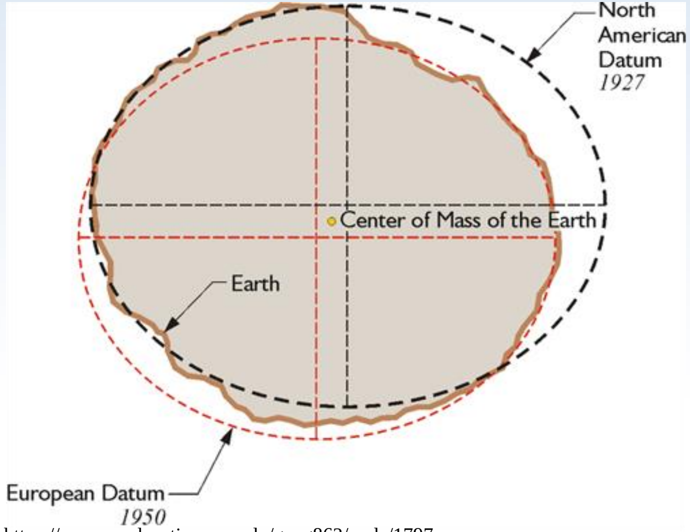
Traditional horizontal geodetic datums (NAD 27)



Traditional horizontal geodetic datums

Drawbacks of using this approach:

- The reference ellipsoid is optimized for the region; it is not suitable for global positioning
- The center of the reference ellipsoid does not coincide with the location of the center of mass of the Earth
- Neighboring countries may use different datums which can cause unnecessary complications when dealing with points of interest in border regions



https://www.e-education.psu.edu/geog862/node/1797

Drawbacks of Passive Control

Traditional horizontal and vertical datums were built onand accessed through passive control

GEOMETRIC REFERENCE FRAMES

Definitions

Reference System

A set of prescriptions and conventions together with the modeling required to define at any time a triad of coordinate axes

ITRS: International Terrestrial Reference System

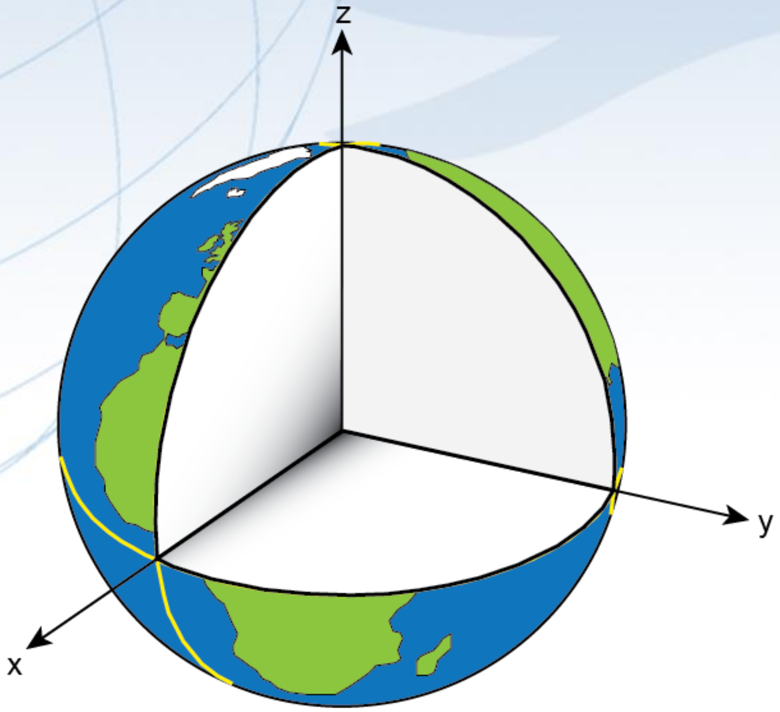
Reference Frame

Realizes the system by means of coordinates of definite points that are accessible directly by occupation or observation

ITRF: International Terrestrial Reference Frame

From Springer Handbook of Global Navigation Satellite Systems, Ch. 2, p. 34

International Terrestrial Reference System (ITRS)



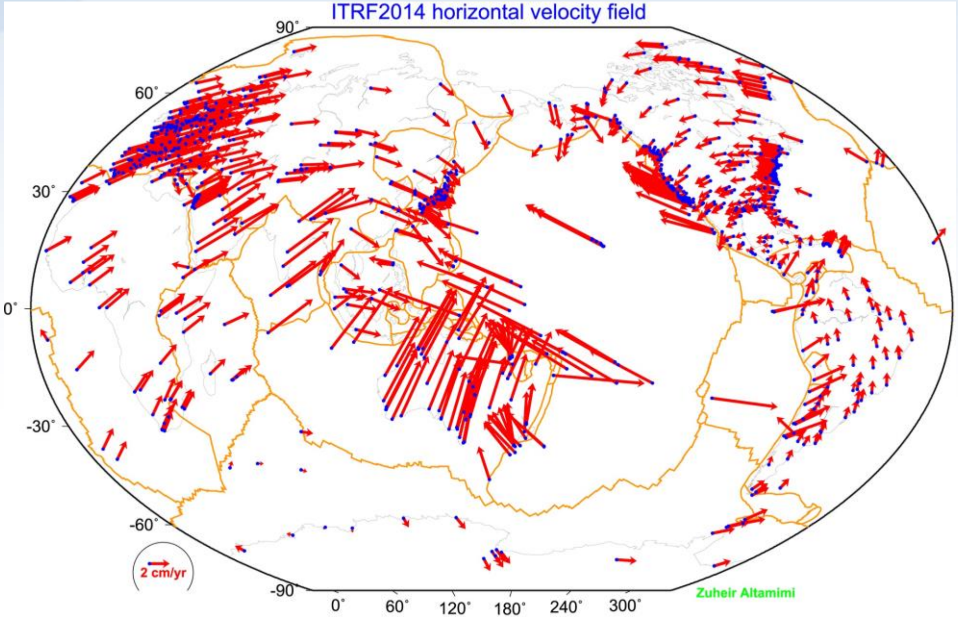
- Defined and maintained by the International Earth Rotation and Reference System Service (IERS)
- Defines conventions for:
  - Origin (Where is the zero point?)
  - Scale (What is the measure of length?)
  - Orientation (How are the axes oriented in space?)

Ideal Geometric Frames

- ITRF
  - Combination of four frames (SLR, VLBI, GNSS, DORIS)
- IGS
  - Post-ITRF frame
  - Most accurate GNSS orbits are in this frame
- Currently the NSRS is mathematically defined:
  - Three NAD 83 frames: North America, Pacific, Mariana plates
  - All 3 defined with respect to ITRF94 (same as ITRF96)
  - All other ITRFs defined with transformations between ITRFs

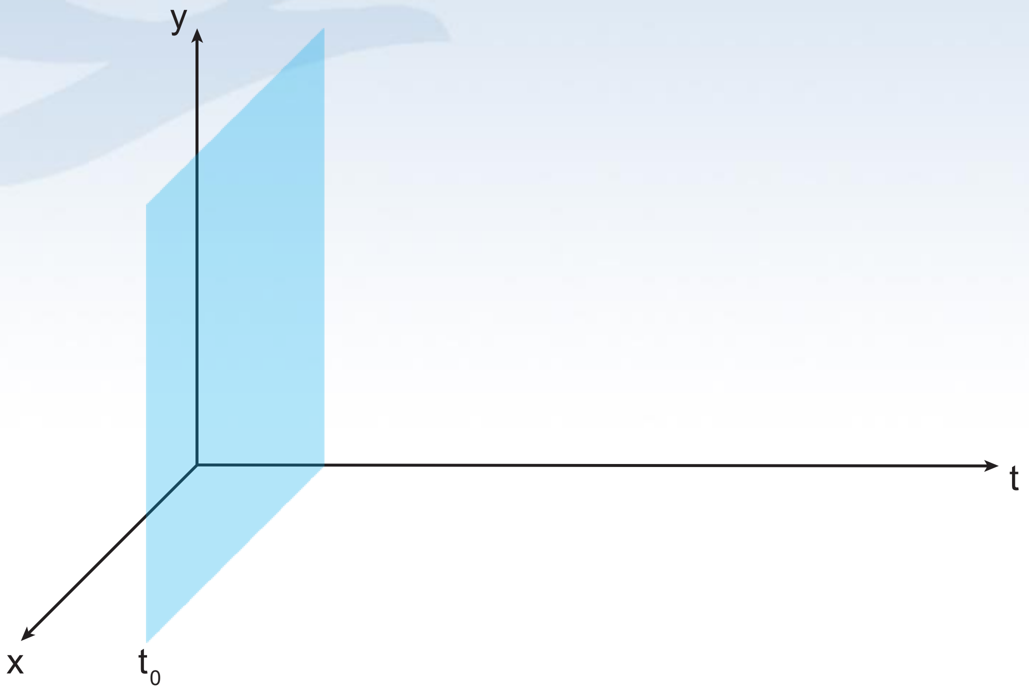
The IGS Reference Frame

- 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

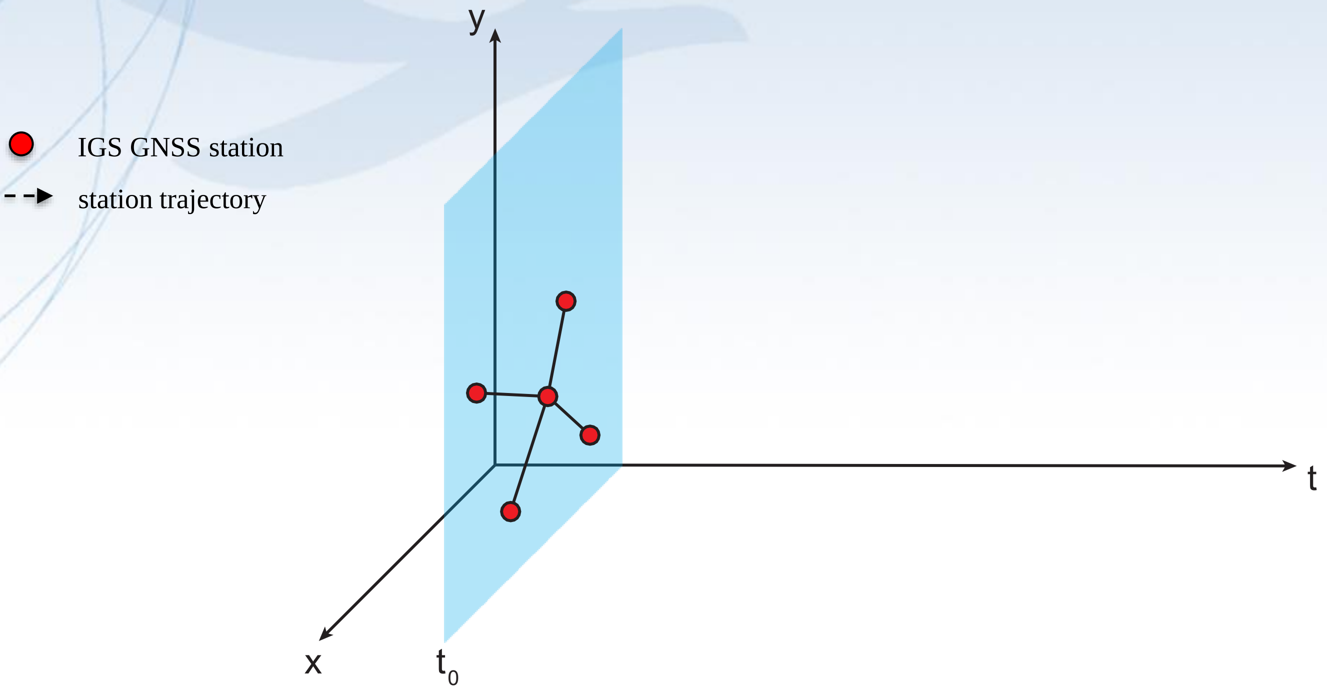


Altamimi et al., 2016, JGR

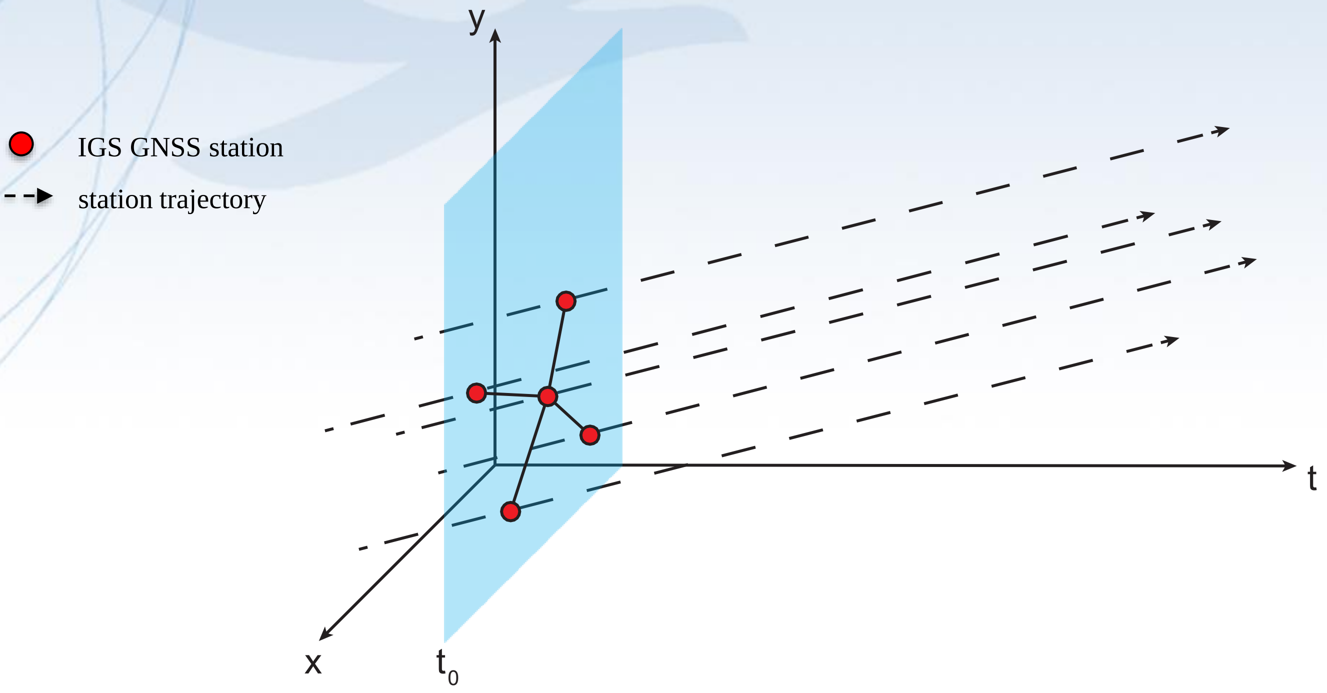
Aligning the NSRS to the IGS reference frame



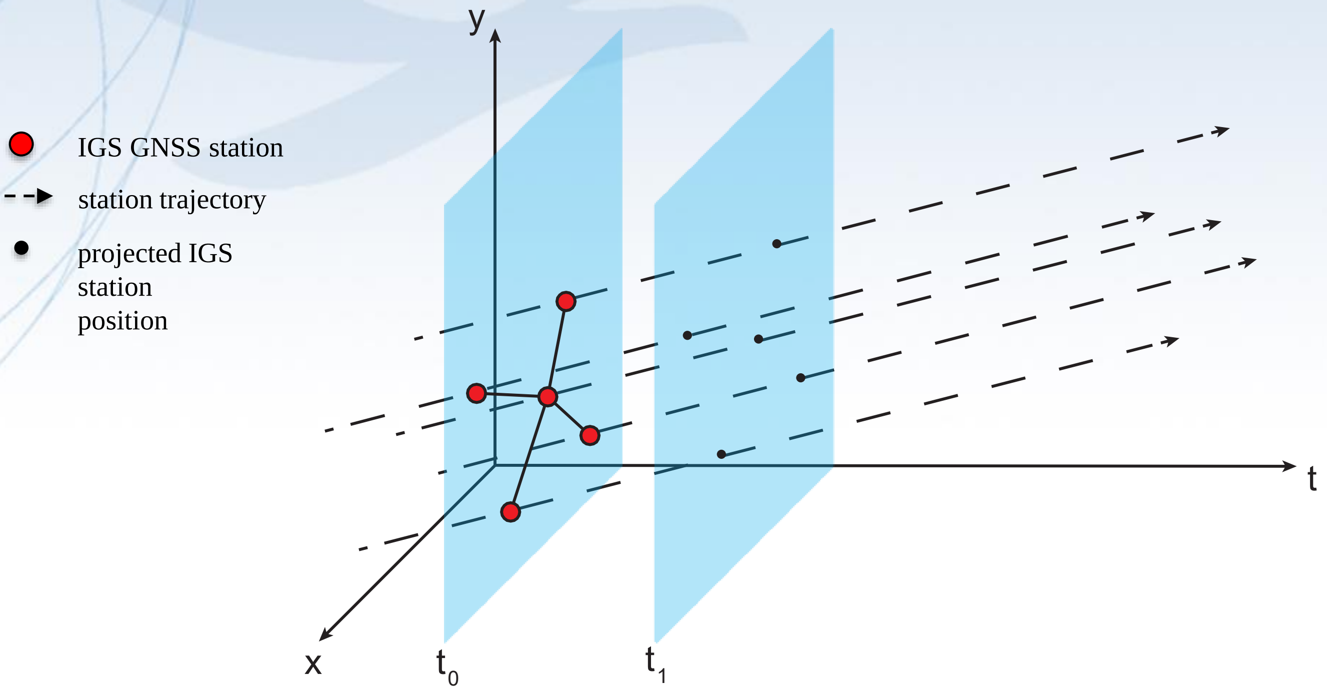
Aligning the NSRS to the IGS reference frame



