Getting Ready For 2022 in New Jersey On-Going Activities of the NJ Geodetic Survey

Prepared for:

NEW - GEODETIC TASK FORCE is forming! First meeting will be held on March 11th, 1:30 - 3:30 pm at 300 Riverview Plaza, Trenton, room 402

Surveying From the Center of the Earth (X, Y, Z)

Ron Kuzma, PLS, NJDOT, Geodetic Survey, ron.kuzma@dot.nj.gov

Note: All material referenced from a National Geodetic Survey (NGS) source, several web links appear at end of paper.

A Journey to the Interior of the Earth, 1864 science fiction novel by Jules Verne

North American Terrestrial Reference Frame of 2022 (NATRF2022)
North American-Pacific Geopotential Datum of 2022 (NAPGD2022)

Did we finally figure it out?

Naming Convention

NGS, in cooperation with the Canadian Geodetic Survey, has finalized certain key decisions in the replacement of the three NAD 83 reference frames, and in the replacement of the various vertical datums of the NSRS.

Four Terrestrial Reference Frames

Replacing the three existing NAD 83 reference frames will be four plate-fixed terrestrial reference frames. The tectonic plate for each frame may be inferred from their names, which are:

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

Relationship to the International GNSS Service (IGS) frame

Each of the four frames will be identical to the latest IGS reference frame (as available in 2022) at an epoch to be determined. Away from that epoch, the four frames will relate to the IGS frame through the definition of an Euler Pole rotation specific to that plate. All CORS velocities which deviate from the rotation of a rigid plate will be captured in a residual 3-D velocity model.

Heights and Other Physical Coordinates

A geopotential datum will be created which will contain all of the necessary information to provide mutually consistent orthometric heights, geoid undulations, gravity anomalies, deflections of the vertical and all other geodetic coordinates related to the gravity field. This geopotential datum will be called:

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

Geoid Model

Within NAPGD2022, a variety of products will exist. The most prominent of these products will be a time dependent model of the geoid, provided in three regions (the first covering the entirety of North and Central America, Hawaii, Alaska, Greenland and the Caribbean, the second covering American Samoa and the third covering Guam and the Commonwealth of the Mariana Islands). The name of this model will be:

- **GEOID2022**

The North American Terrestrial Reference Frame of 2022 (NATRF2022)

Geometric Datum: provides latitude, longitude, height, and time information

- **NAD27#**-origin (Meades Ranch)-Clark1866 ellipsoid (best fit continental US)-old terrestrial observations.
- **NAD83-1983 to present**-Origin Geocentric (Mass Center of Earth)-GRS80 (Global Ellipsoid)-spaced based observations. 4 adjustments (realizations). 1986/1996/2007/2011 due in part to more and better observations (GPS) and ties to the Continuously Operating Reference Station (CORS). CORS provide the geometric foundation of the NSRS.
  - **NAD83 (1986)#** based on old terrestrial observations, a few spaced based observations.
  - **NAD83 (1996)*** based on new and old observations, same system, (HARN) station ties.
  - **NAD83 (2007)*** based on new GPS observations, same system, removed regional distortions and made consistent with CORS.
  - **NAD83 (2011) epoch 2010.00*** based on new GPS observations, same system, kept consistent with CORS.

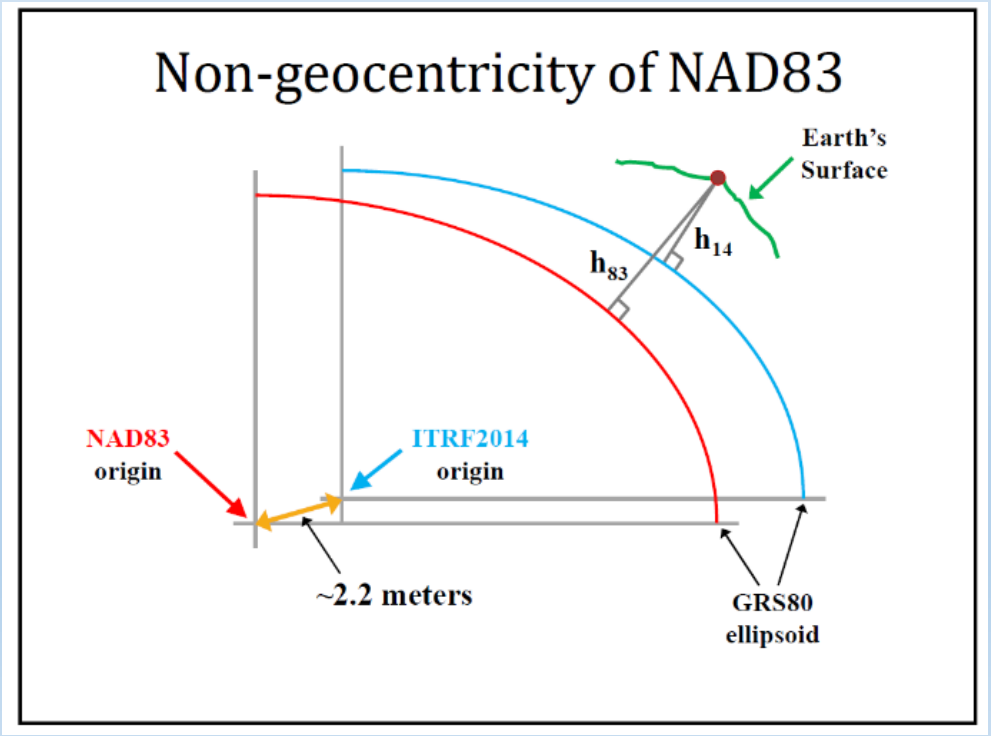
Today, the NAD83 origin is not as geocentric as it could be (approx. +/-2 m) from the International Terrestrial Reference Frame (ITRF2014). The ITRF is the global reference frame.

NAD83 fixed to North American plate which is rotating. Stations on same plate it has good relative agreement.

NAD83 is not well defined with positional velocities.

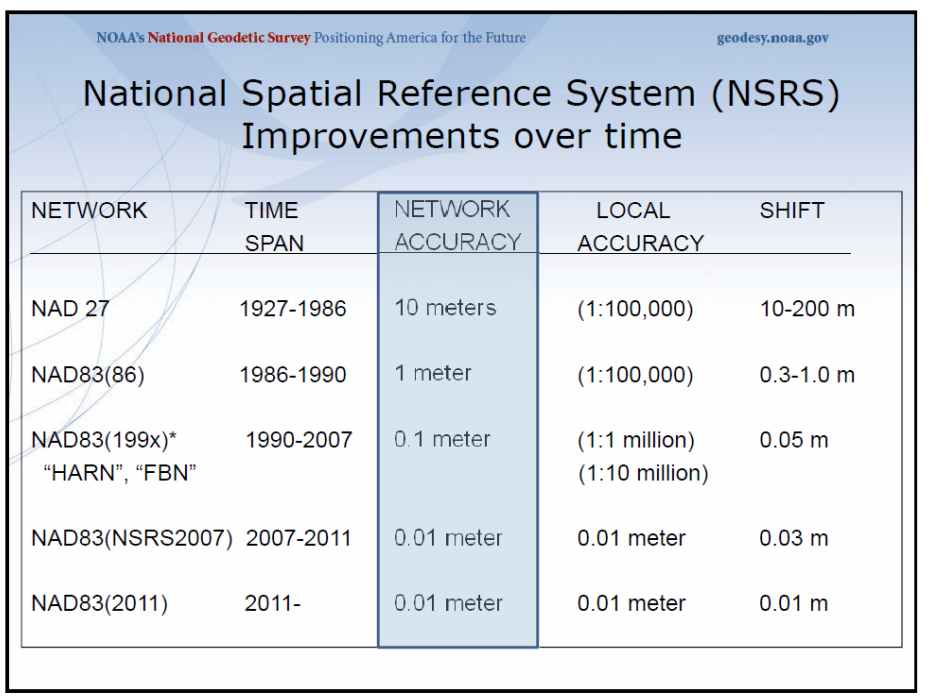
Geodetic Datum Realizations

- #: 2-D Horizontal (Latitude, Longitude)
- *: Geometric Datum 3-D (Latitude, Longitude, And Ellipsoid Height)



A degree, minute or second of latitude remains fairly constant from the equator to the poles; however a degree, minute, or second of longitude can vary greatly as one approaches the poles (because of the convergence of the meridians). At 38 degrees North latitude, one degree of **latitude** equals approximately 364,000 ft. (69 miles), one minute equals 6068 ft. (1.15 miles), one-second equals 101 ft.; one-degree of **longitude** equals 288,200 ft. (54.6 miles), one minute equals 4800 ft. (0.91 mile), and one second equals 80 ft.

https://www.usgs.gov/faqs/how-much-distance-does-a-degree-minute-and-second-cover-your-maps?qt-news_science_products=0#qt-news_science_products