Aligning the NSRS to the IGS reference frame



Aligning the NSRS to the IGS reference frame



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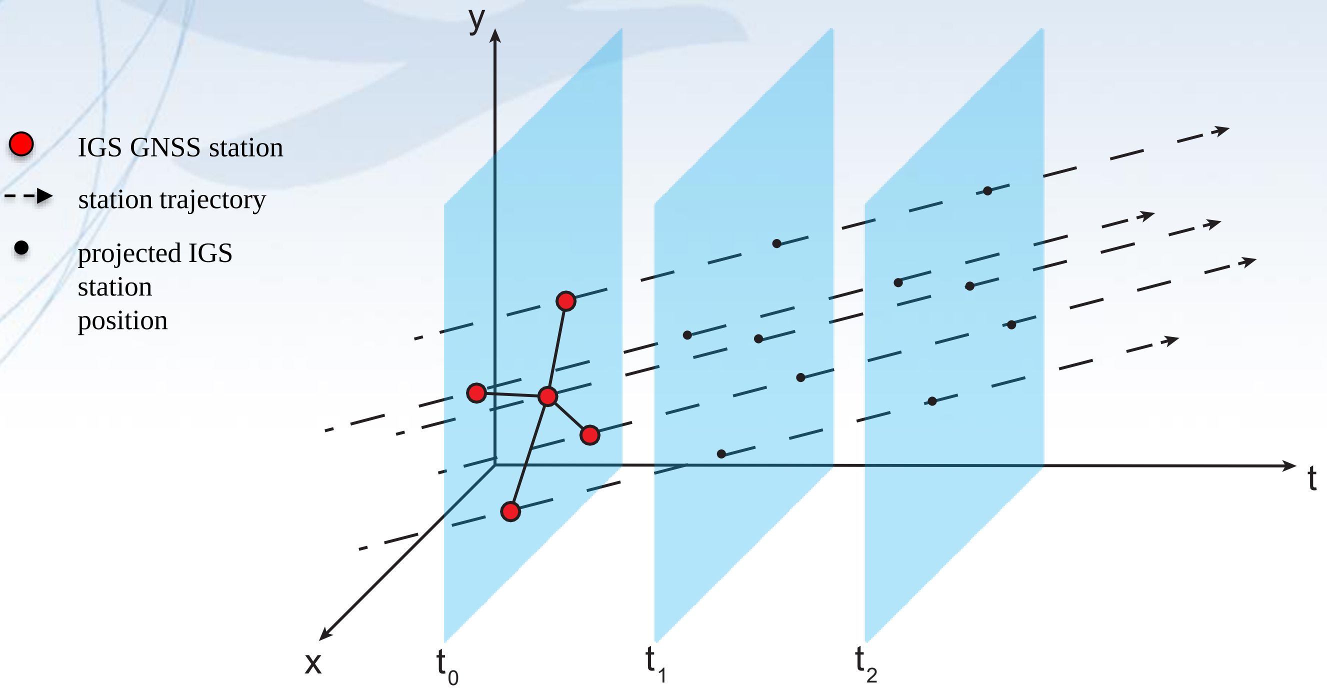
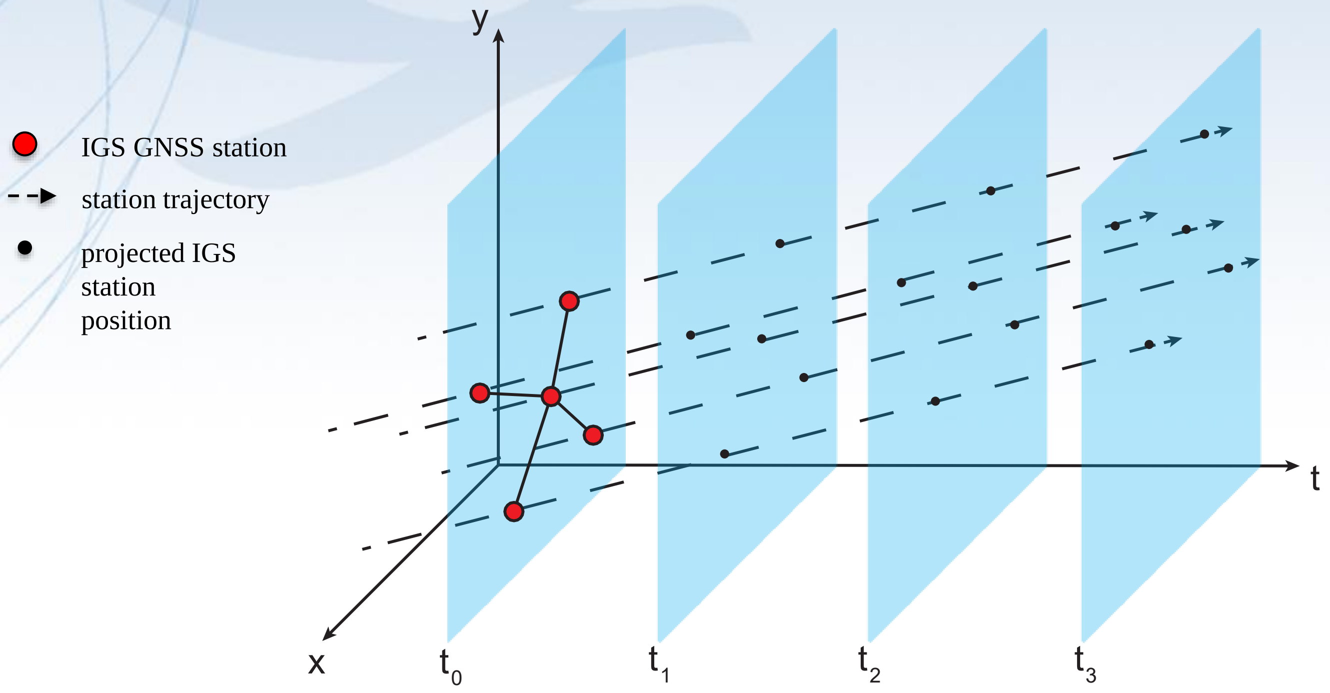
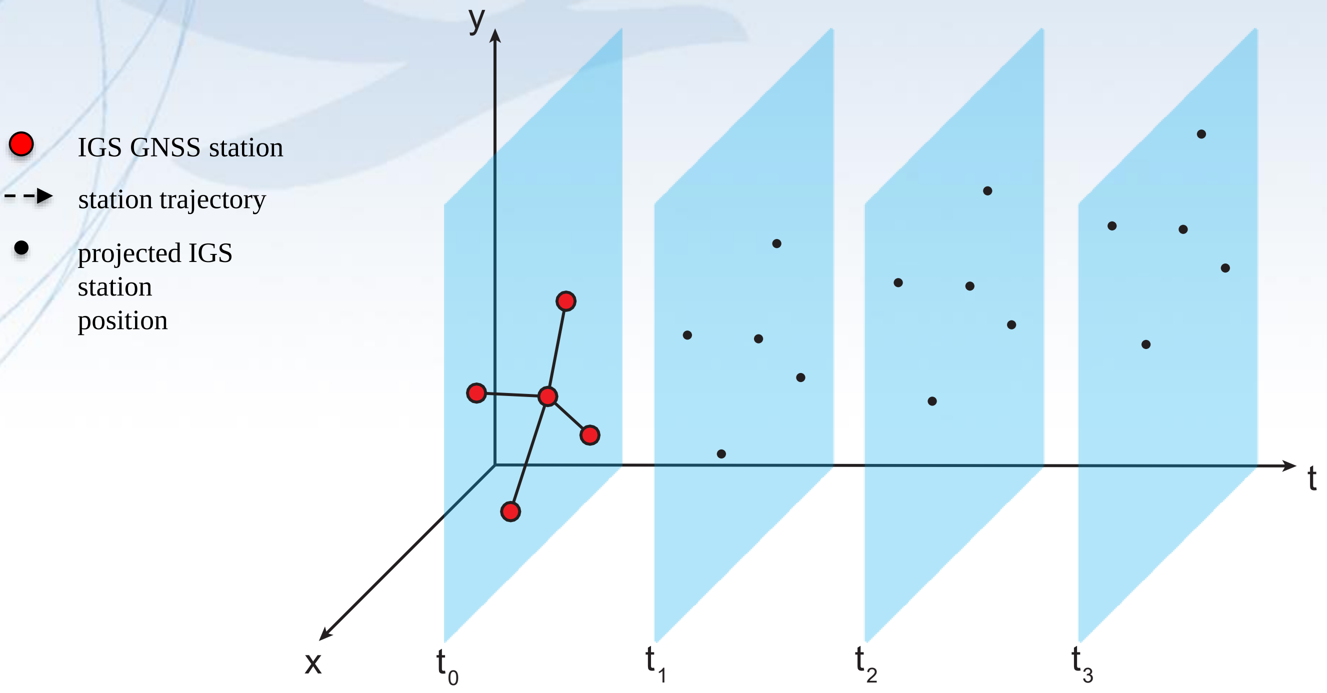


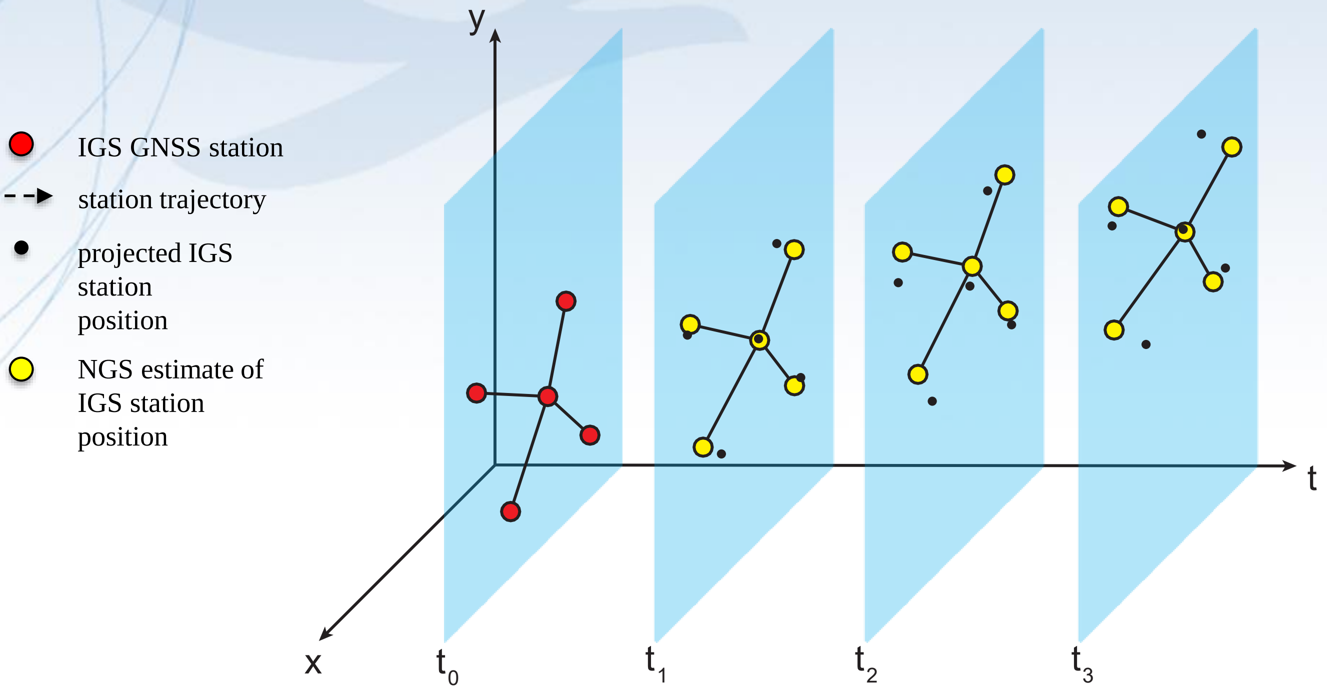
Aligning the NSRS to the IGS reference frame



Aligning the NSRS to the IGS reference frame

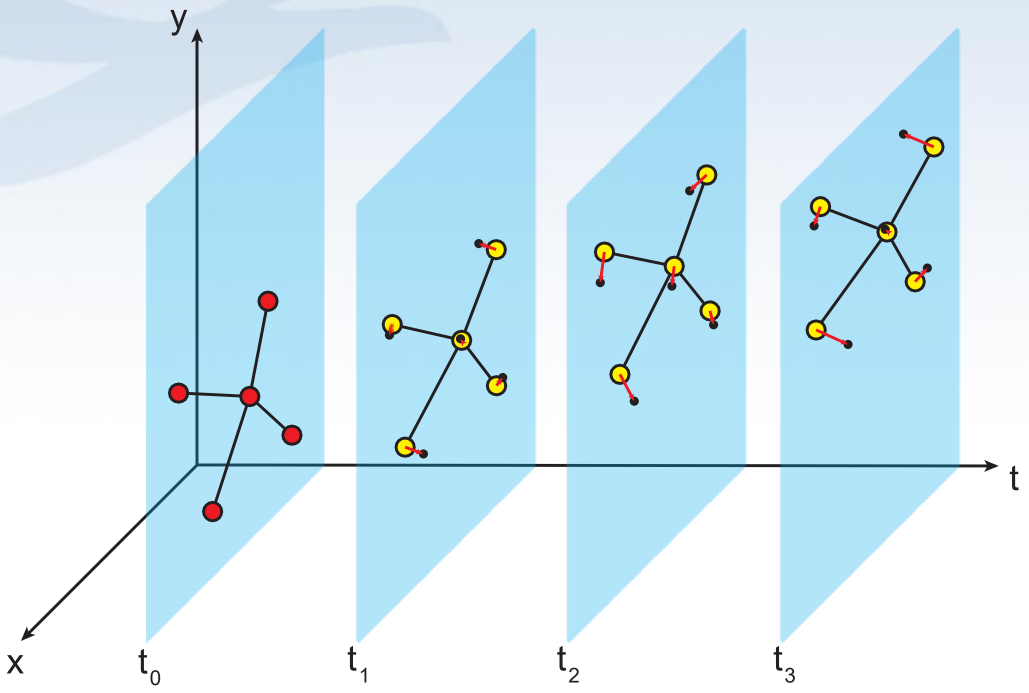


Aligning the NSRS to the IGS reference frame

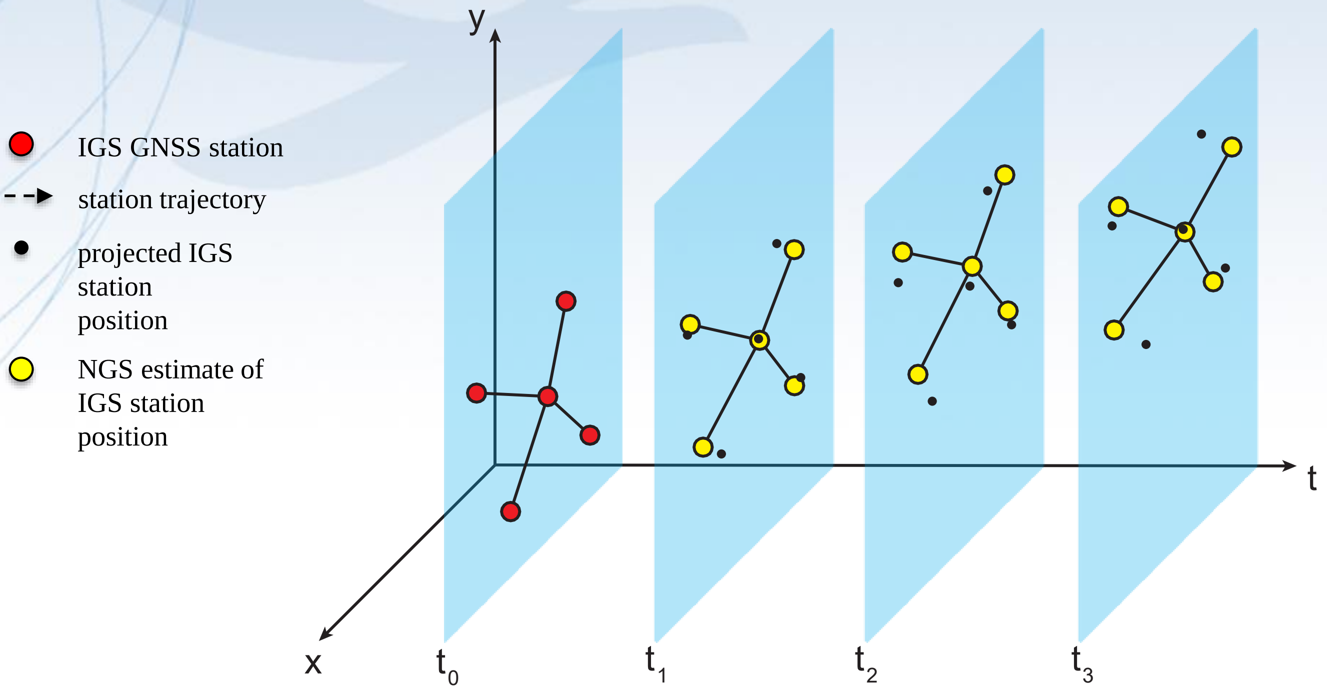


Aligning the NSRS to the IGS reference frame

- IGS GNSS station
- station trajectory
- projected IGS station position
- NGS estimate of IGS station position



Aligning the NSRS to the IGS reference frame



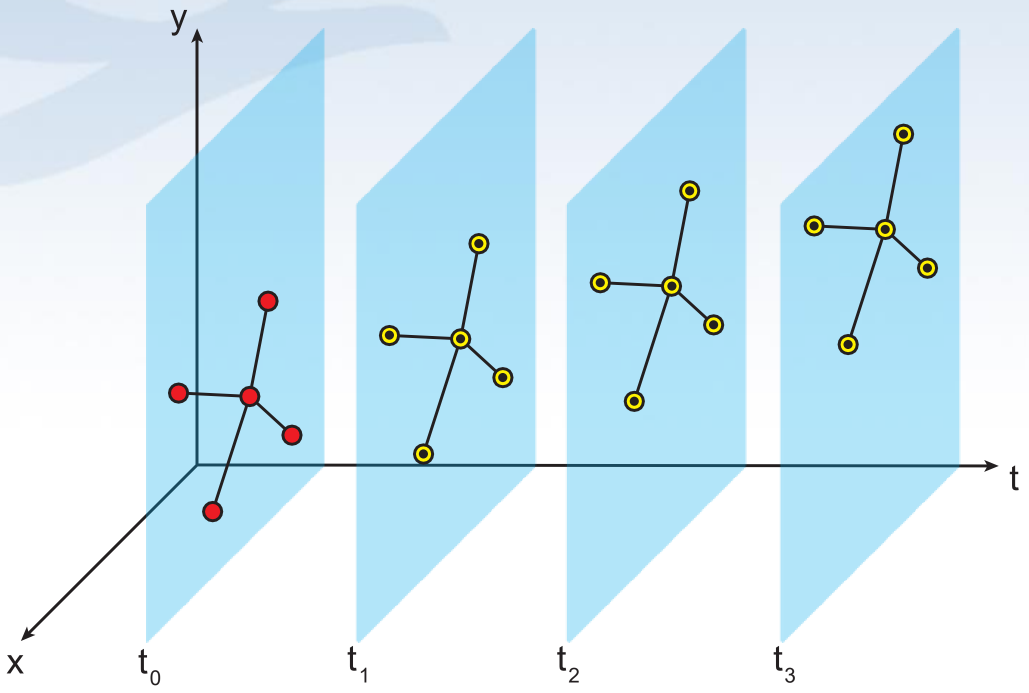
Aligning the NSRS to the IGS reference frame