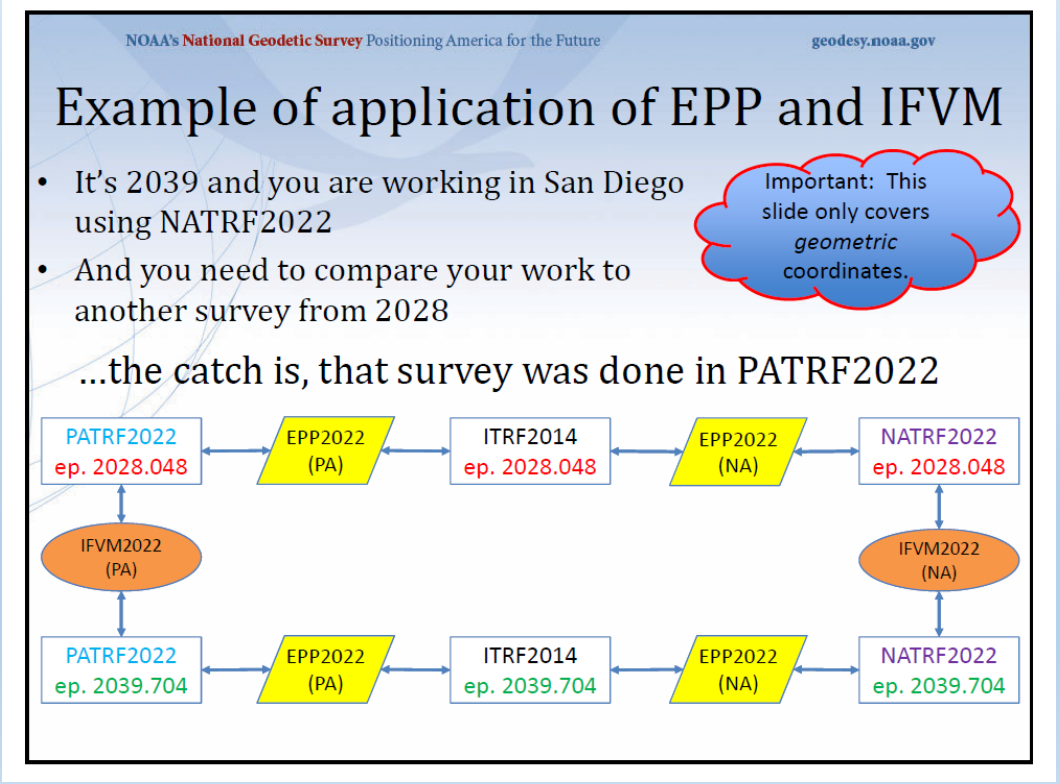


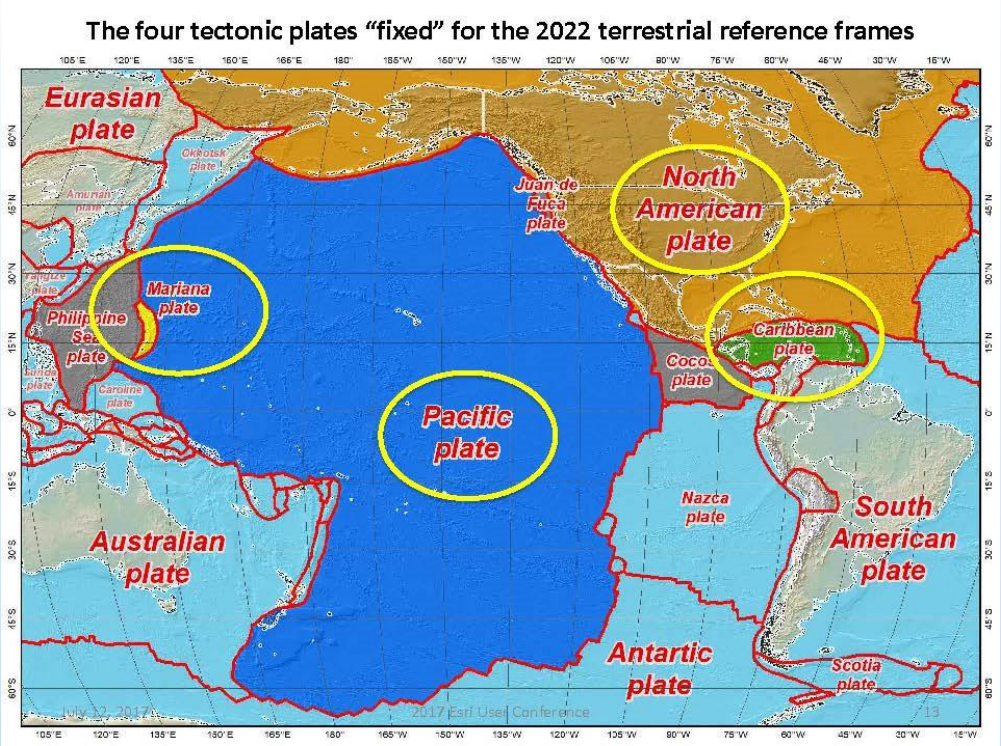
Example: **BELMAR (KV0806)** Data Sheet

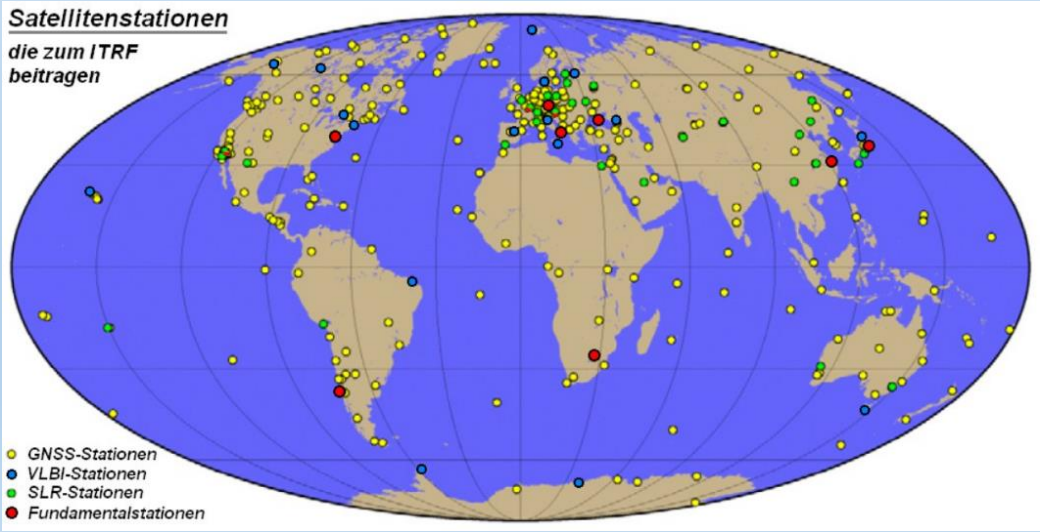
NAD 83(2011)	40 11 08.96282(N)	074 00 39.09721(W)
NAD 83(2011) ELLIP HT	-28.577 (meters)	
NAD 83(2007)	40 11 08.96323(N)	074 00 39.09766(W)
ELLIP H (02/10/07)	-28.569 (m)	
NAD 83(1996)	40 11 08.96305(N)	074 00 39.09764(W)
ELLIP H	-28.572 (m)	
NAD 83(1992)	40 11 08.96262(N)	074 00 39.09988(W)
ELLIP H	-28.532 (m)	
NAD 83(1986)	40 11 08.96423(N)	074 00 39.10071(W)
NAD 83(1986)	40 11 08.96259(N)	074 00 39.09117(W)
NAD 27	40 11 08.55220(N)	074 00 40.59520(W)

NATRF2022 Geocentric Reference Frame

- Remove long-standing non-geocentricity of NAD83 frames relative to today's knowledge of the geocenter, causing it to be misaligned with the primary global GNSS-related reference frames – World Geodetic System 1984 (WGS84) and International GNSS Service 2008 (IGS08) – and related products, including GNSS satellite ephemerides
- Three plate- (pseudo) fixed frames will be replaced with four plate-fixed reference frames (N. Amer., Pacific, Mariana, Caribbean).
- All four frames align to ITRF2014 based on International Earth Rotation and Reference Systems Service (IERS) and International Union of Geodesy and Geophysics (IUGG) at epoch 2020.00
- An ITRF is a realization of the ITRS. New ITRF solutions are produced every few years, using the latest mathematical and surveying techniques to attempt to realize the ITRS as precisely as possible.
- Align with Global Navigation Satellite Systems (GNSS)
- Two new tools, working together, to make time-dependent geodetic control practical among or within the respective plate.
  - ✓ Euler Pole Parameters (EPP2022): Remove most of the tectonic plate rotation, velocities, from ITRF2014 via Eular Pole Parameters (points about which plate rotates) thereby achieving the fixed frame: ITRF (constant frame, rotating plate), NATRF2022 (rotating frame, constant with plate). Apply EPP2022 to move between. (ITRF2014 + EPP2022 = NATRF2022).
  - ✓ Intra-Frame Velocity Model (IFVM2022): Remove residual velocities due to complex velocity changes (localized movement, change of epoch). Coordinates will be associated with the actual date when the data was collected, move collected data thru time to Reference Epochs for coordinate comparisons/analysis.







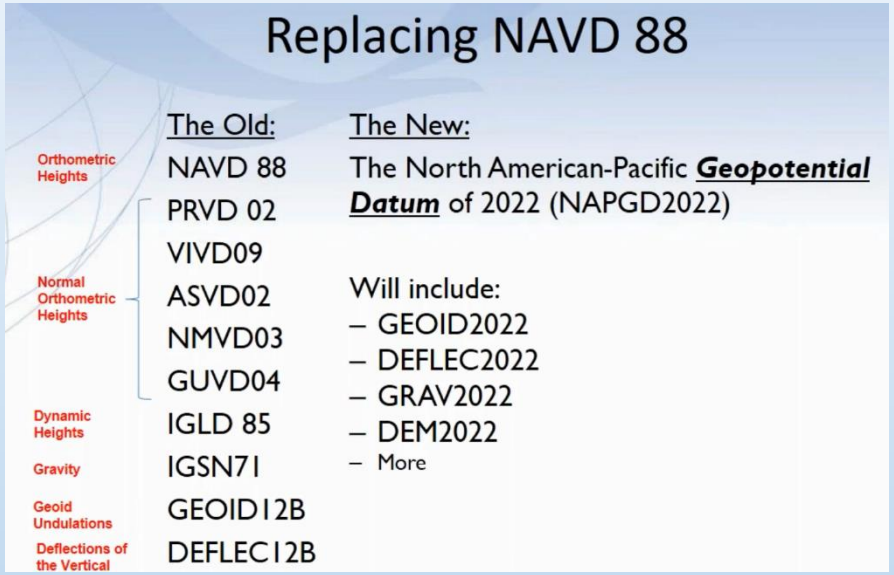
Worldwide Tracking Stations

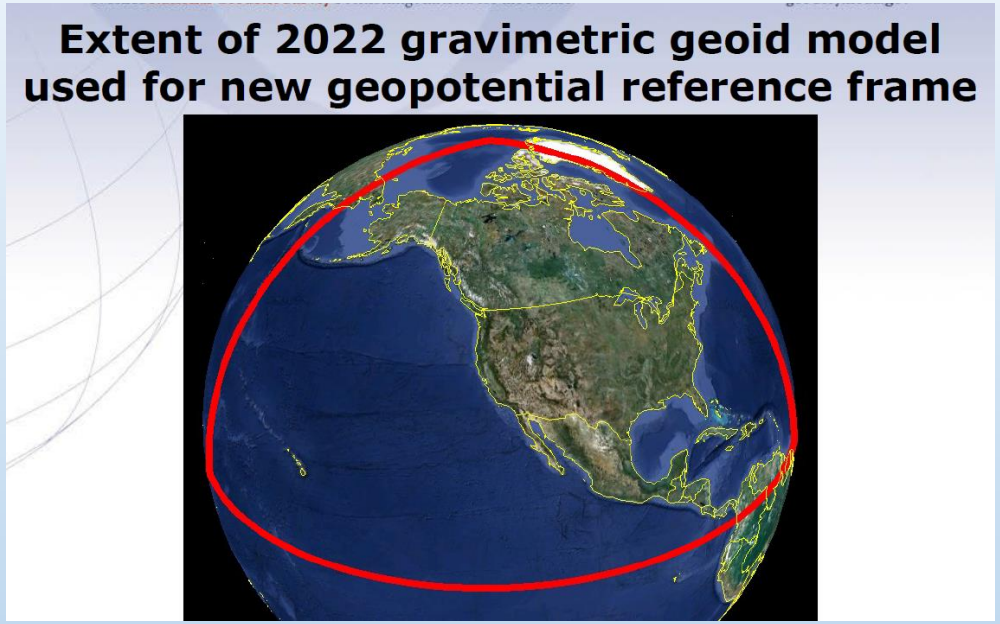
North American-Pacific Geopotential Datum of 2022 (NAPGD2022)

Geopotential / Vertical Datum

One Vertical Datum - pole-to-equator

(Replacing NAVD88)





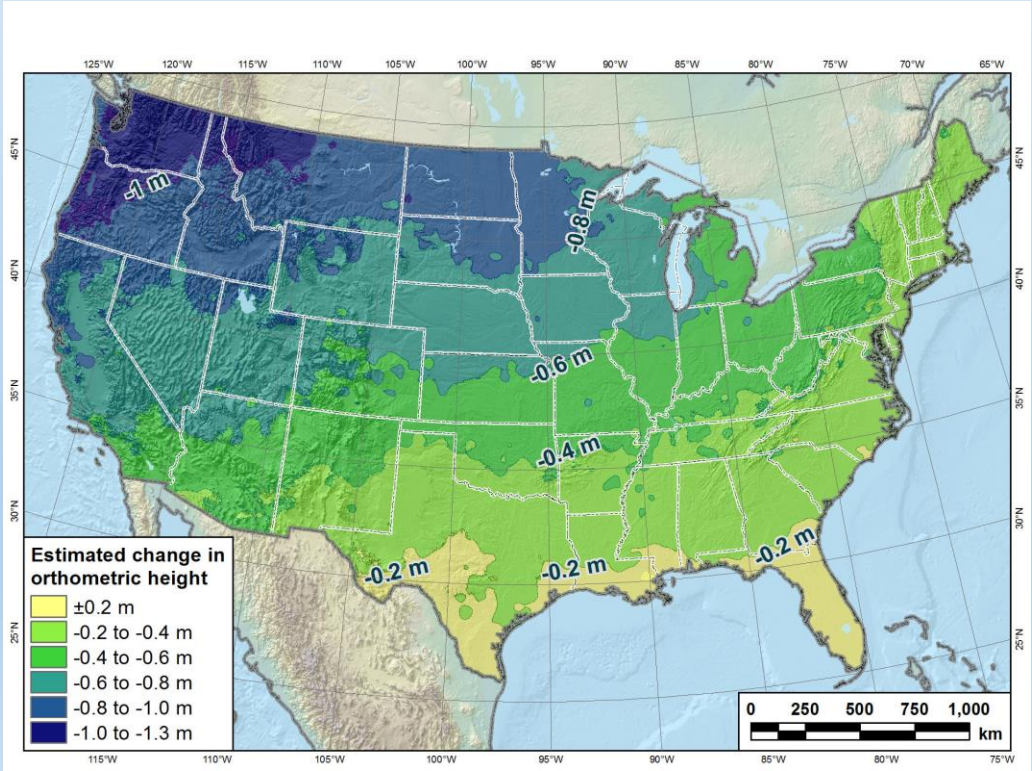
NAPGD2022

- Primary access via GNSS and geoid (think OPUS)
  Orthometric height (traditional elevation) will be user-determined by GNSS observations combined with **GEOID2022**, via the classic equation: ***Orthometric Height (H) = Ellipsoid Height (h) (GNSS) – Geoid Height (N) (GEOID2022***)
- Accurate continental gravimetric geoid: GEOID2022
- Aligned with: 1) Terrestrial Reference Frame 2022
  2) **Global** mean sea level (GMSL)
- Monitor time-varying nature of gravity - via the Geoid Monitoring Service (GeMS)

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

- Replace the National Vertical Datum 1988 (NAVD88) by 2022 with a **1 cm** accurate gravimetric geoid.
- Orthometric heights accessed via GNSS accurate to **2 cm**
- Thrusts of project:
  - Airborne gravity survey of entire country and its holdings.
  - Long-term geoid change monitoring.
  - Partnership surveys.

- Development of NAPGD2022 relies on gravity datasets including satellite, terrestrial, and airborne, the latter being collected during an ambitious ongoing NGS airborne gravity data collection program.
- GEOID2022 is based on variations in gravity across the earth surface and is the basis for this new geopotential datum.
- GEOID2022 will define zero orthometric height by specifying the geopotential surface best fit to global mean sea level and provide multi-nation consistency.
- Time dependent as per Geoid model updates.