IGS GNSS station

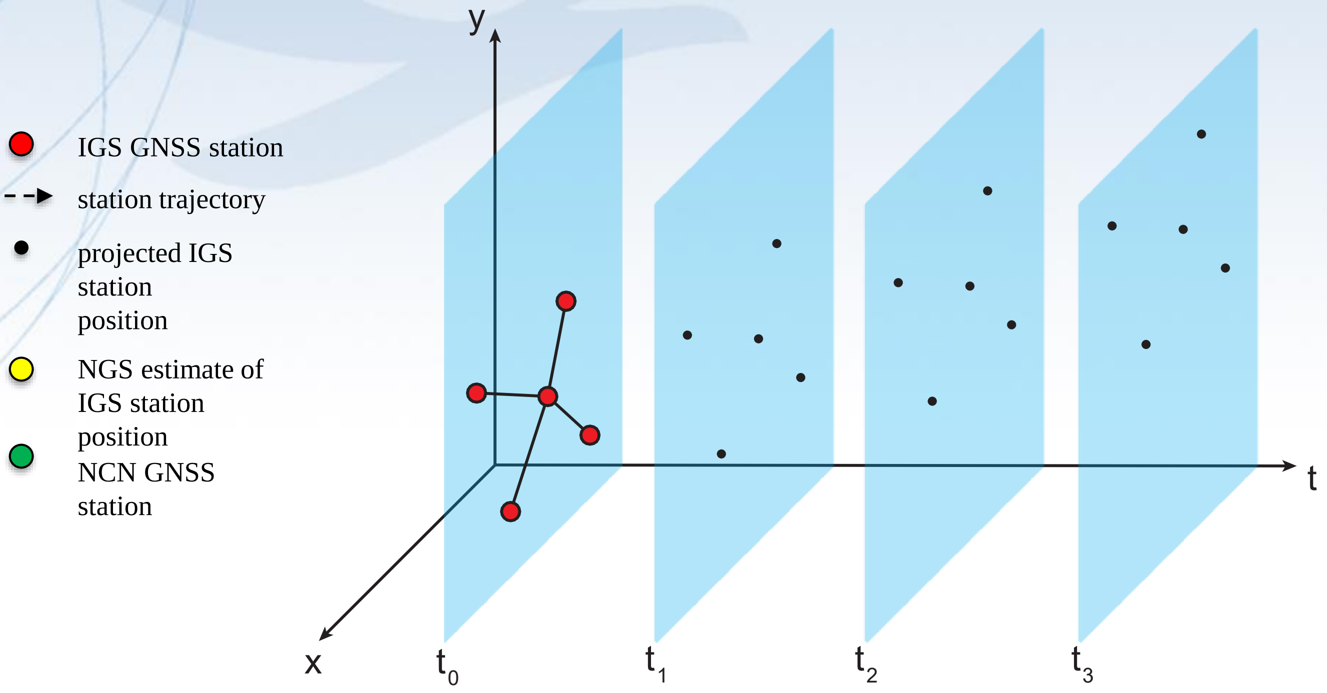
station trajectory

projected IGS station position

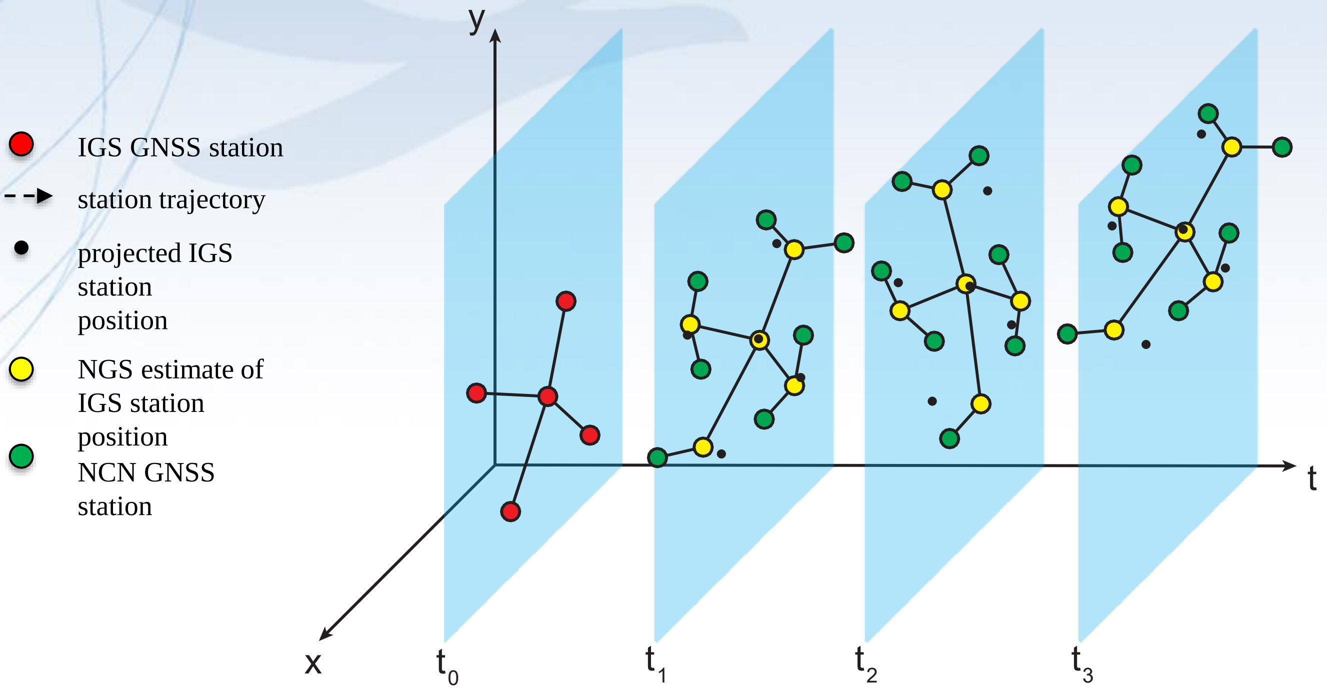
NGS estimate of IGS station position



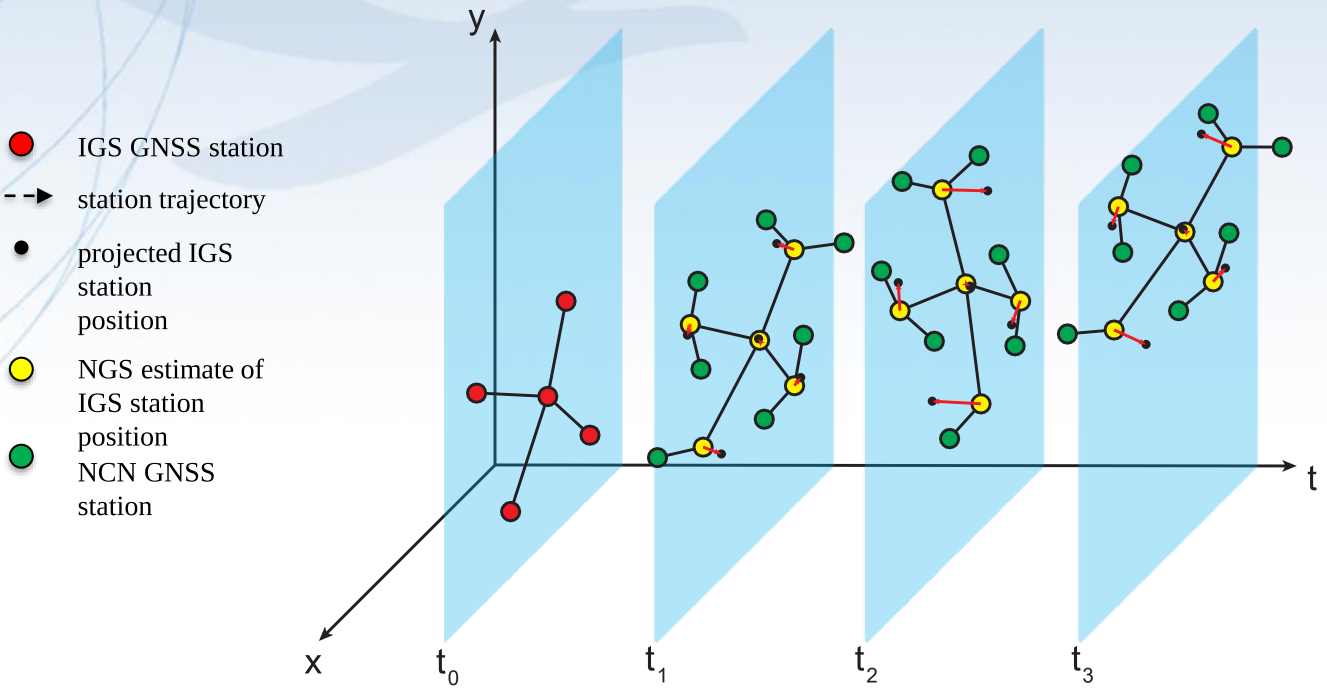
Aligning the NSRS to the IGS reference frame



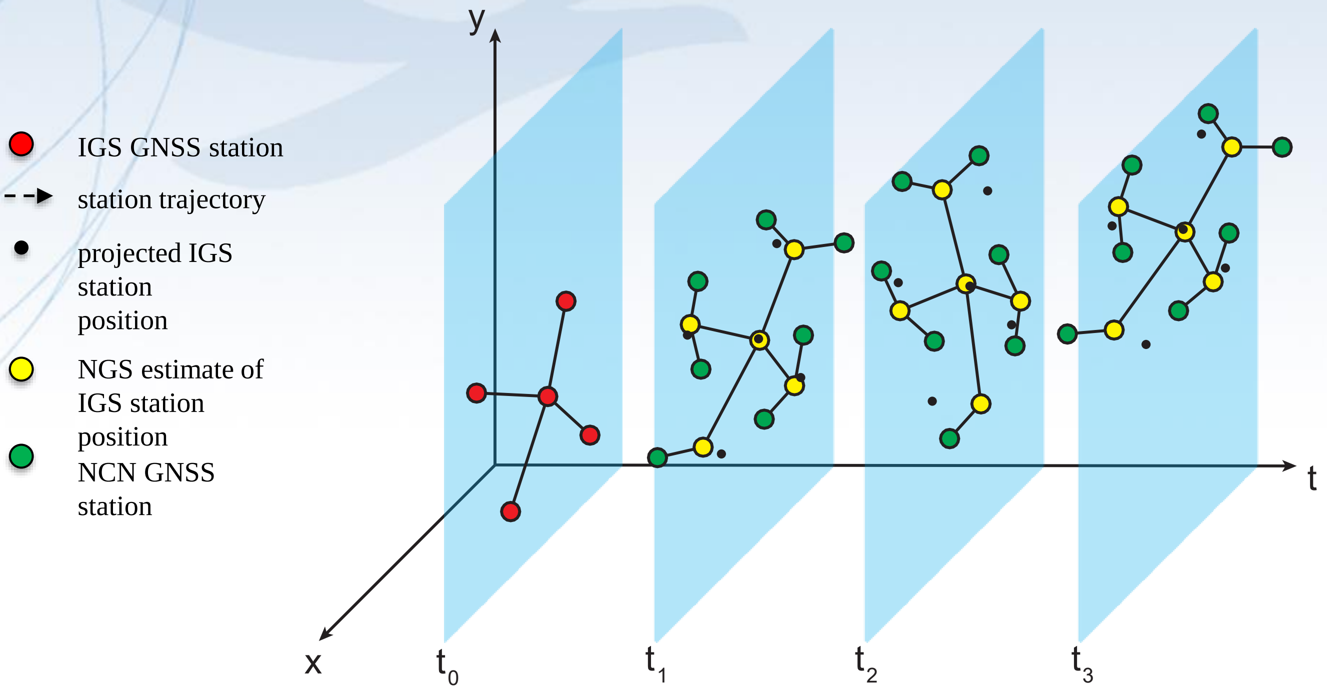
Aligning the NSRS to the IGS reference frame



Aligning the NSRS to the IGS reference frame



Aligning the NSRS to the IGS reference frame



Aligning the NSRS to the IGS reference frame

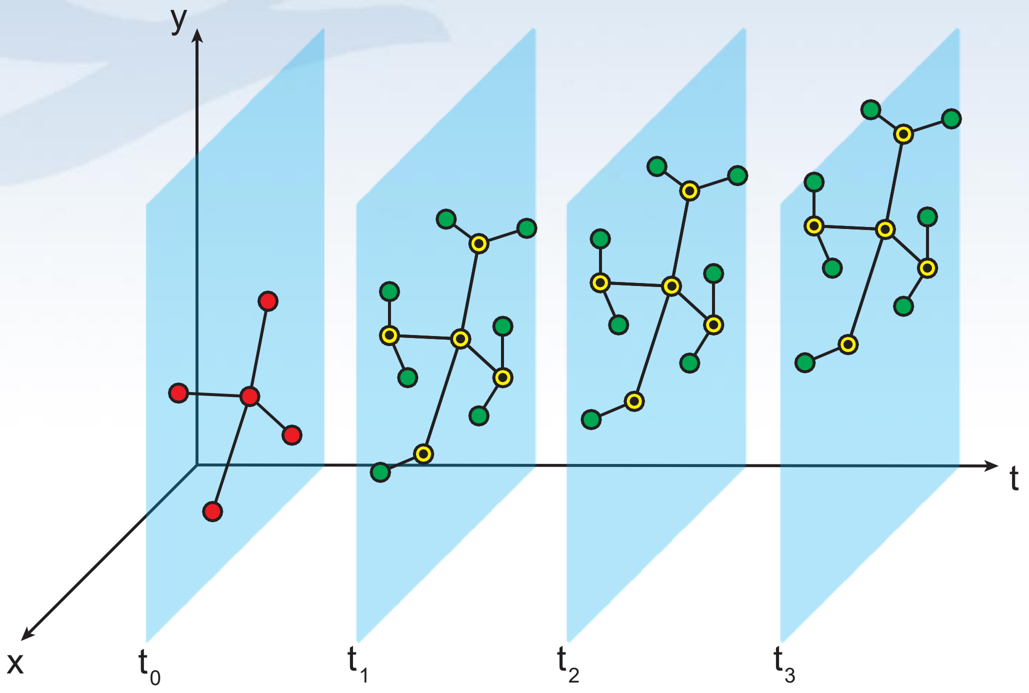
IGS GNSS station

station trajectory

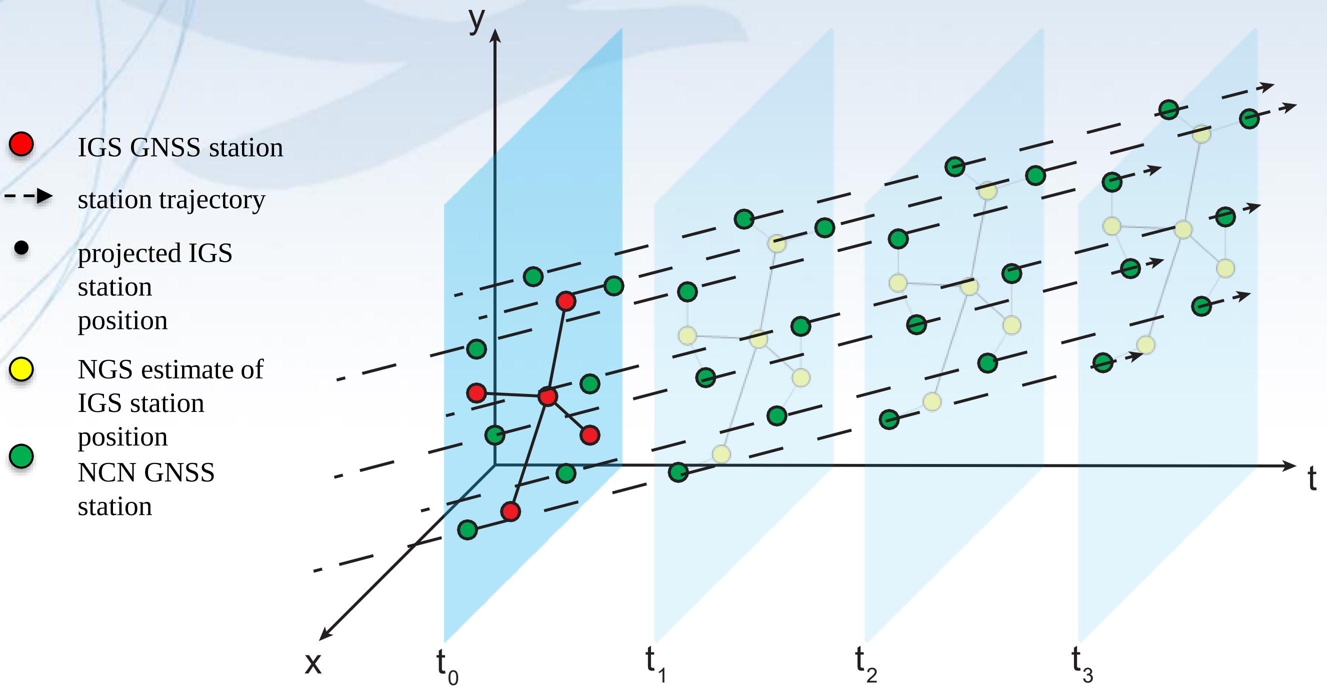
projected IGS station position

NGS estimate of IGS station position

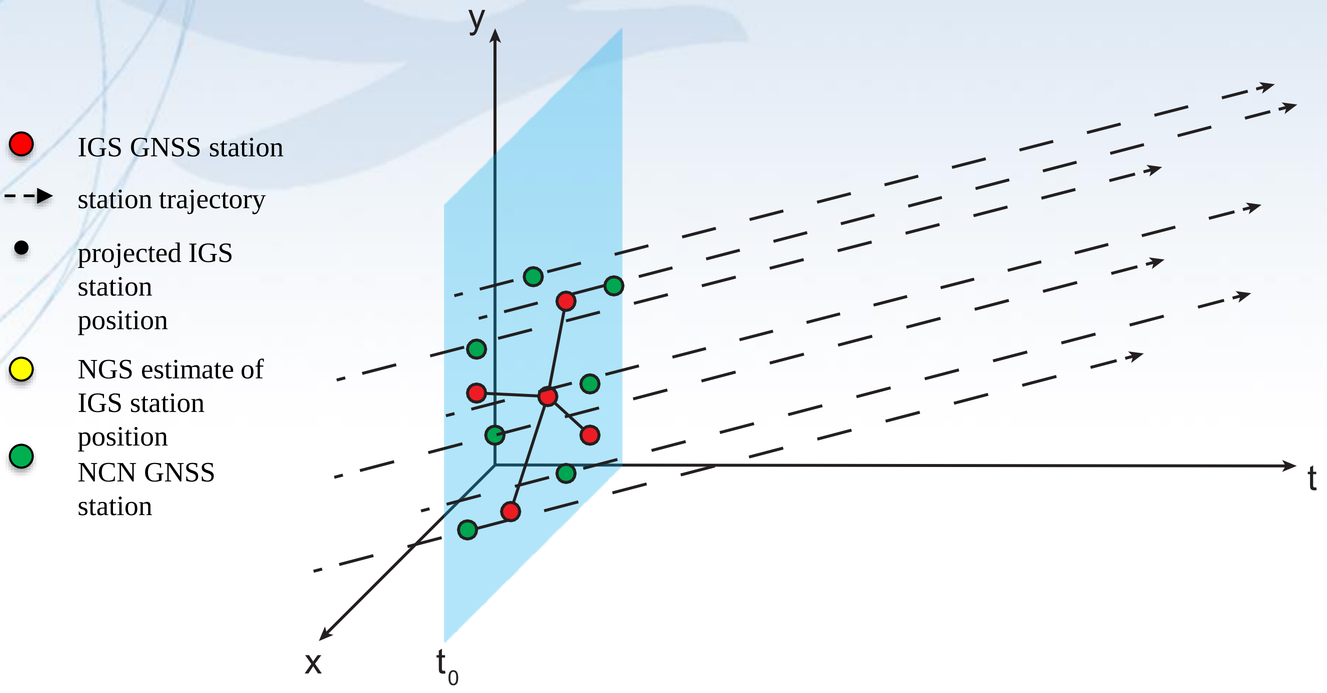
NCN GNSS station



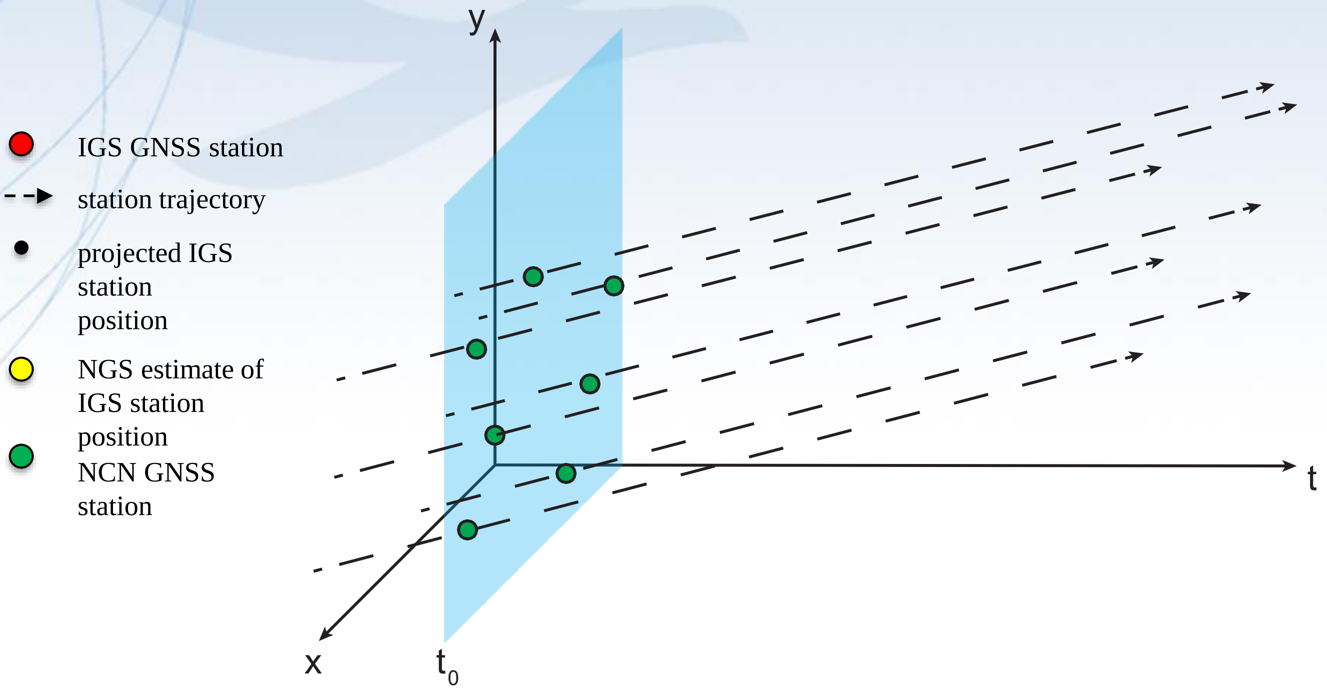
Aligning the NSRS to the IGS reference frame