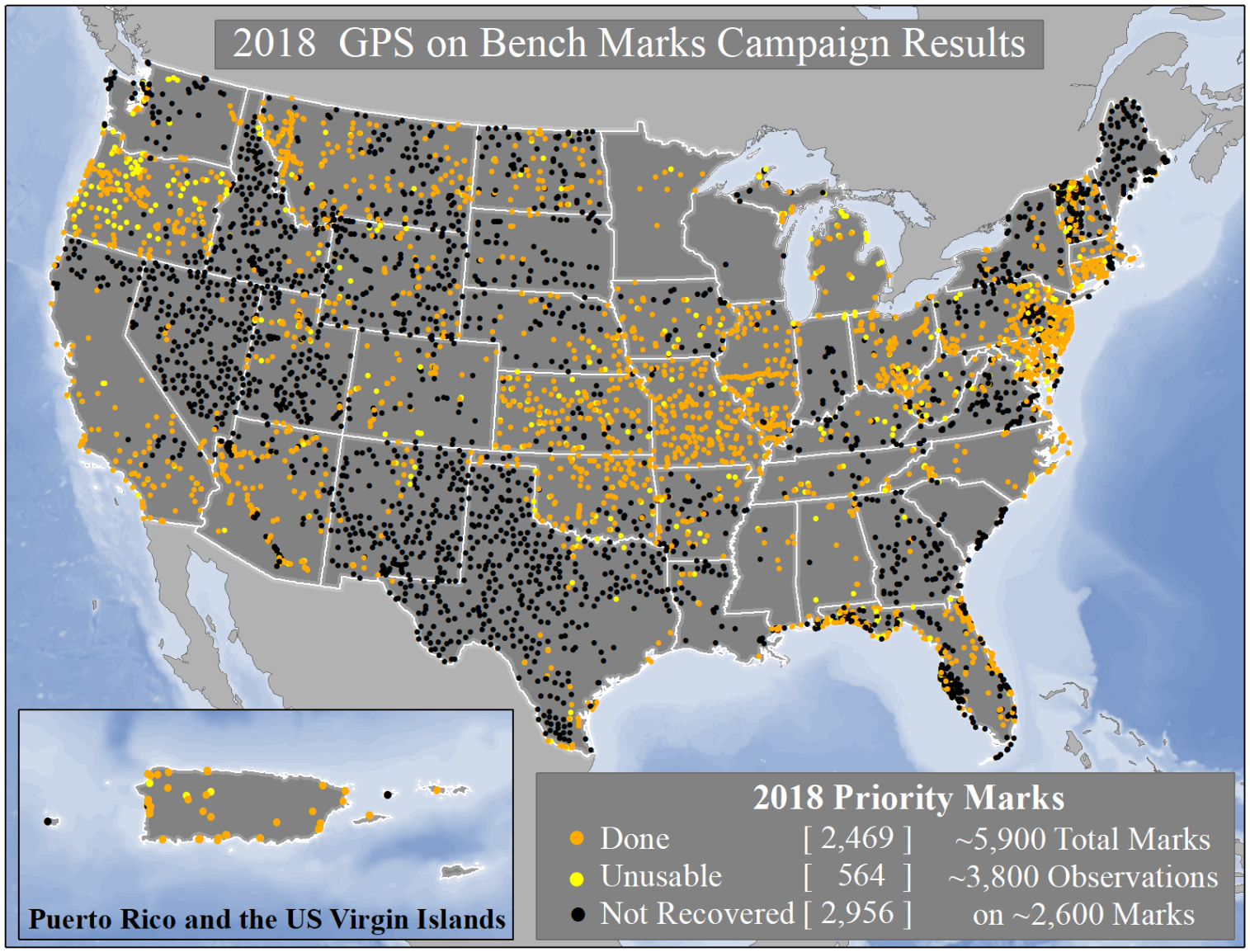


Estimated change in orthometric heights from NAVD88 to **NAPGD2022**

New Jersey Geodetic Survey Activities

2018 GPS on Bench Marks (Geoid18 - “Phase I” Completed) Spacing criteria 30 km

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



2018 Campaign Links
2018 Home
2018 Web Map
Prioritized List

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

Contact information
Email us

Subscribe for GPS on Bench Mark Updates

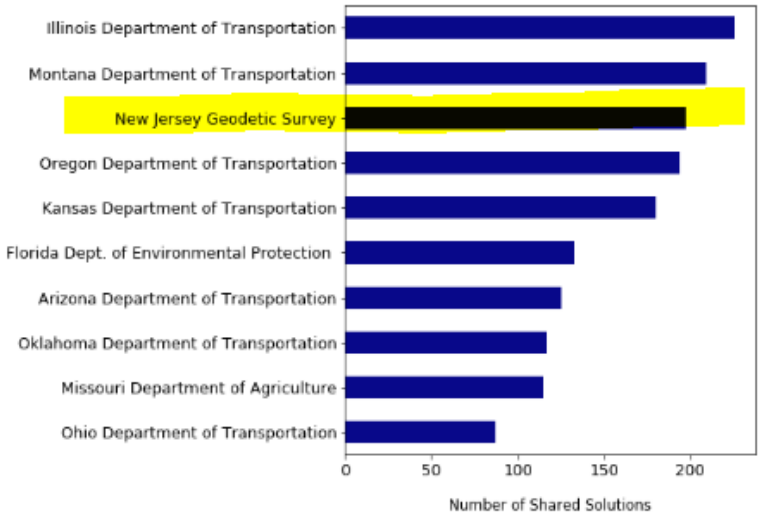
2018 GPS on Bench Marks Campaign Results

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

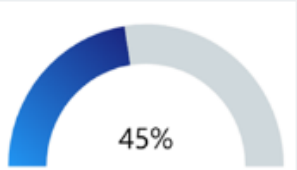
Approximately **2,469** GPS observations were submitted. We reached **45.5%** of our nationwide goal, however the number of marks requested per state varies greatly, and many states have submitted observations on a much higher percentage of the requested marks.

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

Top Ten Submitting Agencies

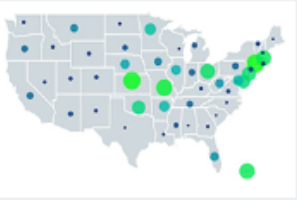


Percent of Goal Reached



Progress Tracking Map

View Progress by State



Priority A & B Requests Results by State

State	Priority A Requested	Priority A Completed	% A Complete	Priority B Requested	Priority B Completed	% B Complete	Total % Complete
AL	24	8	33.3%	9	8	88.9%	48.5%
AR	16	9	56.2%	65	25	38.5%	42.0%
AZ	113	79	69.9%	115	53	46.1%	57.9%
CA	89	45	50.6%	38	36	94.7%	63.8%
CO	40	15	37.5%	29	22	75.9%	53.6%
CT	11	11	100.0%	35	35	100.0%	100.0%
DC	0	0	0.0%	0	0	0.0%	0.0%
DE	3	2	66.7%	45	37	82.2%	81.2%
FL	33	17	51.5%	421	165	39.2%	40.1%
GA	71	4	5.6%	3	0	0.0%	5.4%
IA	58	39	67.2%	10	1	10.0%	58.8%
ID	151	10	6.6%	13	3	23.1%	7.9%
IL	3	1	33.3%	143	133	93.0%	91.8%
IN	12	2	16.7%	16	4	25.0%	21.4%
KS	117	96	82.1%	5	5	100.0%	82.8%
KY	22	4	18.2%	14	4	28.6%	22.2%
LA	30	4	13.3%	9	1	11.1%	12.8%
MA	14	9	64.3%	10	10	100.0%	79.2%
MD	10	10	100.0%	59	48	81.4%	84.1%
ME	80	1	1.2%	15	0	0.0%	1.1%
MI	21	16	76.2%	19	13	68.4%	72.5%
MN	0	0	0.0%	8	8	100.0%	100.0%
MO	122	119	97.5%	43	43	100.0%	98.2%
MS	21	12	57.1%	8	6	75.0%	62.1%
MT	235	137	58.3%	43	24	55.8%	57.9%
NC	25	25	100.0%	29	29	100.0%	100.0%
ND	107	41	38.3%	6	0	0.0%	36.3%
NE	59	24	40.7%	15	9	60.0%	44.6%
NH	20	10	50.0%	7	3	42.9%	48.1%
NJ	8	8	100.0%	177	177	100.0%	100.0%
NM	197	17	8.1%	12	1	7.7%	9.9%