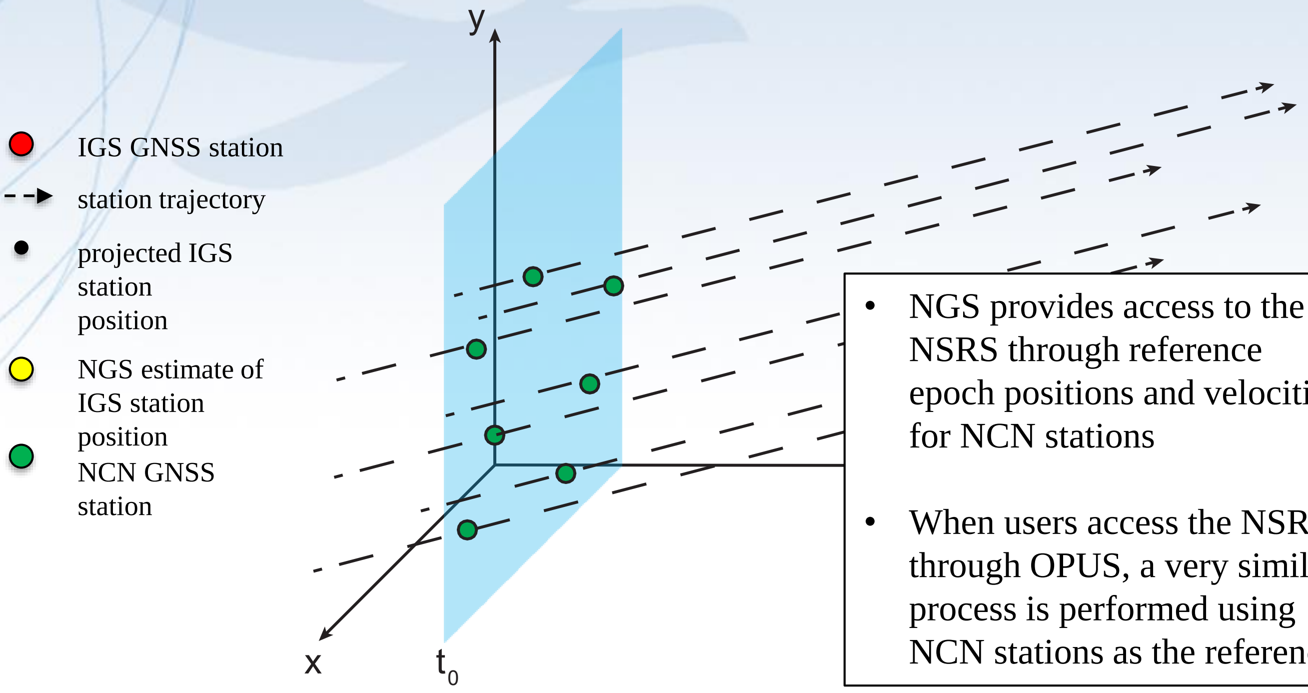
Aligning the NSRS to the IGS reference frame



Aligning the NSRS to the IGS reference frame

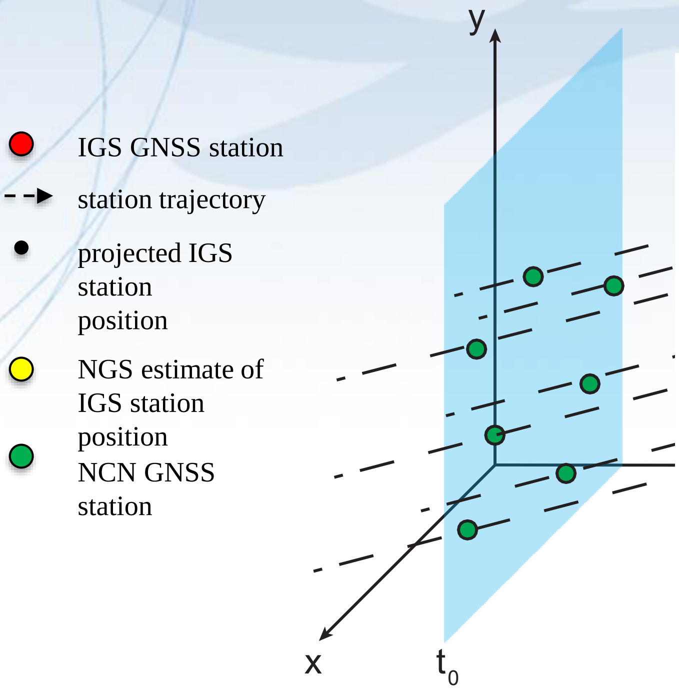


Aligning the NSRS to the IGS reference frame



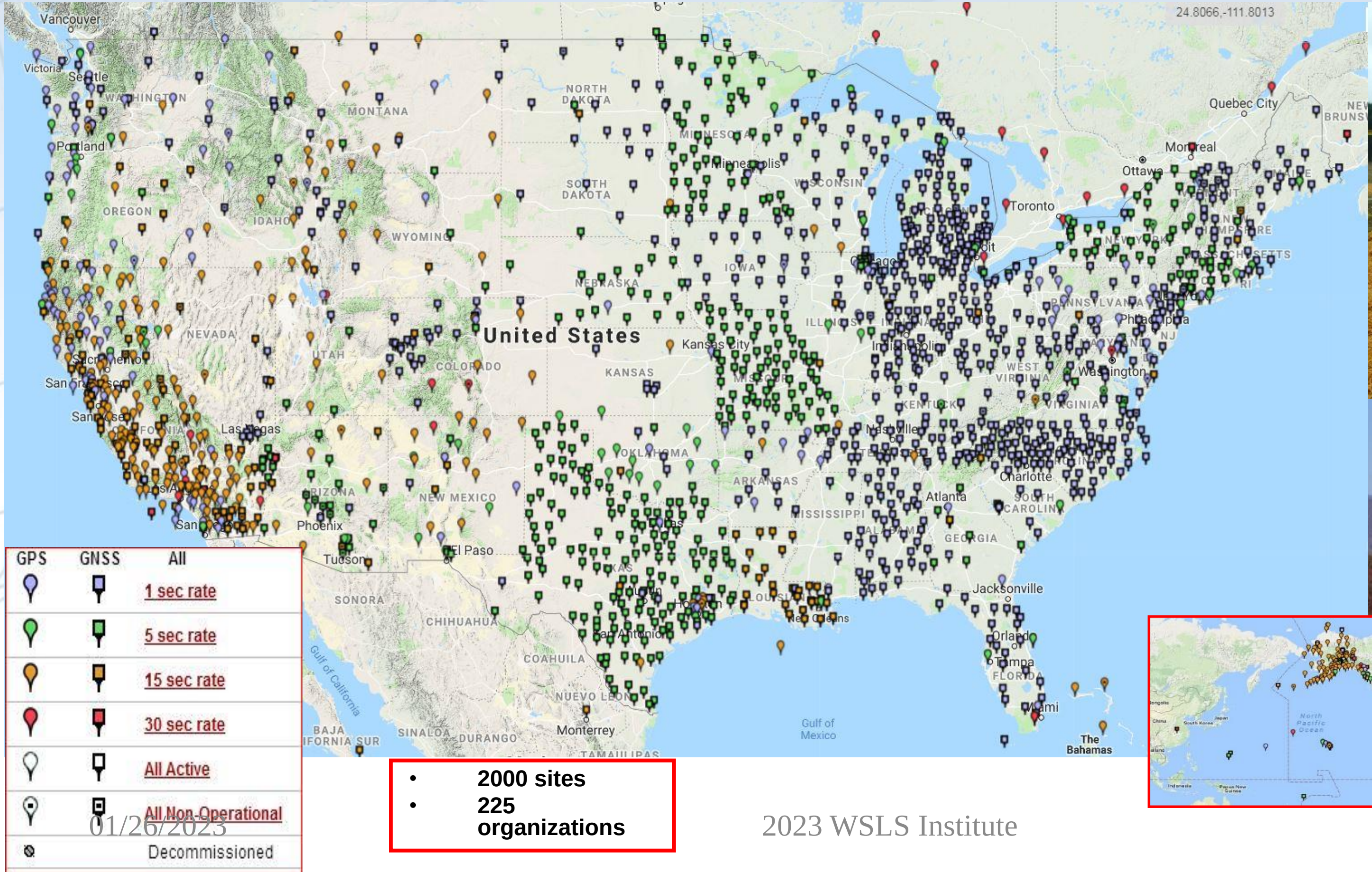
- NGS provides access to the NSRS through reference epoch positions and velocities for NCN stations
- When users access the NSRS through OPUS, a very similar process is performed using NCN stations as the reference

Aligning the NSRS to the IGS reference frame




```
                    ***ITRF2014***
        SPRINGFIELD (ILSA),  ILLINOIS

Retrieved from NGS DataBase on 06/16/20 at 12:08:08.

      Antenna Reference Point(ARP): SPRINGFIELD CORS ARP
      --------------------------------------------------
                      PID = DH3759

 ITRF2014 POSITION (EPOCH 2010.0)
 Computed in Jun 2019 using data through gpswk 1933.
     X =      33385.661 m      latitude     =  39 46 43.08662 N
     Y =   -4908474.037 m      longitude    = 089 36 37.08320 W
     Z =    4059224.558 m      ellipsoid height =   152.899    m

 ITRF2014 VELOCITY
 Computed in Jun 2019 using data through gpswk 1933.
     VX =   -0.0152 m/yr      northward =   -0.0003 m/yr
     VY =    0.0013 m/yr      eastward  =   -0.0152 m/yr
     VZ =   -0.0016 m/yr      upward    =   -0.0021 m/yr

 NAD_83 (2011) POSITION (EPOCH 2010.0)
 Transformed from ITRF2014 (epoch 2010.0) position in Jun 2019.
     X =      33386.414 m      latitude     =  39 46 43.06019 N
     Y =   -4908475.423 m      longitude    = 089 36 37.05194 W
     Z =    4059224.655 m      ellipsoid height =   154.031    m

 NAD_83 (2011) VELOCITY
 Transformed from ITRF2014 velocity in Jun 2019.
     VX =    0.0017 m/yr      northward =    0.0001 m/yr
     VY =    0.0024 m/yr      eastward  =    0.0017 m/yr
     VZ =   -0.0019 m/yr      upward    =   -0.0031 m/yr
```

Continuously Operating Reference Station (CORS) Network



- 2000 sites
- 225 organizations

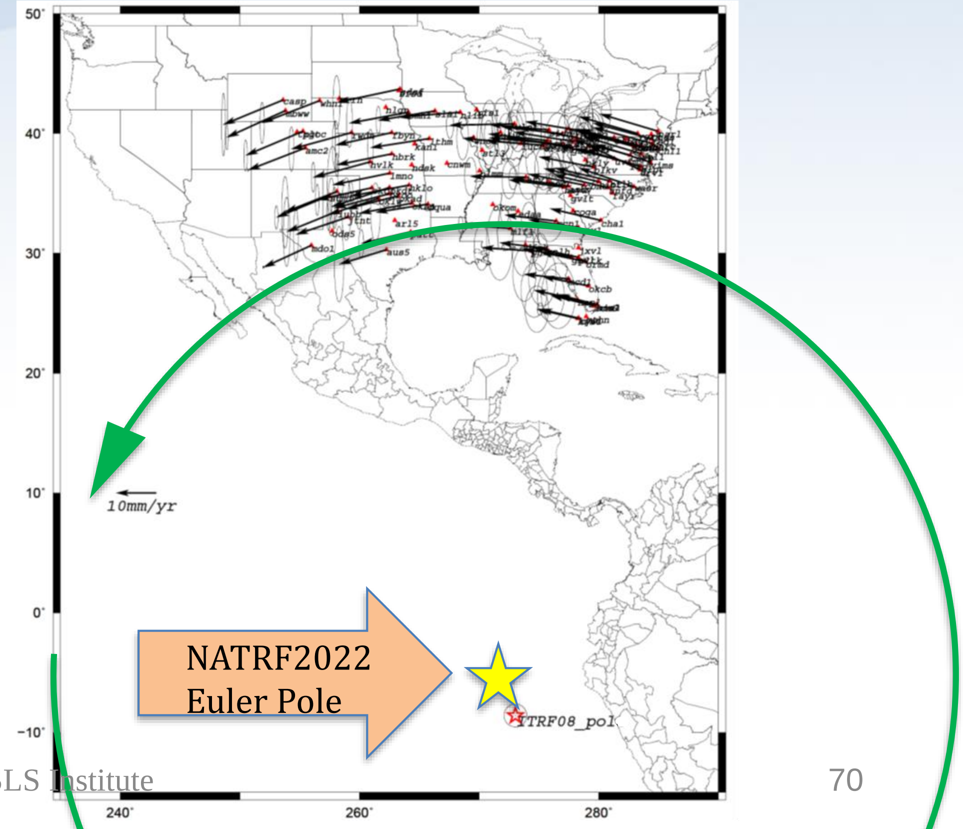
Euler Poles and "Plate-Fixed"

– In the ITRF, many tectonic plates have a *dominant* motion: **rotation**

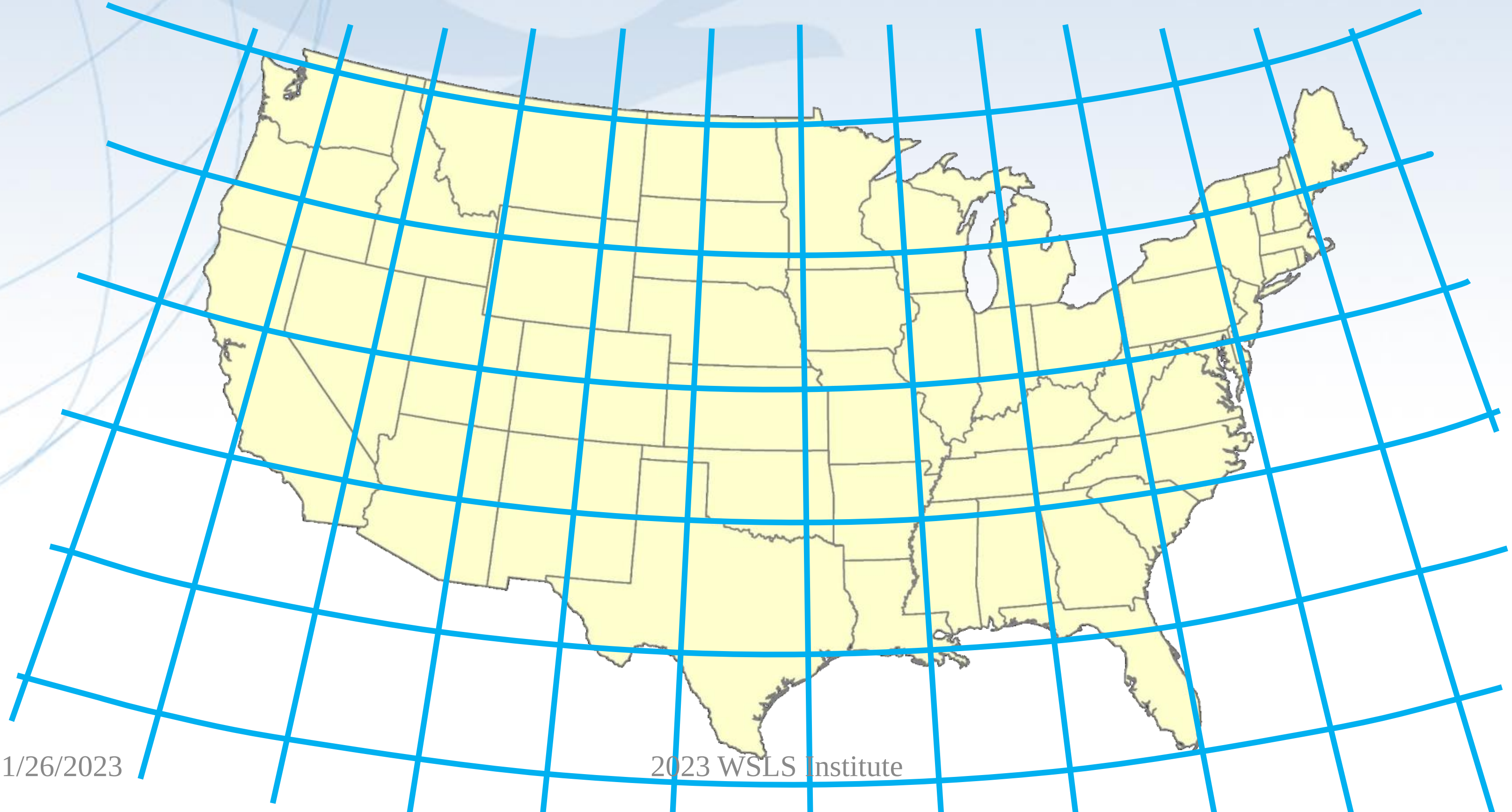
– **Euler Pole** - point about which a plate rotates (yellow star)

– Euler Pole Parameters (**EPP**) define this rotation

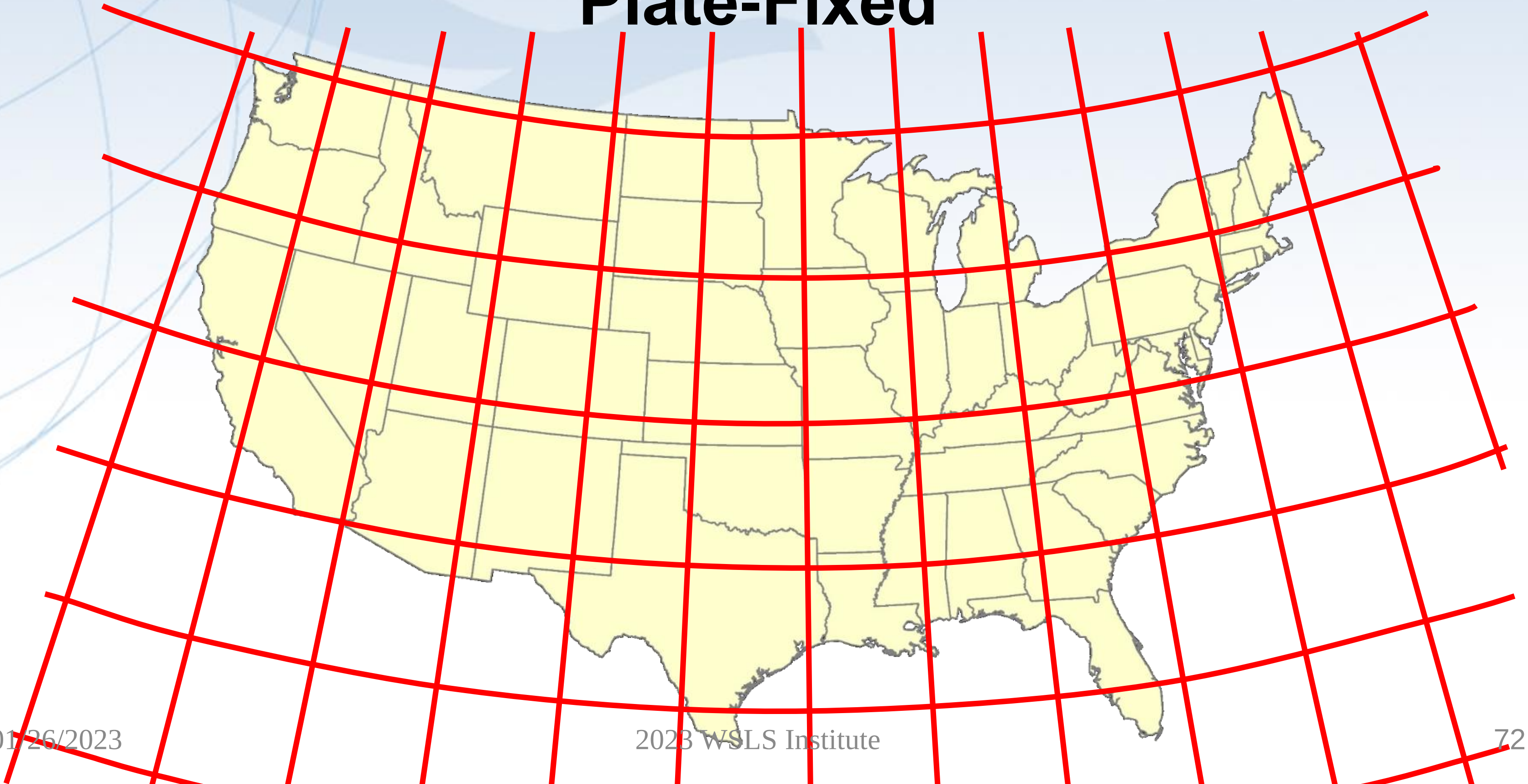
– Residual motion is characterized in an Intra-Frame Deformation Model (**IFDM**)



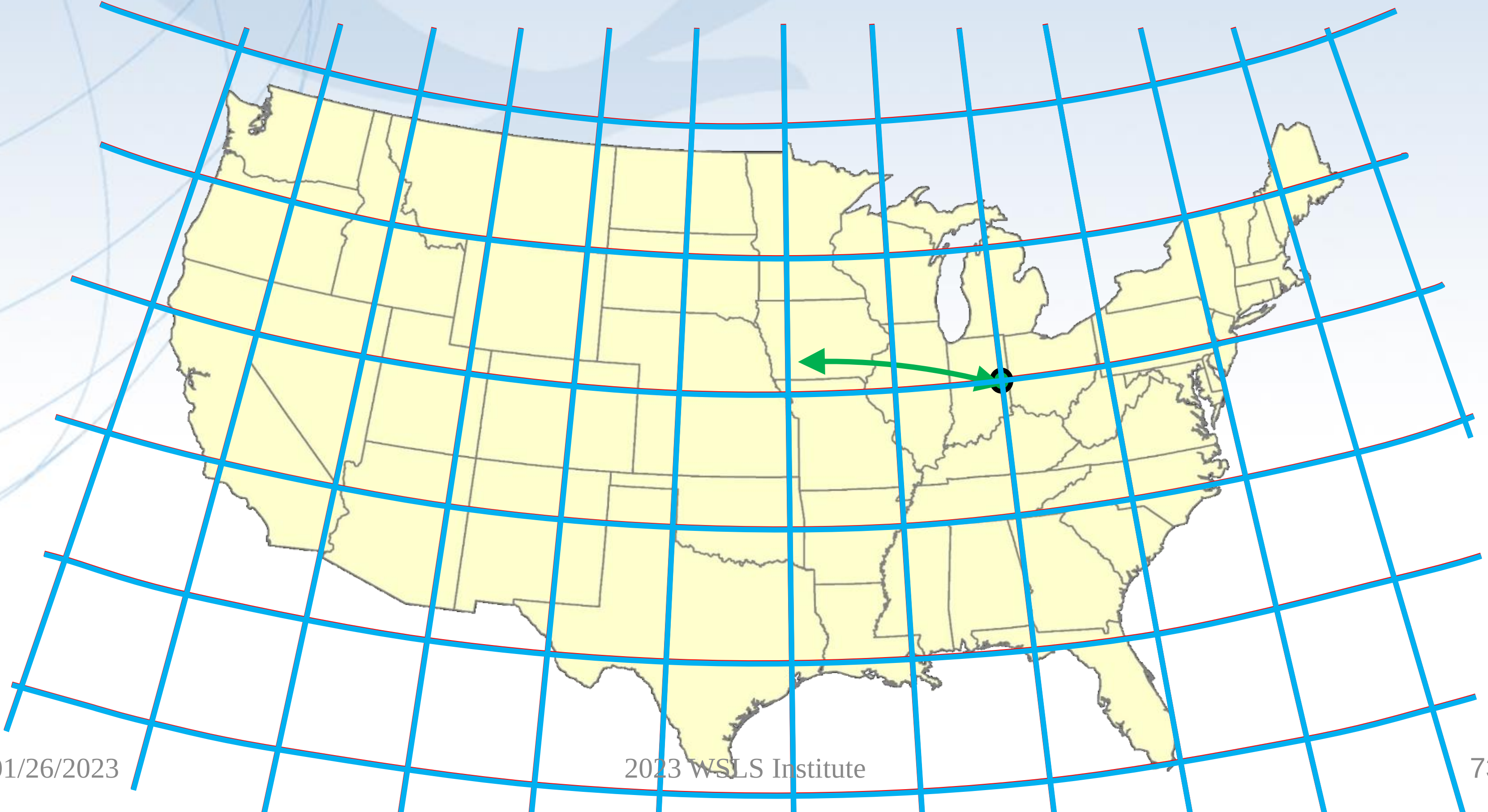
ITRF2020: Constant Frame, Rotating Plate



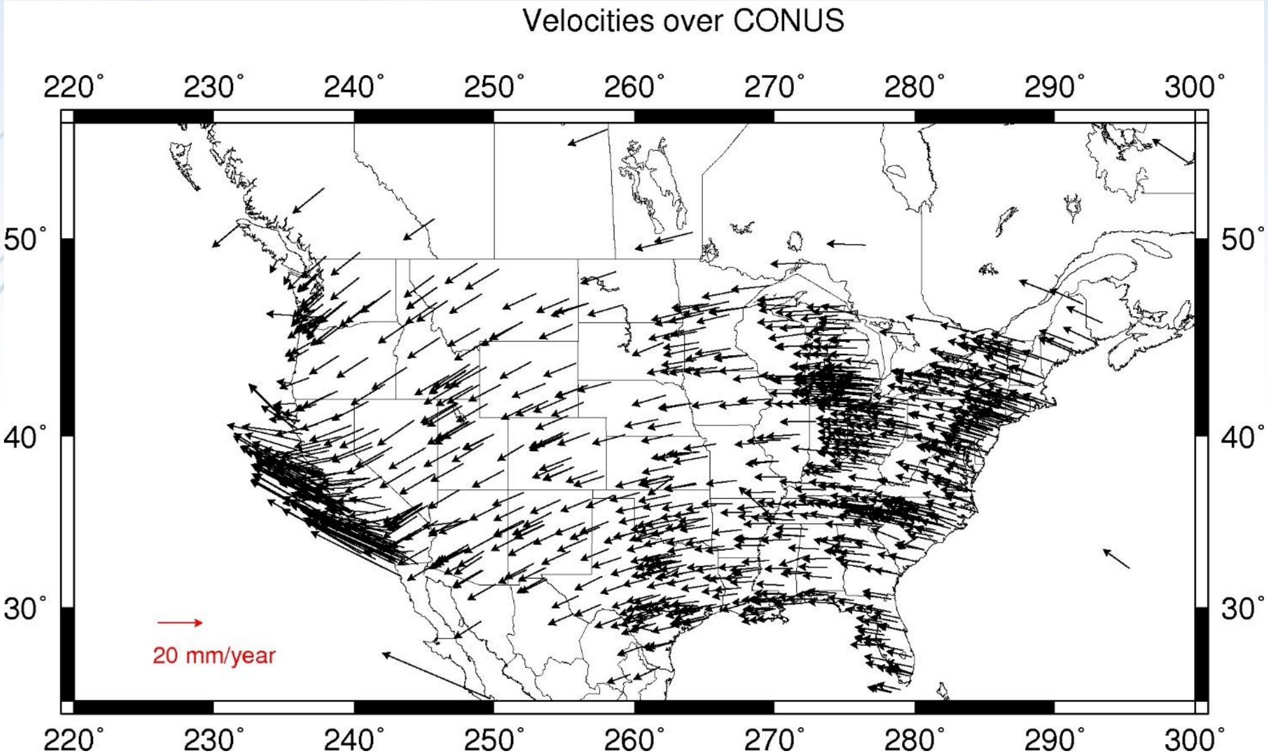
NATRF2022: Constant Frame, Rotating Plate "Plate-Fixed"