GPS on Bench Marks Campaign for the Transformation Tool (NCAT)

https://geodesy.noaa.gov/GPSonBM/technical-details.shtml

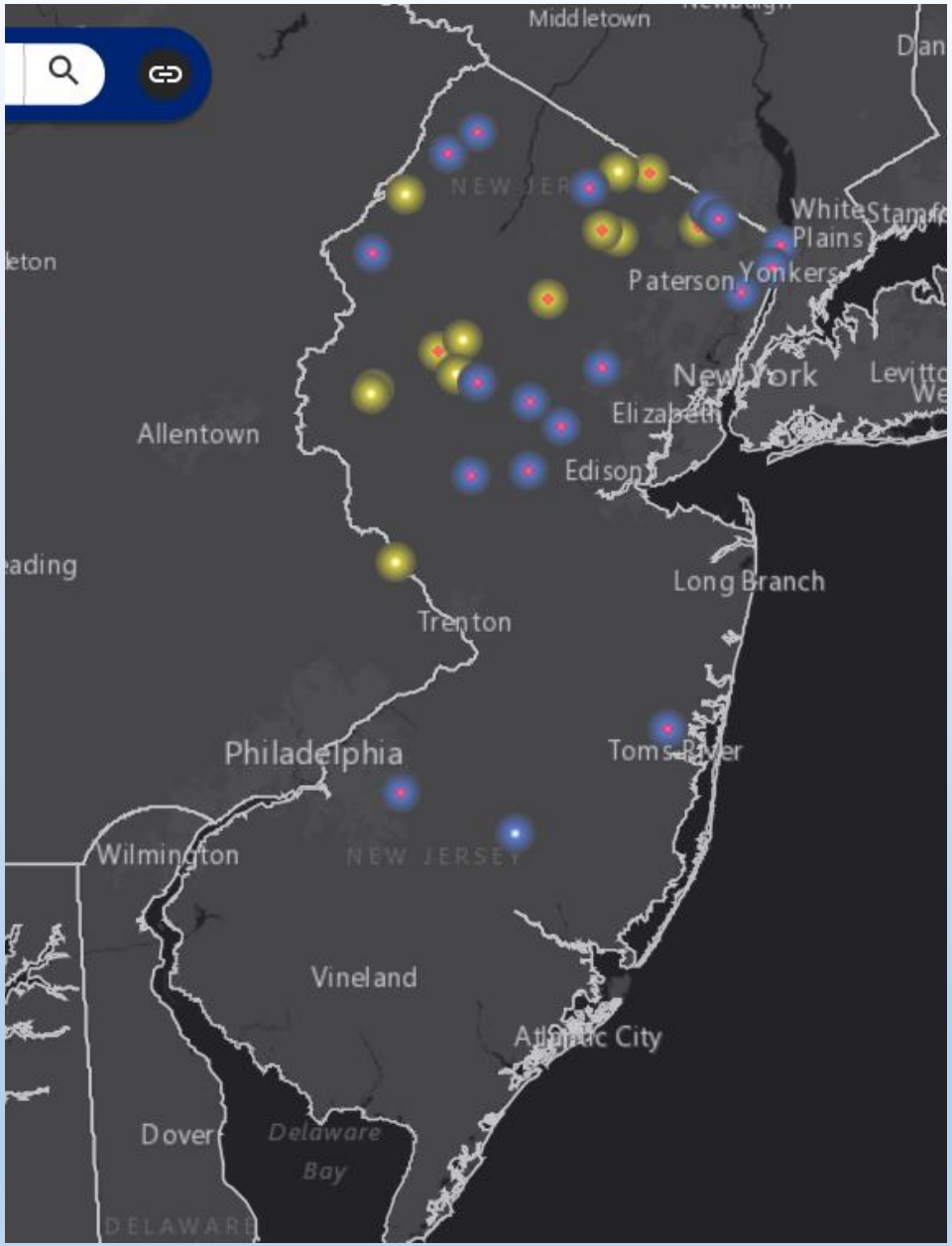
(“Phase II” - Deadline to submit GPS on BMs for the Transformation Tool		December 31, 2021
10 km hexagon (National Coverage)	2 km hexagon (Local Coverage)	

NGS has also prioritized marks at two spatial resolutions: 10 km and 2 km. NGS wants to reach a 10 km density to provide good national accuracy. Additionally, users can help improve local accuracy by collecting data at the 2 km level.

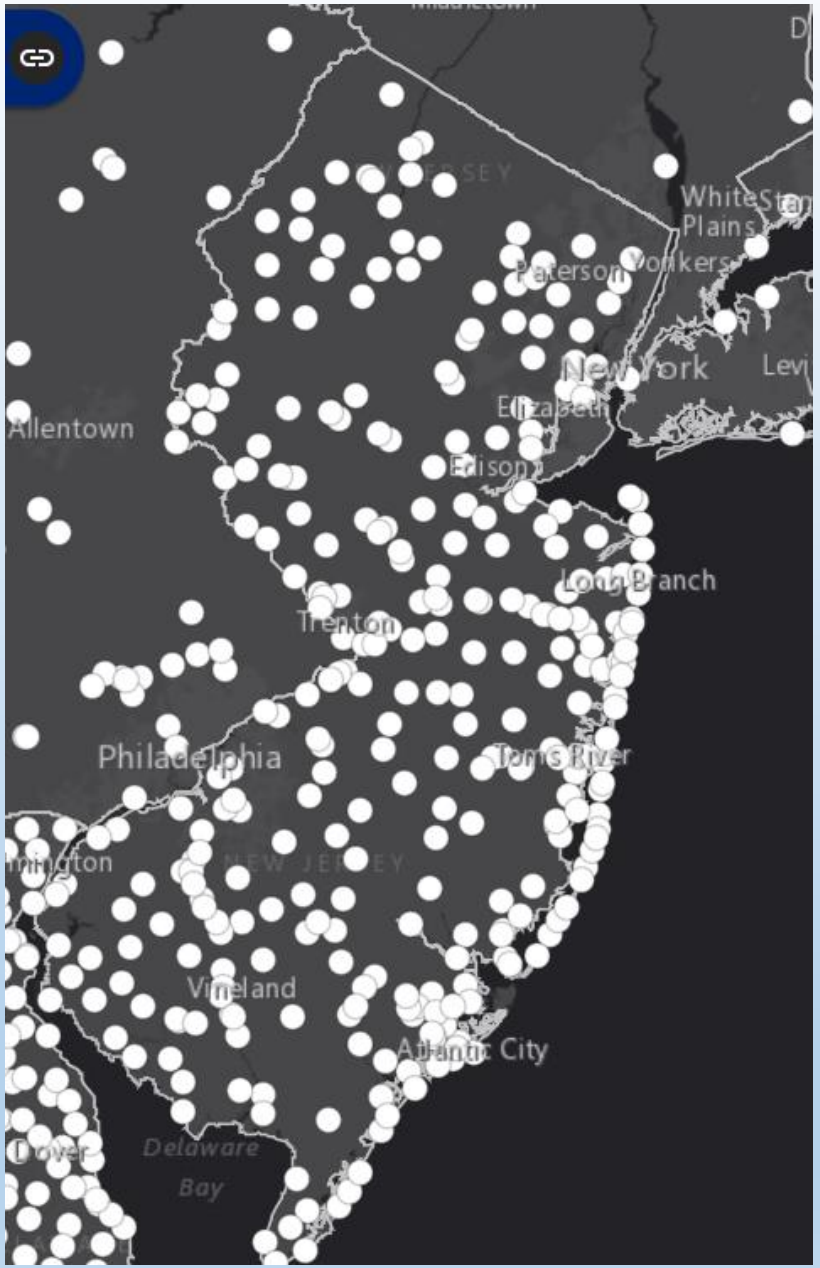
Currently there are over 400,000 bench marks across the Conterminous United States (CONUS), Alaska, Hawaii and U.S. territories. Tidal marks and bench marks are used for determining heights and when possible providing GPS on these marks can help to relate the GPS derived ellipsoid height with the leveling derived orthometric height associated with these marks.