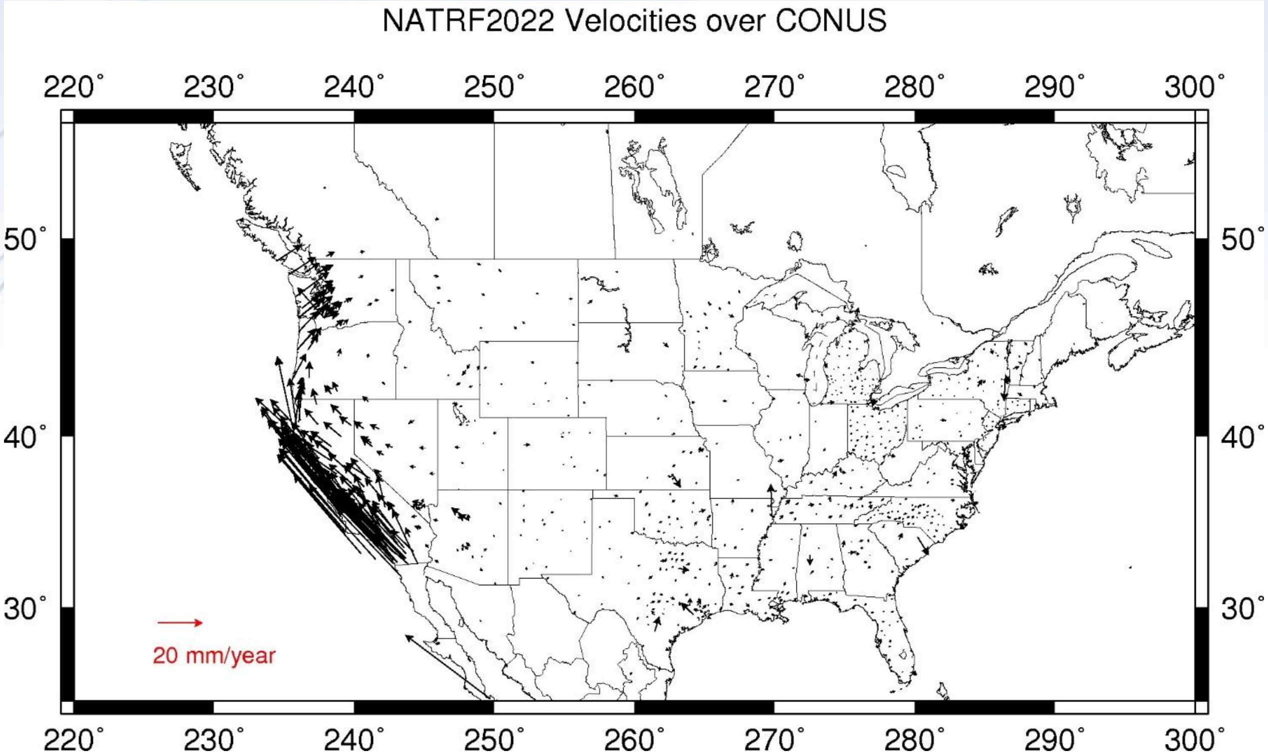
ITRF2020 or NATRF2022

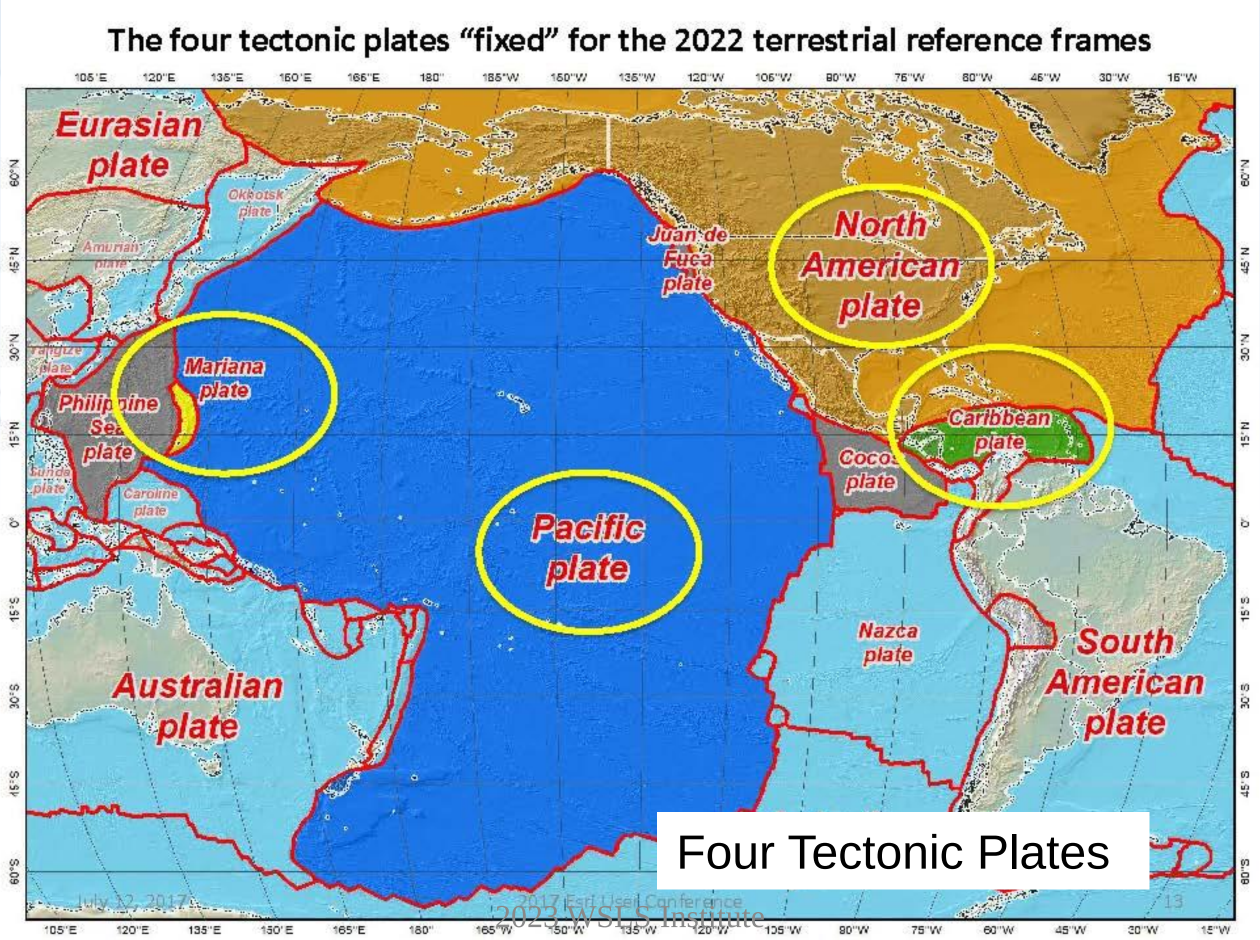


Residual Velocities – ITRF2020/CONUS



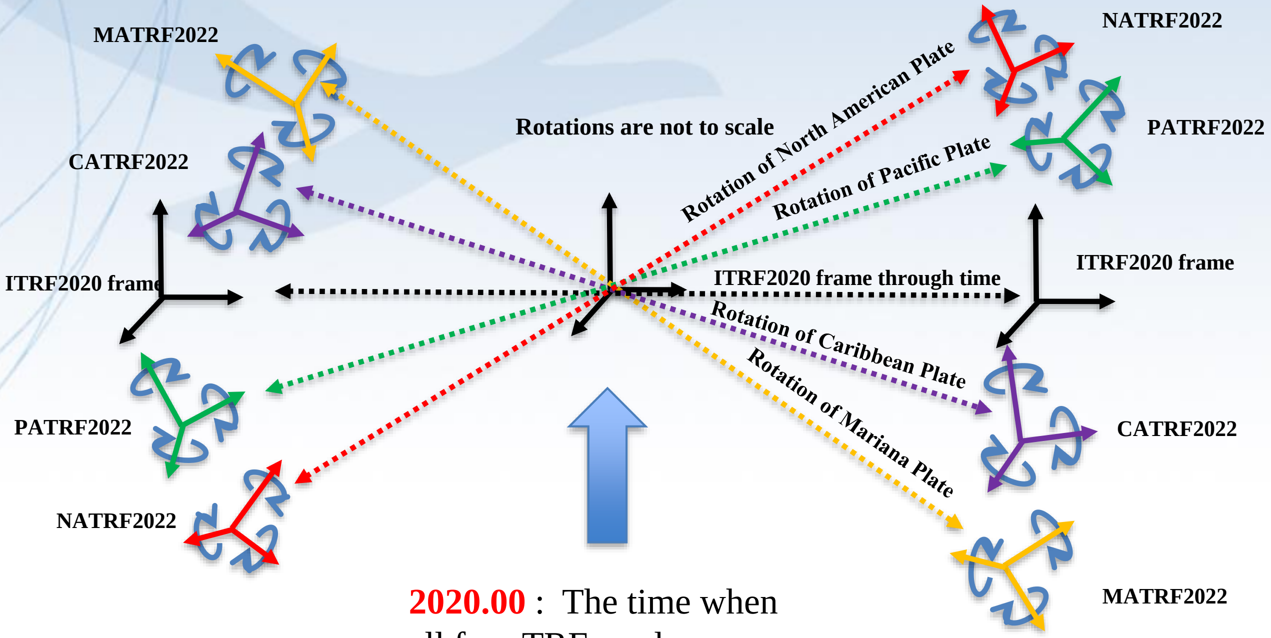
Residual Velocities – NATRF2022/CONUS





Four Tectonic Plates

The Relation of 5 Global Reference Frames through Time



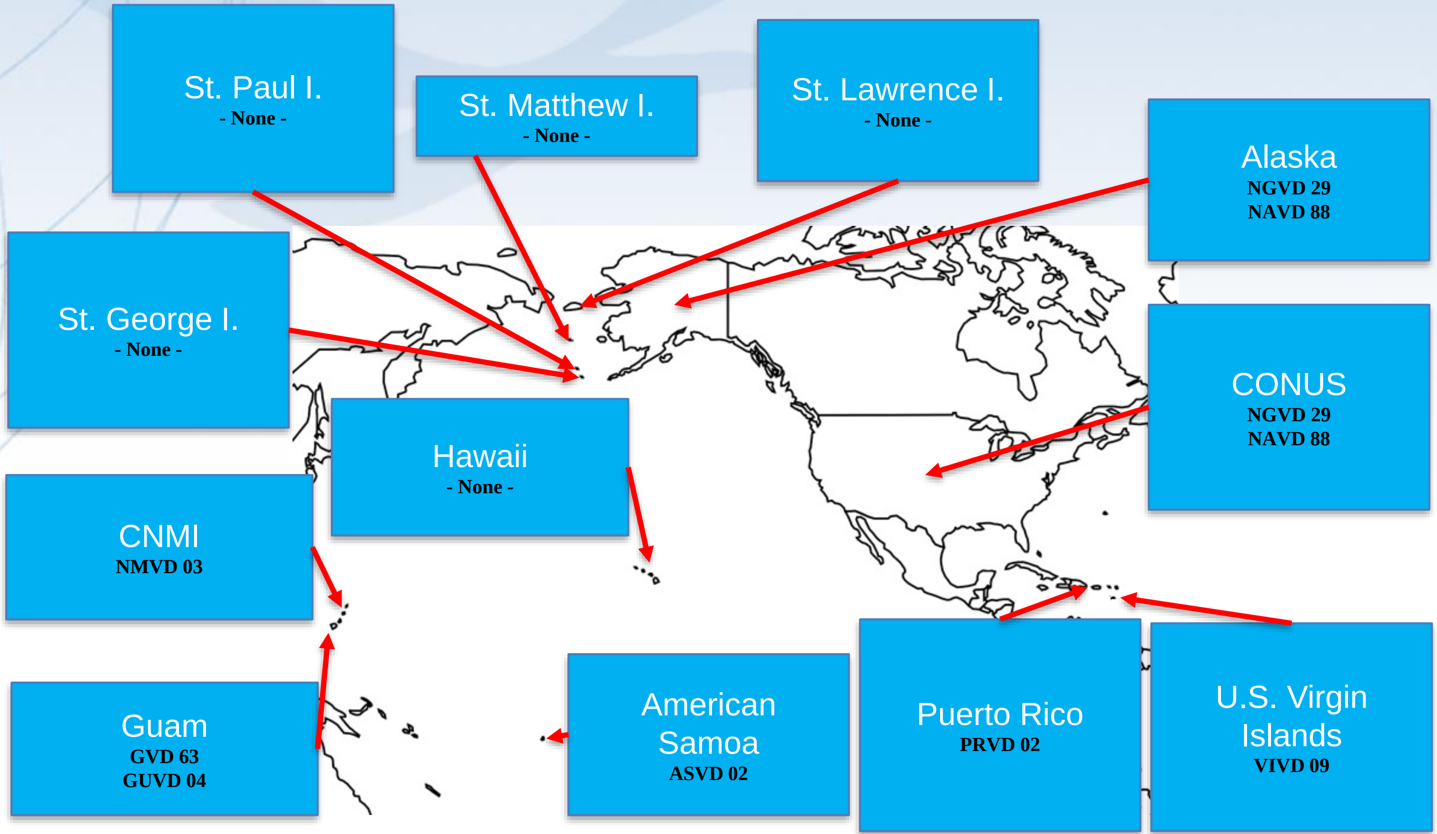
t = 2020.00 - Dt
("the past")

2020.00 : The time when all four TRFs and ITRF2020 are identical by definition.

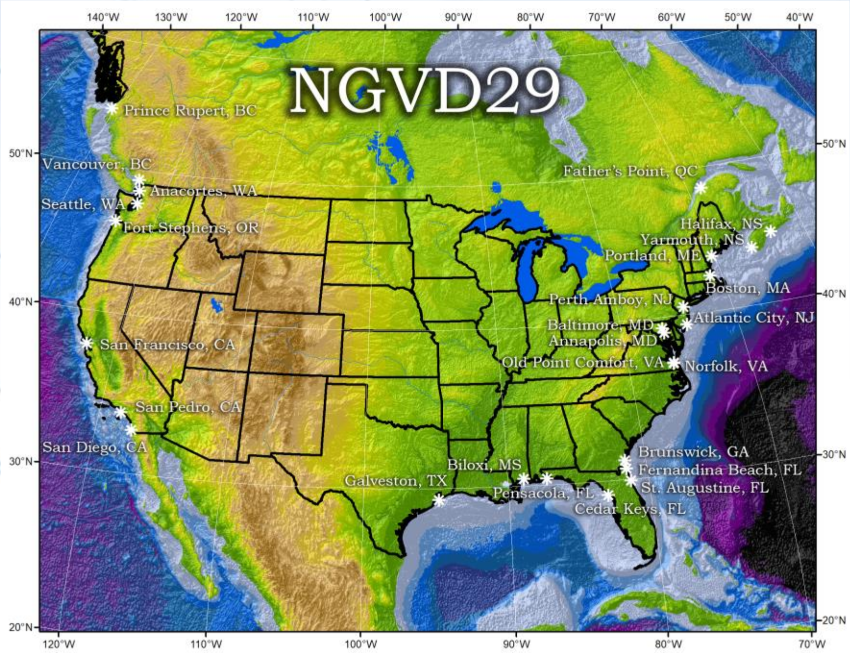
t = 2020.00 + Dt
("the future")

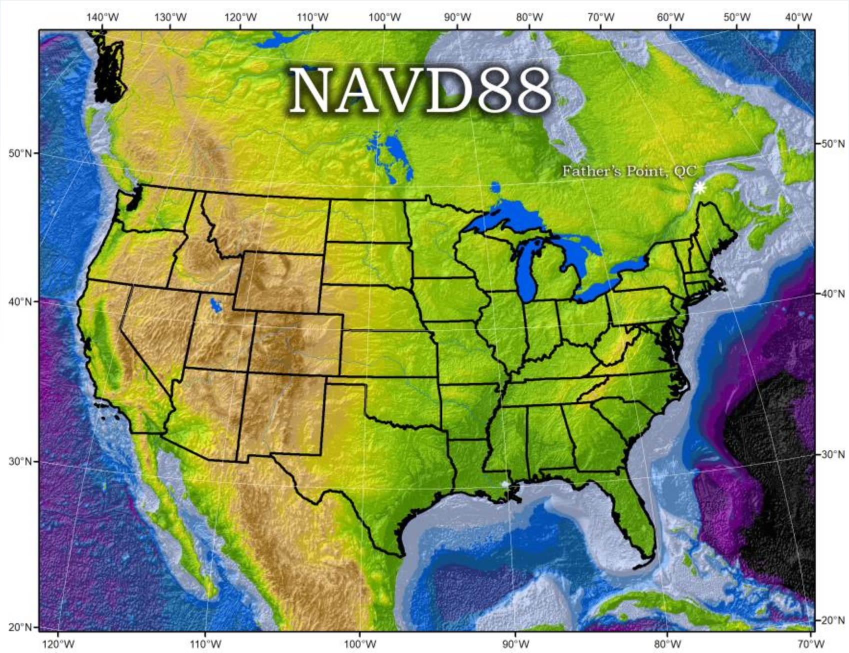
VERTICAL DATUMS

Vertical Datums of the NSRS



Developing the previous vertical datums

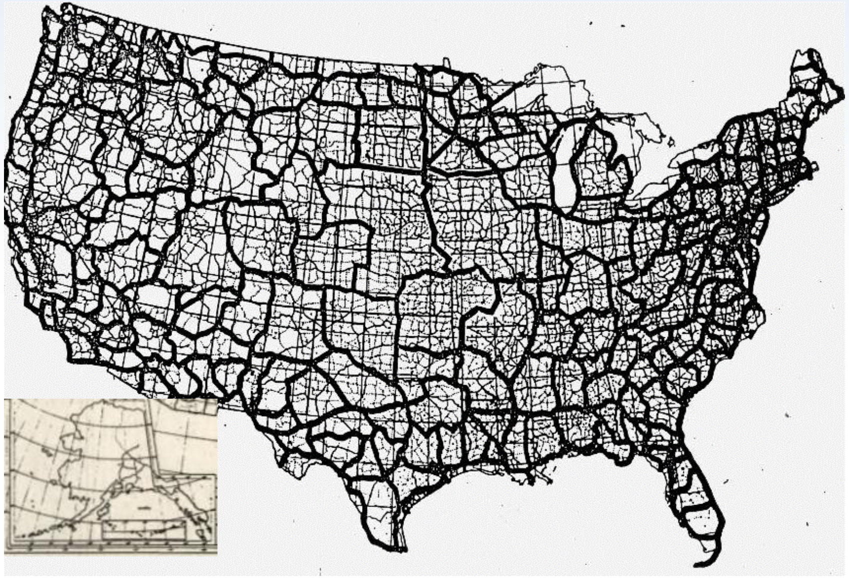




Developing the previous vertical datums

NGVD 29

NAVD 88

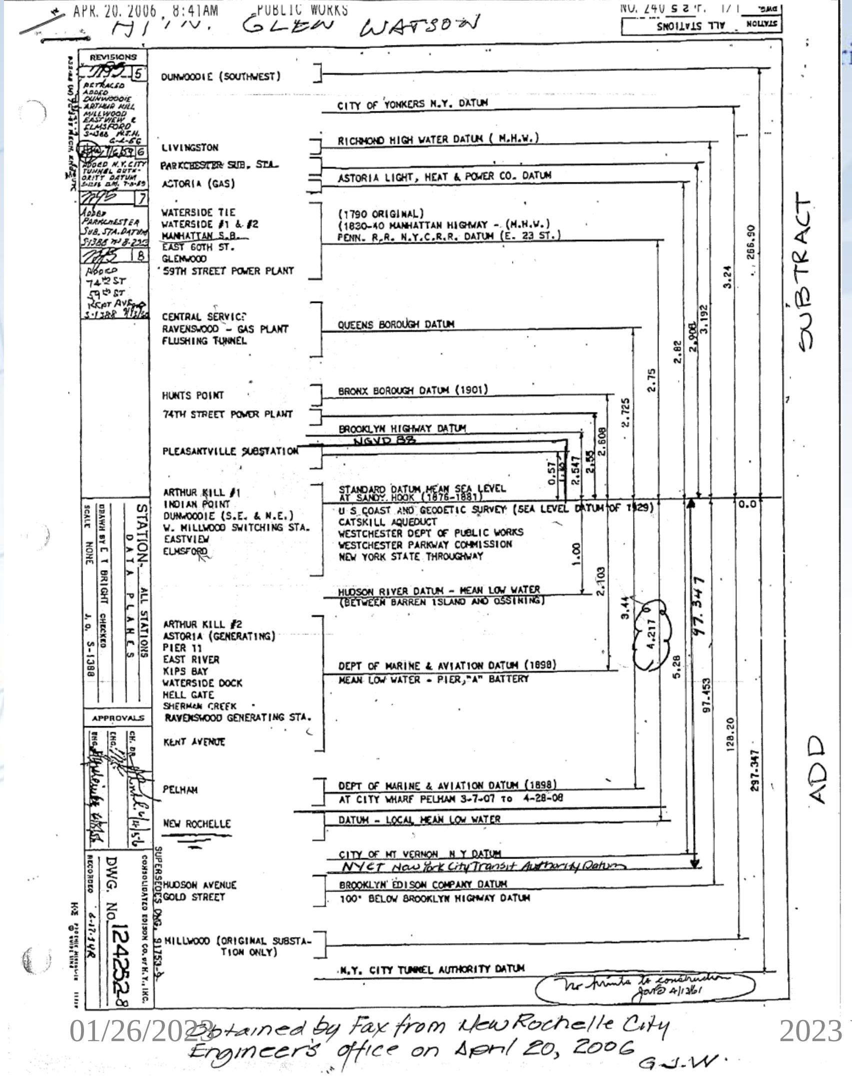


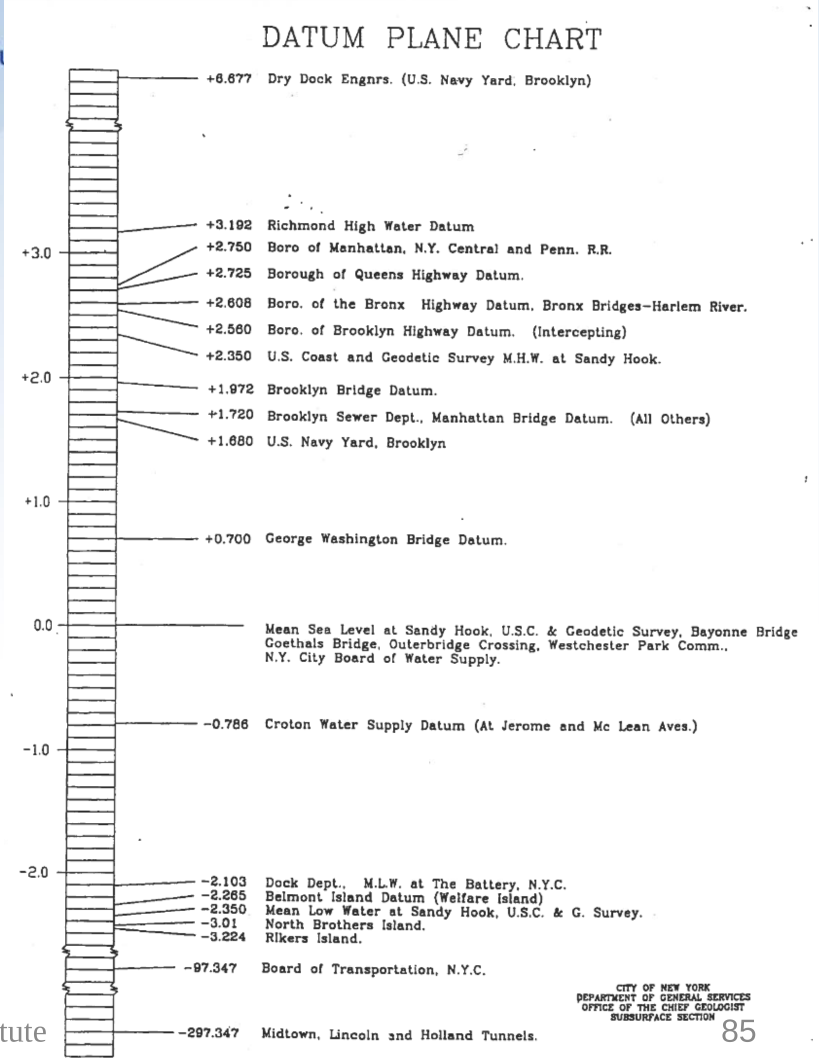
Leveling


& GEODETIC SURVEY
ELEV.
FEET
$250 FINE OR IMPRISONMENT
FOR DISTURBING THIS MARK
E 134
1947
MEAN SEA LEVEL
BENCH MARK

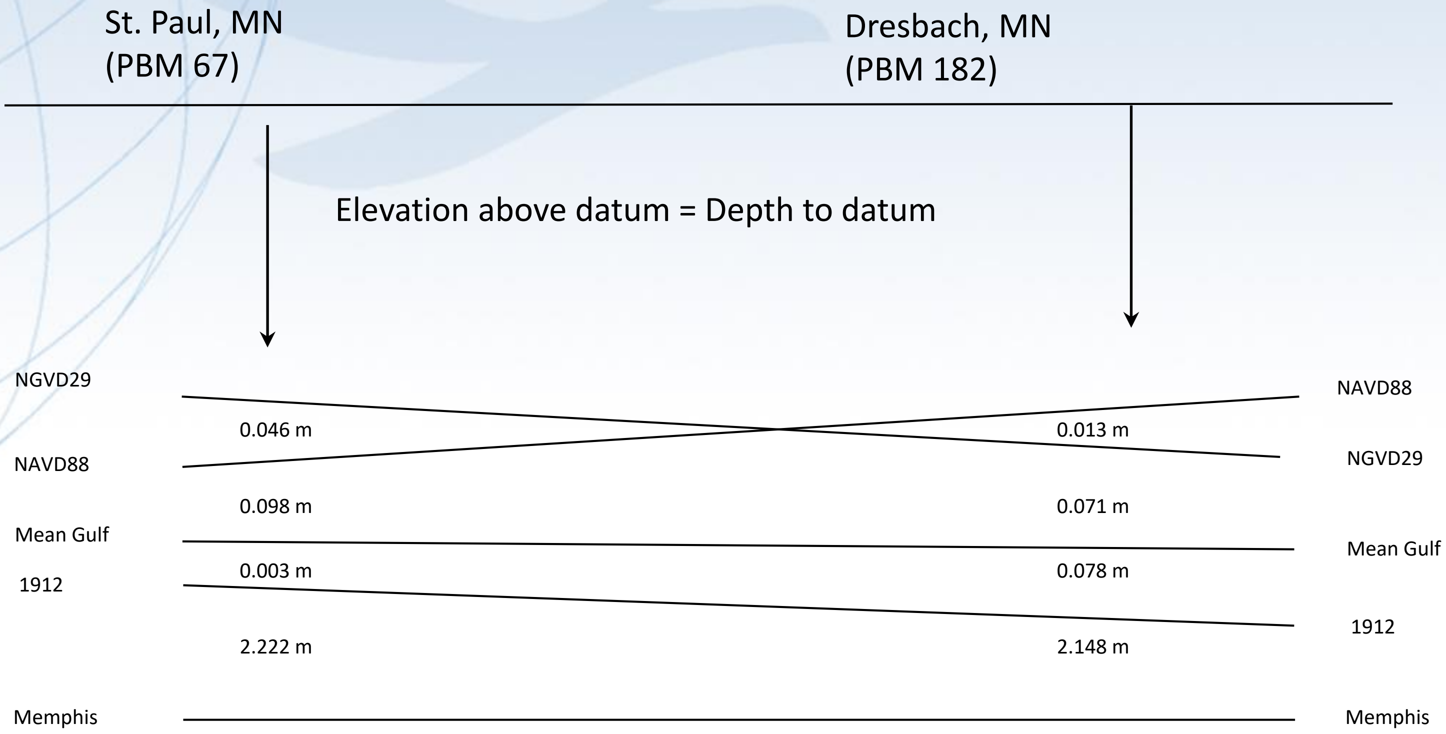
Other vertical datums

- International Great Lakes Datum (more on that later)
- Pre-1929 General Adjustments (1900, 1903, 1907, 1912)
- River datums (Mean Gulf Level, Memphis, others)
- Tidal Datums (NTDE)


APR. 20. 2006 8:41AM PUBLIC WORKS
H/I'N. GLEN WATSON
STATION ALL STATIONS
REVISIONS
DUNWOODIE (SOUTHWEST)
CITY OF YONKERS N.Y. DATUM
LIVINGSTON
PARKCHESTER SUB. STA.
ASTORIA (GAS)
RICHMOND HIGH WATER DATUM (M.H.W.)
ASTORIA LIGHT, HEAT & POWER CO. DATUM
WATERSIDE TIE
WATERSIDE #1 & #2
MANHATTAN S.B.
EAST 60TH ST.
GLENWOOD
59TH STREET POWER PLANT
(1790 ORIGINAL)
(1830-40 MANHATTAN HIGHWAY - (M.H.W.)
PENN. R.R. N.Y.C.R.R. DATUM (E. 23 ST.)
CENTRAL SERVICE
RAVENSWOOD - GAS PLANT
FLUSHING TUNNEL
QUEENS BOROUGH DATUM
HUNTS POINT
74TH STREET POWER PLANT
BRONX BOROUGH DATUM (1901)
BROOKLYN HIGHWAY DATUM
NGVD 88
PLEASANTVILLE SUBSTATION
STANDARD DATUM MEAN SEA LEVEL AT SANDY HOOK (1876-1881)
ARTHUR KILL #1
INDIAN POINT
DUNWOODIE (S.E. & N.E.)
W. MILLWOOD SWITCHING STA.
EASTVIEW
ELMSFORD
U.S. COAST AND GEODETIC SURVEY (SEA LEVEL DATUM OF 1929)
CATSKILL AQUEDUCT
WESTCHESTER DEPT OF PUBLIC WORKS
WESTCHESTER PARKWAY COMMISSION
NEW YORK STATE THROUGHWAY
HUDSON RIVER DATUM - MEAN LOW WATER (BETWEEN BARREN ISLAND AND OSSINING)
ARTHUR KILL #2
ASTORIA (GENERATING)
PIER 11
EAST RIVER
KIPS BAY
WATERSIDE DOCK
HELL GATE
SHERMAN CREEK
RAVENSWOOD GENERATING STA.
DEPT OF MARINE & AVIATION DATUM (1898)
MEAN LOW WATER - PIER "A" BATTERY
KENT AVENUE
PELHAM
DEPT OF MARINE & AVIATION DATUM (1898)
AT CITY WHARF PELHAM 3-7-07 TO 4-28-08
NEW ROCHELLE
DATUM - LOCAL MEAN LOW WATER
CITY OF MT VERNON N.Y. DATUM
NYCT New York City Transit Authority Datum
HUDSON AVENUE
GOLD STREET
BROOKLYN EDISON COMPANY DATUM
100' BELOW BROOKLYN HIGHWAY DATUM
MILLWOOD (ORIGINAL SUBSTATION ONLY)
N.Y. CITY TUNNEL AUTHORITY DATUM
STATION - ALL STATIONS
DATA PLANES
SCALE NONE
APPROVALS
DWG. No 124252-8
SUBTRACT
ADD
0.0
0.57
1.00
2.103
2.547
2.55
2.608
2.725
2.75
2.82
2.906
3.192
3.24
3.44
4.217
5.28
97.347
97.453
128.20
266.90
297.347
Obtained by Fax from New Rochelle City Engineer's office on April 20, 2006 G.J.W.


DATUM PLANE CHART
+6.677 Dry Dock Engnrs. (U.S. Navy Yard, Brooklyn)
+3.192 Richmond High Water Datum
+2.750 Boro of Manhattan, N.Y. Central and Penn. R.R.
+2.725 Borough of Queens Highway Datum.
+2.608 Boro. of the Bronx Highway Datum, Bronx Bridges-Harlem River.
+2.560 Boro. of Brooklyn Highway Datum. (Intercepting)
+2.350 U.S. Coast and Geodetic Survey M.H.W. at Sandy Hook.
+1.972 Brooklyn Bridge Datum.
+1.720 Brooklyn Sewer Dept., Manhattan Bridge Datum. (All Others)
+1.680 U.S. Navy Yard, Brooklyn
+0.700 George Washington Bridge Datum.
0.0 Mean Sea Level at Sandy Hook, U.S.C. & Geodetic Survey, Bayonne Bridge Goethals Bridge, Outerbridge Crossing, Westchester Park Comm., N.Y. City Board of Water Supply.
-0.786 Croton Water Supply Datum (At Jerome and Mc Lean Aves.)
-2.103 Dock Dept., M.L.W. at The Battery, N.Y.C.
-2.265 Belmont Island Datum (Welfare Island)
-2.350 Mean Low Water at Sandy Hook, U.S.C. & G. Survey.
-3.01 North Brothers Island.
-3.224 Rikers Island.
-97.347 Board of Transportation, N.Y.C.
-297.347 Midtown, Lincoln and Holland Tunnels.
+3.0
+2.0
+1.0
-1.0
-2.0
CITY OF NEW YORK
DEPARTMENT OF GENERAL SERVICES
OFFICE OF THE CHIEF GEOLOGIST
SUBSURFACE SECTION

Draw a DATUM PROFILE



Types of heights summary

Height	Symbol	Equation	Example of datum
Ellipsoidal	h		NAD 83
Orthometric	H	$H = h - N$	NAPGD2022
Helmert	H	$H = \frac{C}{\bar{g}}$	NAVD 88
Dynamic	H^D	$H^D = \frac{C}{\gamma_{45}}$	IGLD (1985)
Normal	H^*	$H^* = \frac{C}{\bar{\gamma}}$	NGVD 29

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)

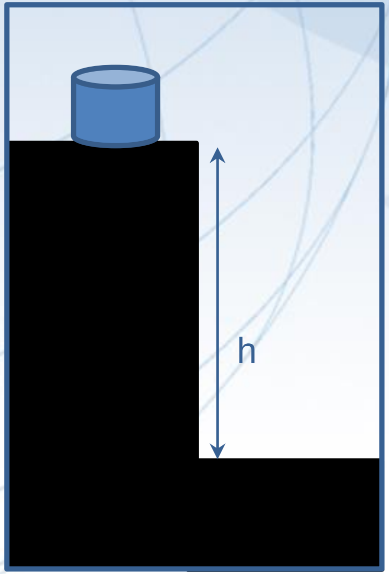
Will include:

- GEOID2022
- DEFLEC2022
- GRAV2022
- DEM2022
- More

A HUGE component of this effort is GRAV-D:

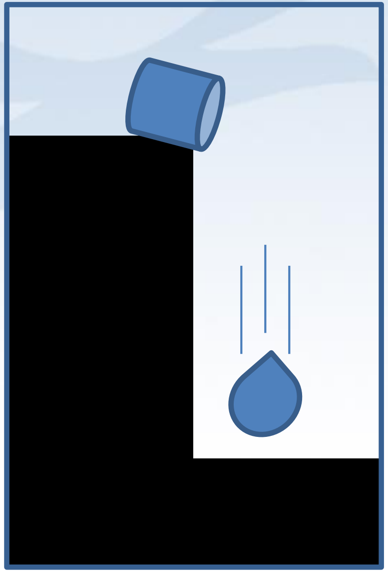
Gravity for the Redefinition of the American Vertical Datum

Understanding "Geo-Potential"



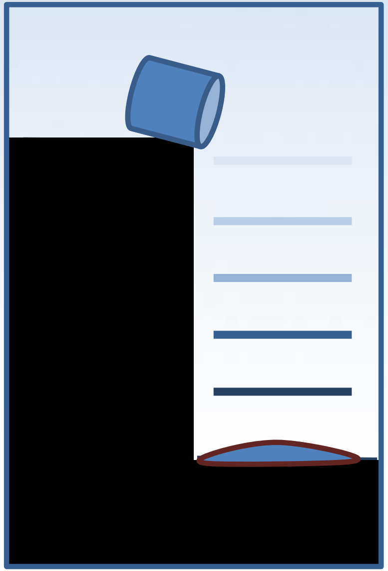
The resting water has "potential" energy just by being high up on this cliff.

Energy = mgh



That potential energy can turn into real (kinetic) energy by falling.

Energy = ½ mv^2 (= mgh)

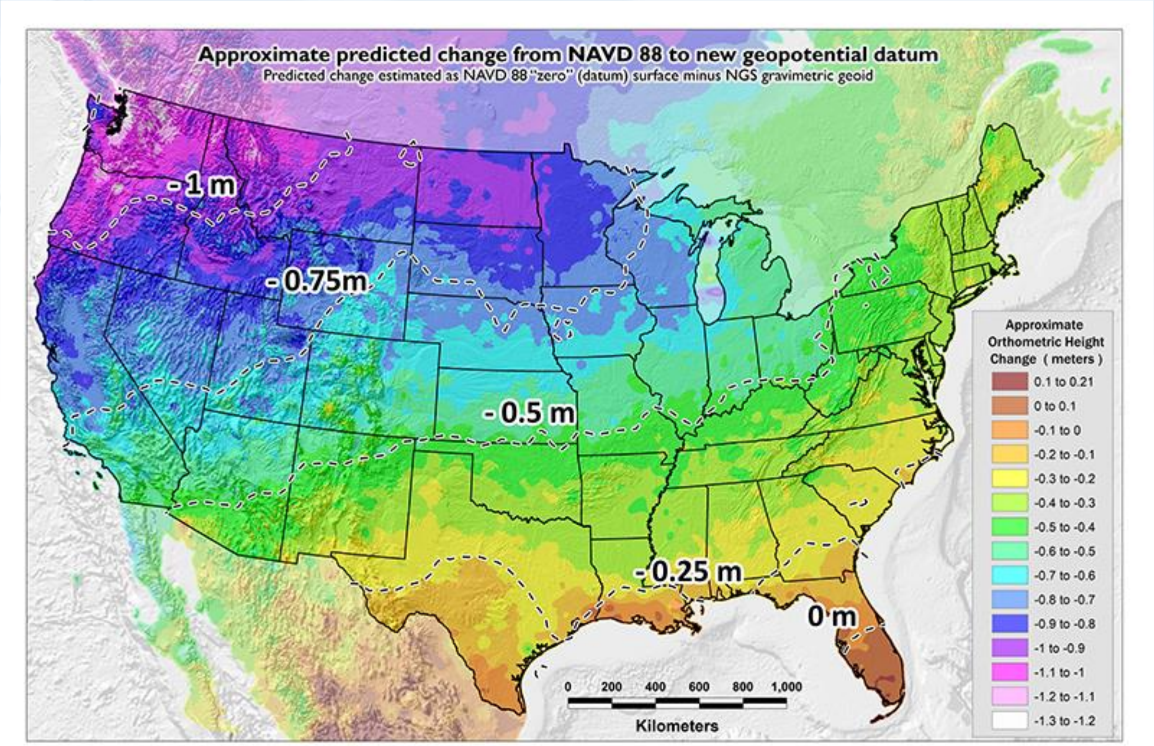


Think of the Earth as creating a "gravity field" that masses experience. I've drawn potential "field lines"

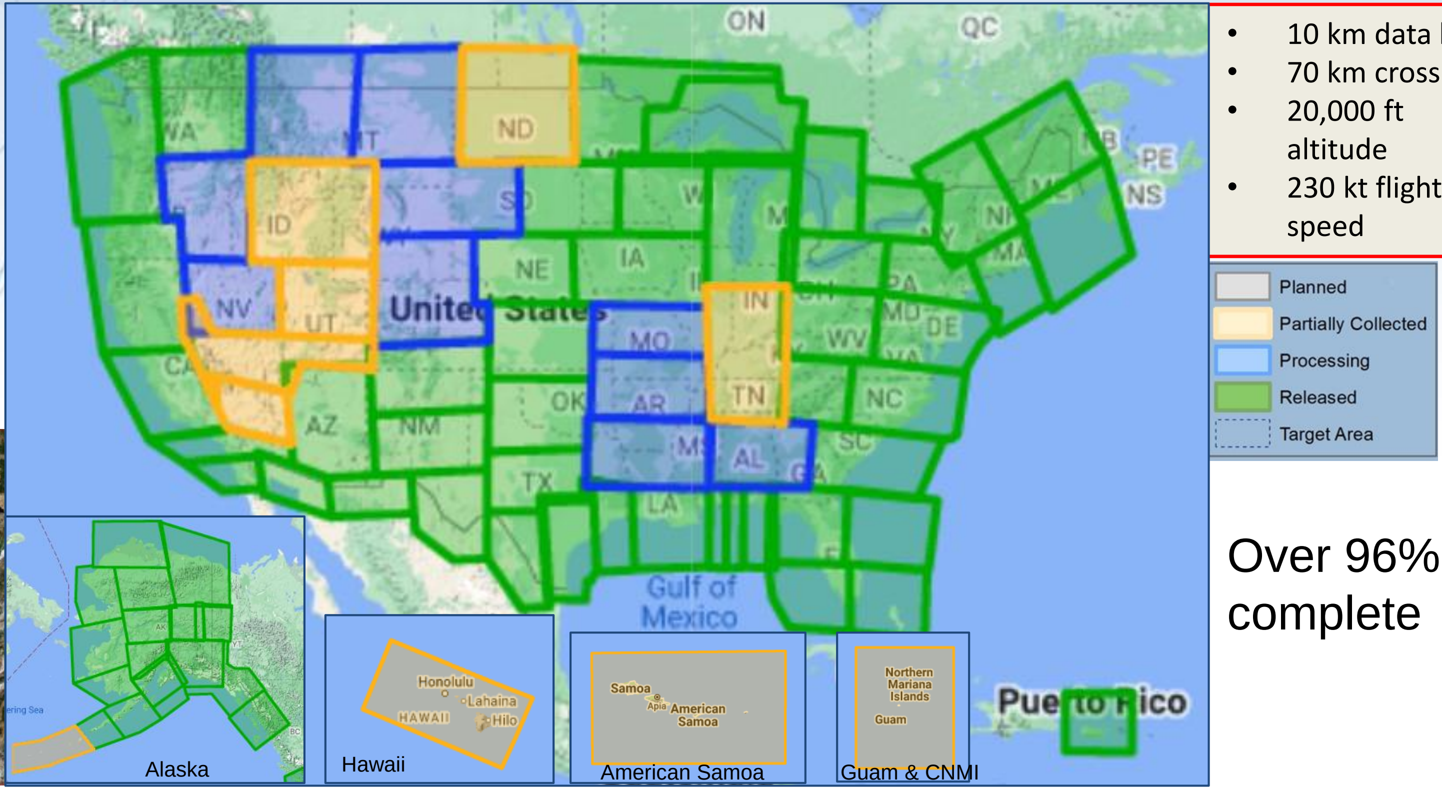
Potential = gh

Gravity x Height is "Geopotential". This is what water "feels".

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

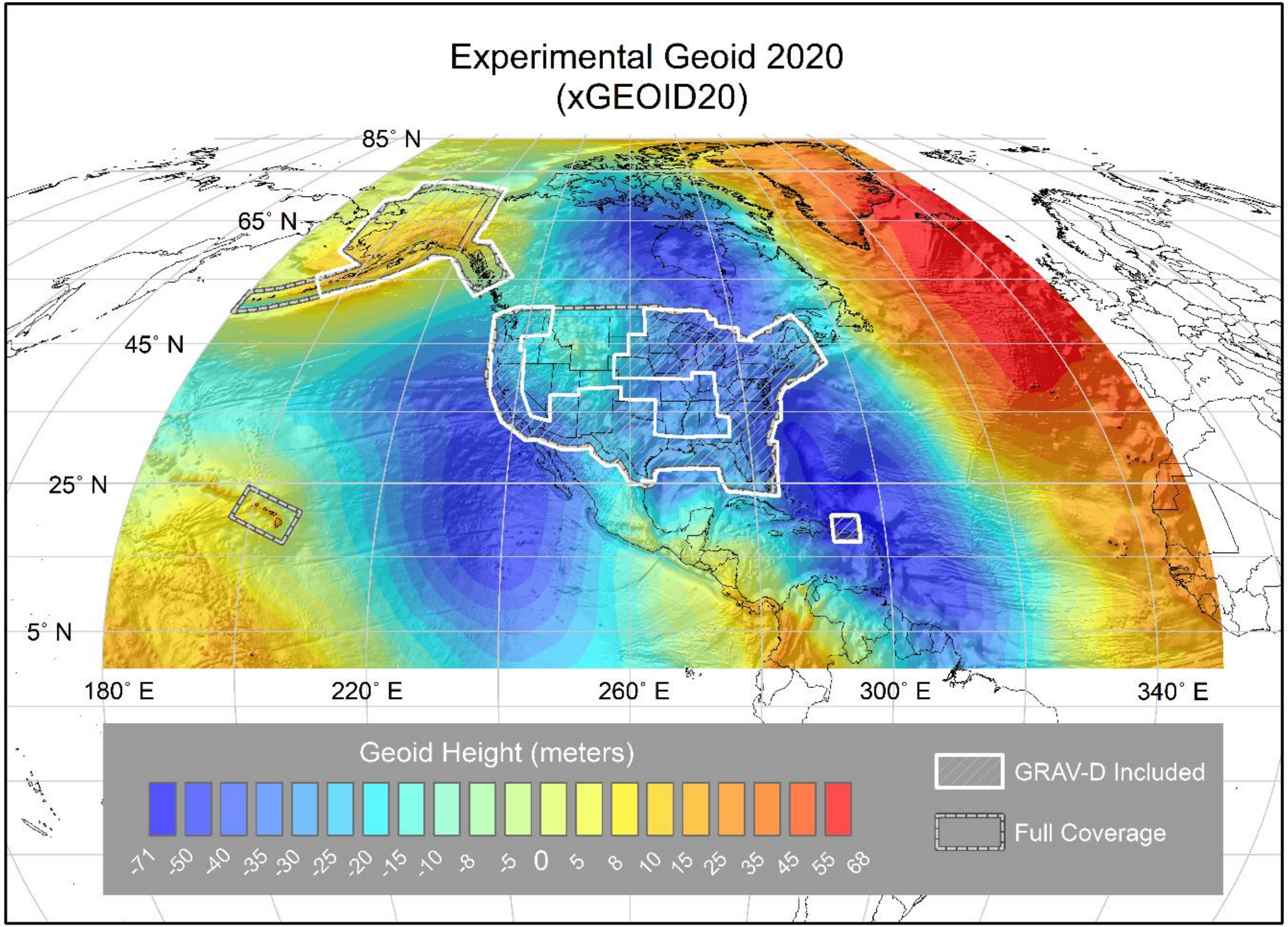


Gravity for the Redefinition of the American Vertical Datum (GRAV-D)