In 2022 NGS will be modernizing the National Spatial Reference System (NSRS) and transitioning to new Reference Frames [CATRF2022, MATRF2022, NATRF2022, PATRF2022] replacing NAD 83 as well as transitioning to the Geopotential Datum (NAPGD2022) which will replace the current Vertical Datums [NAVD 88, ASVD02, PRVD02, NMVD03, GUVD04, VIVD09] for all United States and Territories. When the NSRS modernization occurs, NGS will provide a transformation tool to allow users to convert heights from these current vertical datums into the new geopotential datum.

To develop this transformation tool NGS will use GPS on bench marks (GPS on BM) with heights in the current vertical datums. The transformation tool will be based on a grid developed using all of the data available from GPS on bench marks at the time of development. NGS has developed a list of bench marks that provide the ideal spatial resolution for this transformation grid.



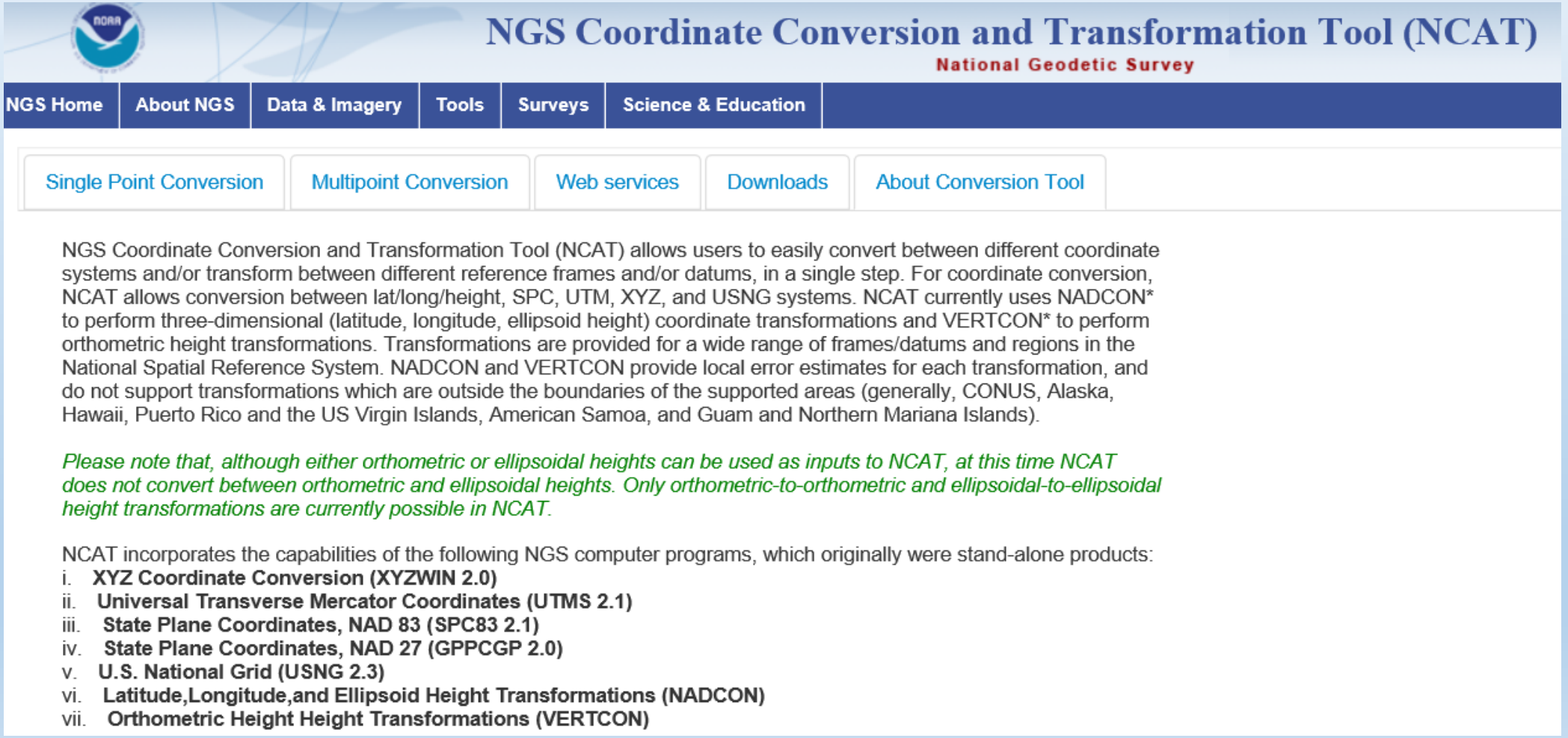
+/- 30 marks 10 km hexagon (National Coverage)
(Currently being worked on)



Completed GPS on BMs Observations

NGS Coordinate Conversion and Transformation Tool (NCAT)

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



NGS Coordinate Conversion and Transformation Tool (NCAT)

National Geodetic Survey

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

Single Point Conversion | Multipoint Conversion | Web services | Downloads | About Conversion Tool

NGS Coordinate Conversion and Transformation Tool (NCAT) allows users to easily convert between different coordinate systems and/or transform between different reference frames and/or datums, in a single step. For coordinate conversion, NCAT allows conversion between lat/long/height, SPC, UTM, XYZ, and USNG systems. NCAT currently uses NADCON* to perform three-dimensional (latitude, longitude, ellipsoid height) coordinate transformations and VERTCON* to perform orthometric height transformations. Transformations are provided for a wide range of frames/datums and regions in the National Spatial Reference System. NADCON and VERTCON provide local error estimates for each transformation, and do not support transformations which are outside the boundaries of the supported areas (generally, CONUS, Alaska, Hawaii, Puerto Rico and the US Virgin Islands, American Samoa, and Guam and Northern Mariana Islands).