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

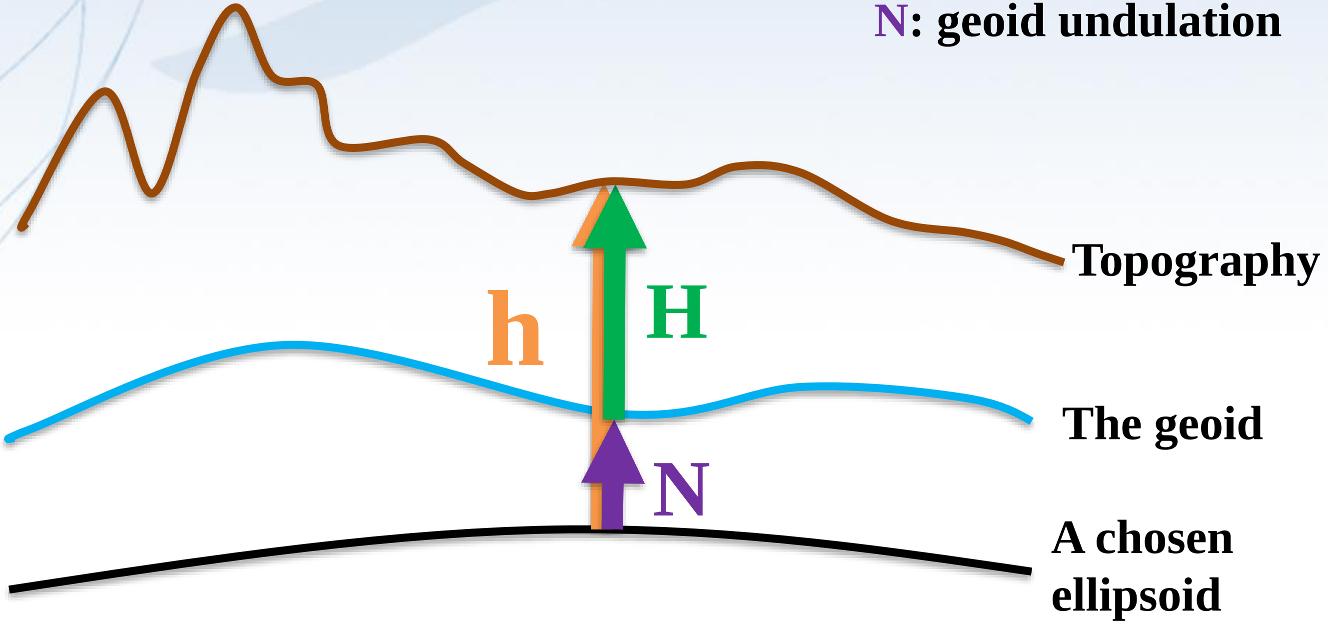
Over 96% complete


Experimental Geoid 2020
(xGEOID20)
85° N
65° N
45° N
25° N
5° N
180° E
220° E
260° E
300° E
340° E
Geoid Height (meters)
-71 -50 -40 -35 -30 -25 -20 -15 -10 -8 -5 0 5 8 10 15 25 35 45 55 68
GRAV-D Included
Full Coverage

The Geoid, and Heights

$$h = H + N$$

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



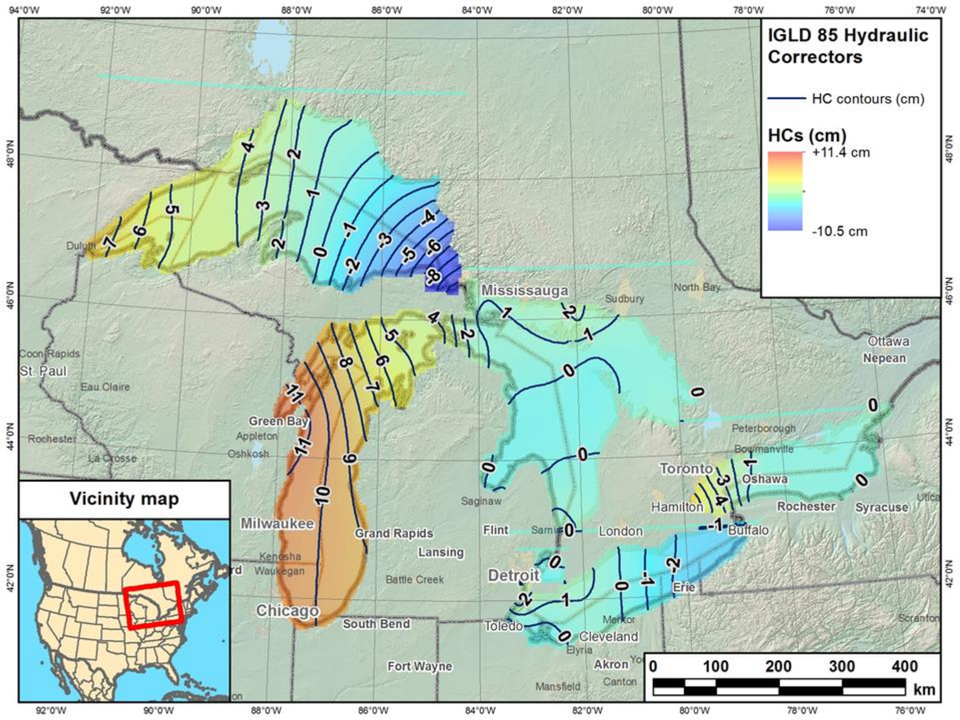
INTERNATIONAL GREAT LAKES DATUM

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)

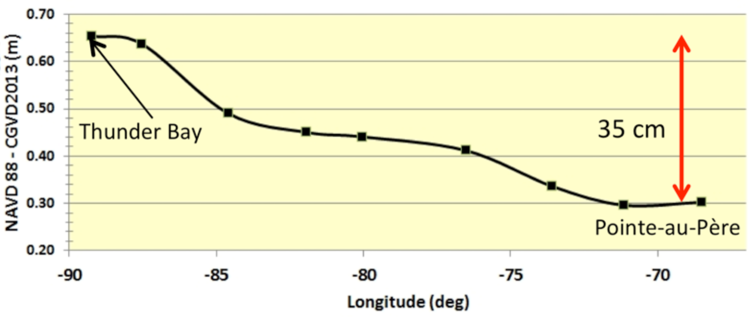
Current IGLD

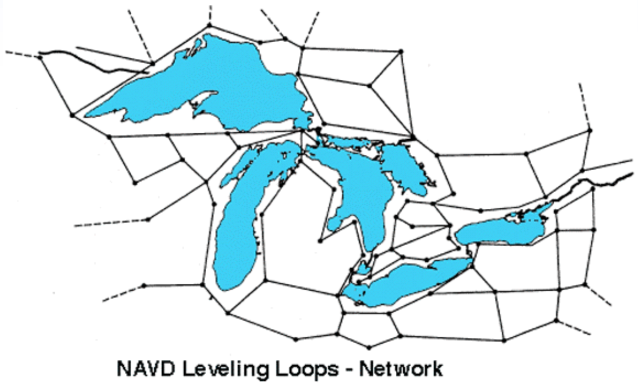
- IGLD (1985) replaced IGLD (1955) in 1992
- Same reference zero as NAVD 88 (at Pointe au Père, Québec)
- Surface determined by leveling
- Dynamic heights
- Hydraulic correctors



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



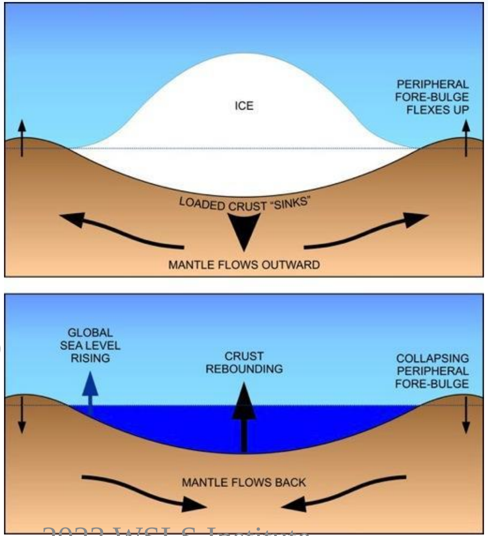


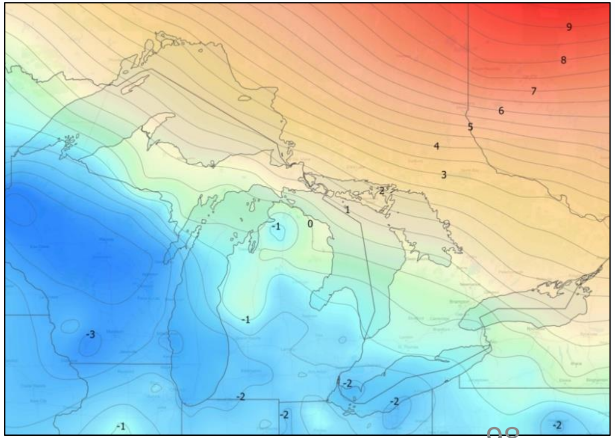
Why a new IGLD?: Glacial Isostatic Adjustment – (GIA)

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:

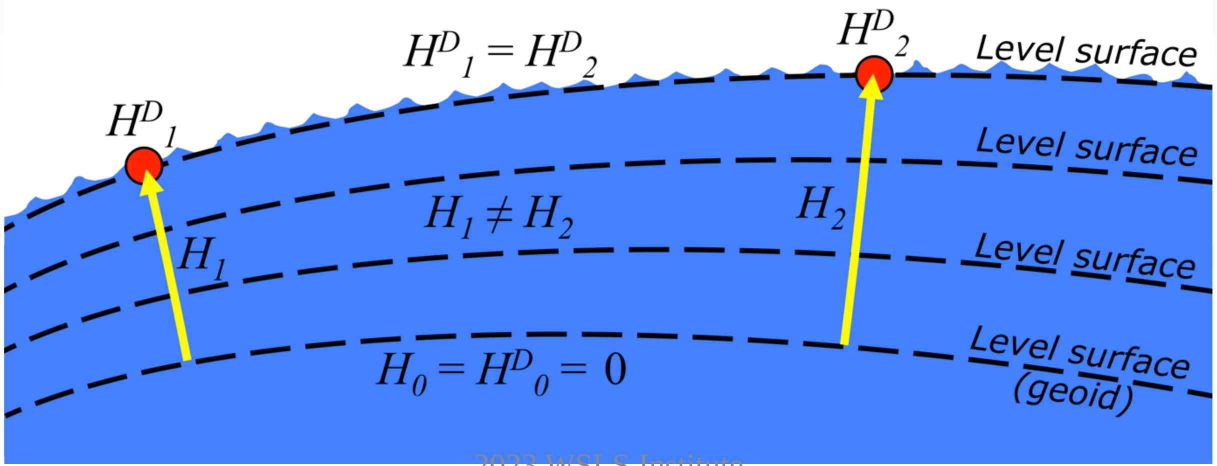
- Uplifting in north
- Subsiding in south
- Overall tilting ~7 mm/year
  (21cm or 0.7' over 30 year)
- Need to update IGLD
  every 25-30 years



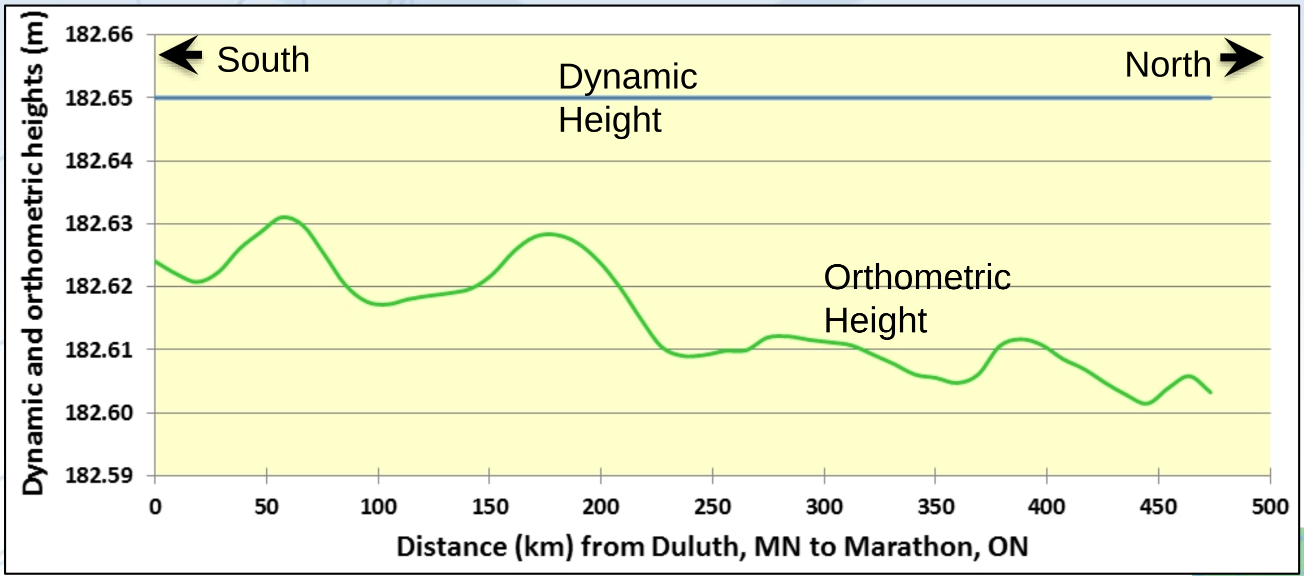


Dynamic height

- $H^D = \frac{C}{\gamma_{45}}$
- Normal gravity value, γ , is a constant



Dynamic vs. Orthometric Heights



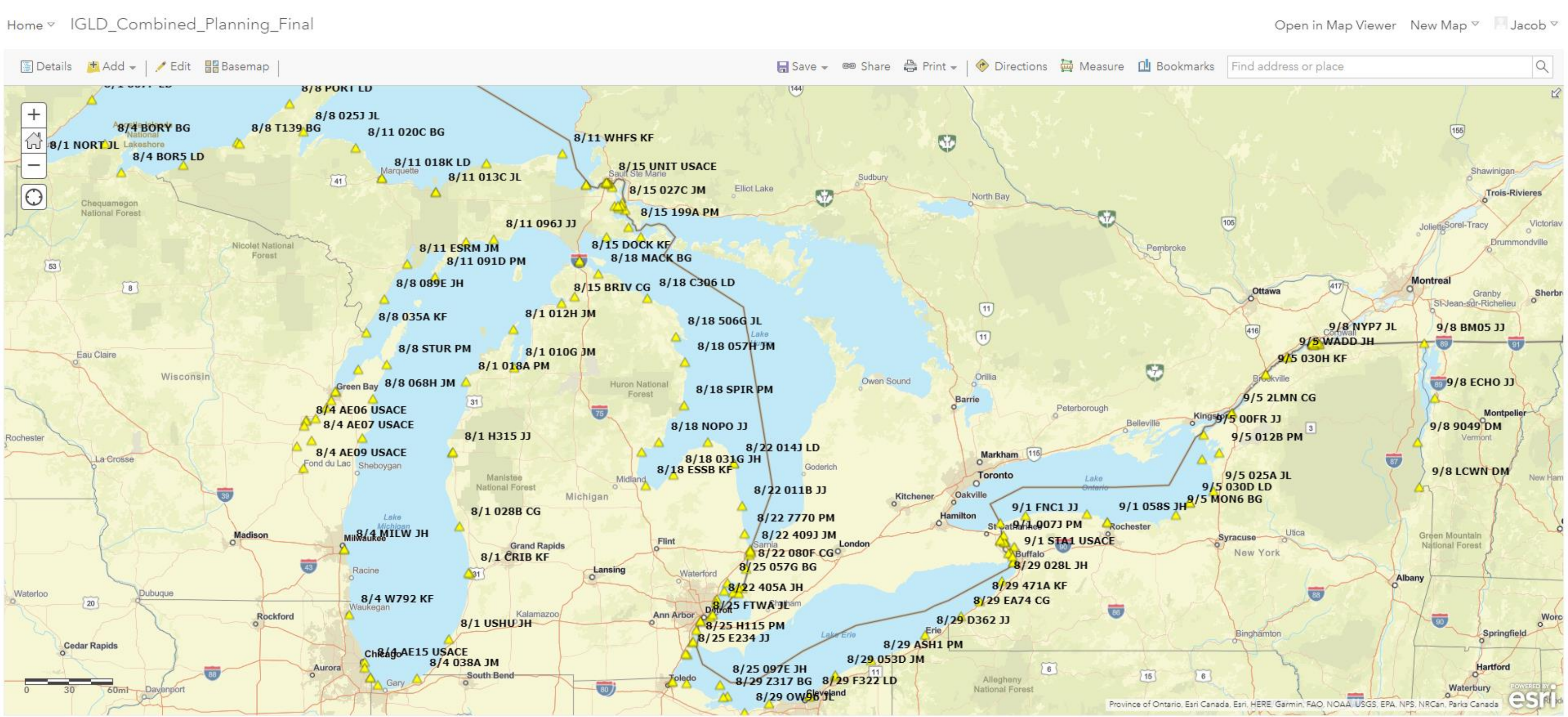
Definition of IGLD (2020)

- 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

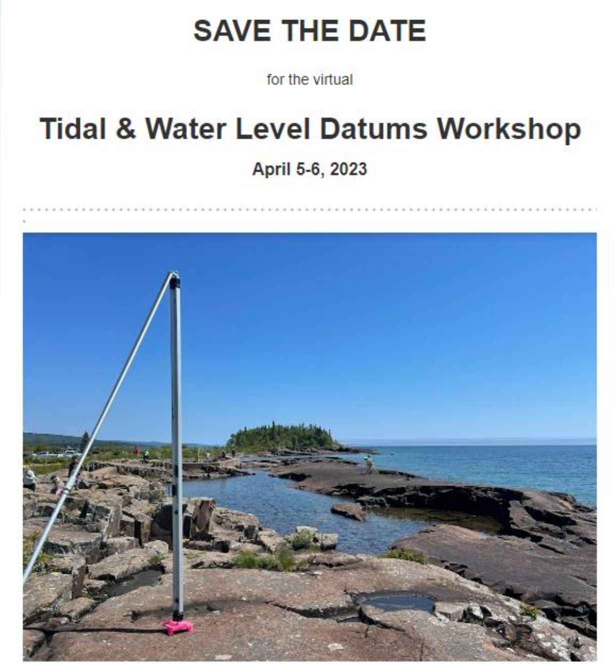
- GNSS field campaign took place in 2022 – data processing continues
- Seasonal gauging continues
- Hydraulic corrector working group is investigating the need for HCs in IGLD (2020)
- IGLD (2020) is planned for release about one year after the release of the NAPGD2022 vertical datum (around 2026)

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.
- ***<u>April 5</u>****: National Tidal Datum Epoch (NTDE)*
- ***<u>April 6</u>****: 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.



Consistent nationwide reference frame
The Modernized NSRS

Revolutionize professional surveying
- No more need for installing and locating bench marks
- Absolute, consistent positioning autonomously, anywhere

Vastly improved flood plain mapping
- Water flows due to differences in gravity
- Critically important in low-lying, flat communities

Fundamental support for new technologies
- “Smart Highways” for autonomous vehicles
- Consistent nationwide reference frame

Support precision agriculture
- Absolute, consistent positioning autonomously, anywhere for efficiency

Impacts on infrastructure

Any application requiring precise positioning -- bridges, tunnels, railways, navigation -- will be easier and more accurate

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: 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

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

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

https://fig.net/fig2023/

FIG 2023 Working Week

Orlando FIG Working Week 2023

FIG WORKING WEEK 2023

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

NSPS FIG

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

Thank You!

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