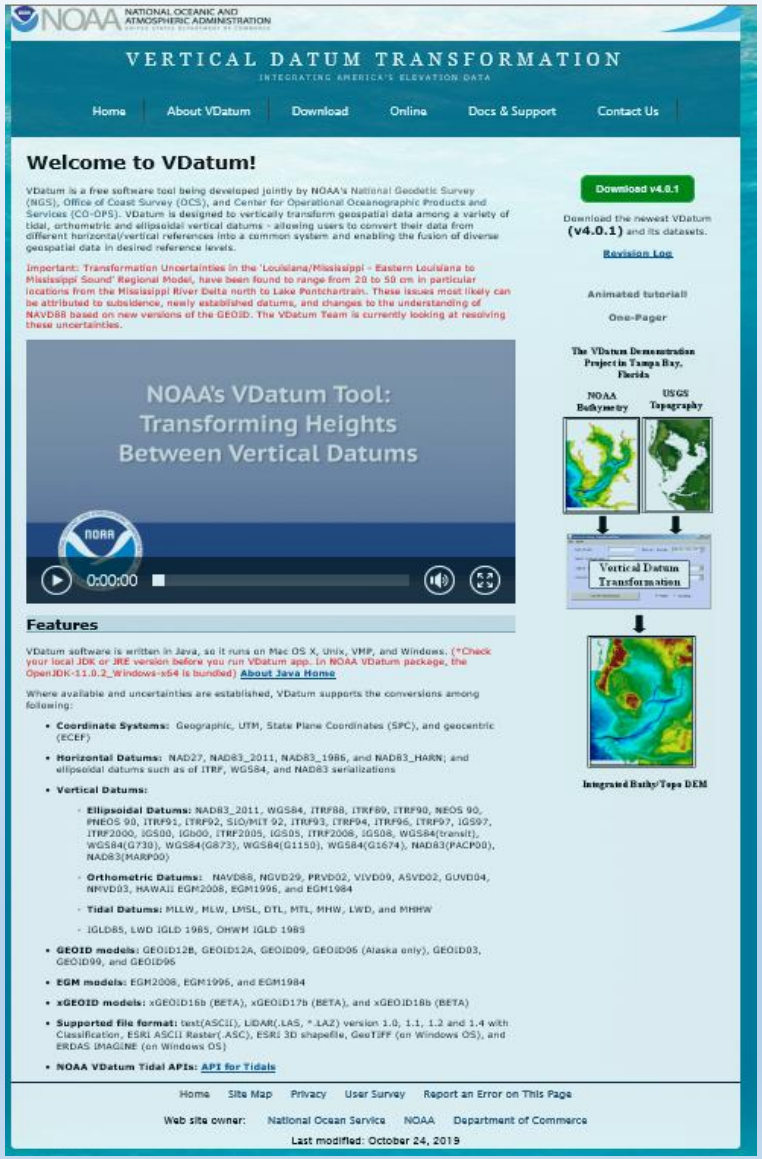
Please note that, although either orthometric or ellipsoidal heights can be used as inputs to NCAT, at this time NCAT does not convert between orthometric and ellipsoidal heights. Only orthometric-to-orthometric and ellipsoidal-to-ellipsoidal height transformations are currently possible in NCAT.

NCAT incorporates the capabilities of the following NGS computer programs, which originally were stand-alone products:

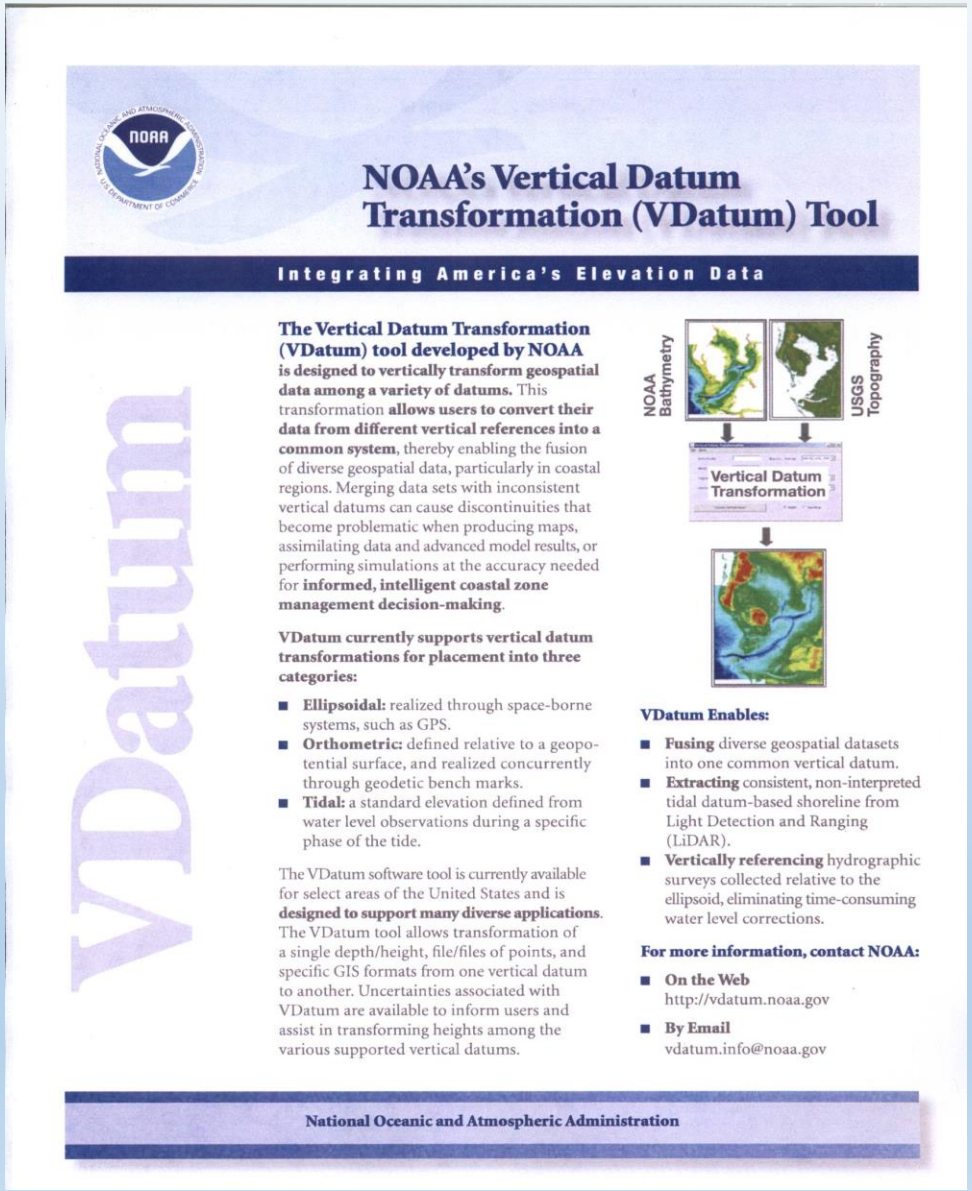
i. **XYZ Coordinate Conversion (XYZWIN 2.0)**
ii. **Universal Transverse Mercator Coordinates (UTMS 2.1)**
iii. **State Plane Coordinates, NAD 83 (SPC83 2.1)**
iv. **State Plane Coordinates, NAD 27 (GPPCGP 2.0)**
v. **U.S. National Grid (USNG 2.3)**
vi. **Latitude,Longitude,and Ellipsoid Height Transformations (NADCON)**
vii. **Orthometric Height Height Transformations (VERTCON)**

NOAA/NGS Vertical Transformation Tool (VDatum)

VDatum is designed to vertically transform geospatial data among a variety of tidal, orthometric and ellipsoidal vertical datums



https://vdatum.noaa.gov/



https://vdatum.noaa.gov/docs/VDatum_one-pager_2016.pdf

Web Links: A Great Start!

The Home Page

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

https://www.ngs.noaa.gov/SPCS/index.shtml

https://www.ngs.noaa.gov/datums/index.shtml

https://www.ngs.noaa.gov/datums/newdatums/index.shtml

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

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

https://www.ngs.noaa.gov/web/science_edu/webinar_series/

https://www.ngs.noaa.gov/web/science_edu/webinar_series/2019-webinars.shtml

https://www.ngs.noaa.gov/PC_PROD/PARTNERS/

https://www.ngs.noaa.gov/web/science_edu/presentations_library/files/stone_caccamise_agu_2017_new_datums_poster_final.pdf

https://www.ngs.noaa.gov/corbin/class_description/NGS_Datums_video_2c/

Thank You