

Squashing a 4D Earth into a 2D Map and Future Geodesy changes for Maryland

Richard Ortt Maryland Geological Survey Department of Natural Resources richard.ortt@maryland.gov



Selected portions of "Datums and Projections: Demystifying the Reference Frame" from the National Geodetic Survey

David Doyle Chief Geodetic Surveyor National Geodetic Survey

National Geodetic Survey





Definitions

<u>Ellipsoid</u> -- Smooth 3D geometric shape similar to a sphere but with different major and minor axes.

<u>Geoid</u> -- a measured and interpolated surface where gravity is the same throughout the world -- typically thought of as global sea level

Topography -- "Real" earth. It is what you stand on, mountains, valleys, the surface of the earth

Datum -- A set of constants that define a coordinate system generally incorporating an Ellipsoid.

<u>Reference</u> System -- A consistent coordinate system and how those coordinates change over time

Projection -- The mathematical model that is used to develop a coordinate system over a portion of the earth.



GRACE Gravity Model 01 - Released July 2003



Image credit: University of Texas Center for Space Research and NASA

THE ELLIPSOID MATHEMATICAL MODEL OF THE EARTH





National Geodetic Survey

An ellipsoid of revolution is the figure which would be obtained by rotating an ellipse about its shorter axis. An ellipsoid revolution describing the figure of the Earth is called a reference ellipsoid.



GRS80 NAD83

Squash the sphere to it at the poles

a= 637813.000007 meters b= 6356752.31414 meters f= 1/((a-b)/a) = 298.2572220972



a = 6,378,137.00000 m

ELLIPSOID - GEOID RELATIONSHIP

H = Orthometric Height (NAVD 88) h = Ellipsoidal Height [NAD 83 (2007) or (CORS96)] N = Geoid Height (GEOID 09)





National Spatial Reference System (NSRS)

Consistent National Coordinate System

- Latitude
- Longitude
- Height
- Scale
- Gravity
- Orientation

and how these values change with time





NATIONAL SPATIAL REFERENCE SYSTEM

ACCURATE -- cm accuracy on a global scale

MULTIPURPOSE -- Supports Geodesy, Geophysics, Land Surveying, Navigation, Mapping, Charting and GIS activities

ACTIVE -- Accessible through Continuously Operating Reference Stations (CORS) and derived products

INTEGRATED -- Related to International services and standards (e.g. International Earth Rotation and Reference Systems Service, International GNSS Service etc.)



GEODETIC DATUMS

A set of constants specifying the coordinate system used for geodetic control, i.e., for calculating coordinates of points on the Earth. Specific geodetic datums are usually given distinctive names. (e.g., North American Datum of 1983, European Datum 1950, National Geodetic Vertical Datum of 1929)

Characterized by:

A set of physical monuments, related by survey measurements and resulting coordinates (horizontal and/or vertical) for those monuments



GEODETIC DATUMS

HORIZONTAL

2-D (Latitude and Longitude) (e.g. NAD 27, NAD 83 (1986))

VERTICAL/GEOPOTENTIAL

1-D (Orthometric Height) (e.g. NGVD 29, NAVD 88, Local Tidal)

GEOMETRIC

3-D (Latitude, Longitude and Ellipsoid Height) Fixed and Stable(?) - Coordinates seldom change (e.g. NAD 83 (1993), NAD 83 (2007))

also

4-D (Latitude, Longitude, Ellipsoid Height, Velocities) Coordinates change with time (e.g. ITRF00, ITRF05)



HORIZONTAL DATUMS

8 Constants

3 – specify the location of the origin of the coordinate system.

3– specify the orientation of the coordinate system.

2 – specify the dimensions of the reference ellipsoid



VERTICAL DATUMS

A set of fundamental elevations to which other elevations are referred.

<u>Datum Types</u>

Tidal – Defined by observation of tidal variations over some period of time (MSL, MLLW, MLW, MHW, MHHW etc.) (NOS Center for Operational Oceanographic Products and Services) (CO-OPS)

Geodetic – Tied to Local Mean Sea Level at one or more points at some epoch (NAVD 88, IGLD85)



National Geodetic Survey

HISTORICAL VERTICAL DATUMS OF THE UNITED STATES

First General Adjustment - 1899

Second General Adjustment - 1903

Third General Adjustment - 1907

Fourth General Adjustment - 1912

Sea Level Datum of 1929 National Geodetic Vertical Datum of 1929 (NGVD 29)

Guam 1963



Fort Stephens

nce/Rupert

The National Geodetic Vertical Datum of 1929 is referenced to 26 tide gauges in the US and Canada

ather's Point alifax Yarmouth Portland Boston Perth Amboy Norfolk Id Point Comfort St. Augustine

Google"

Eye alt 2488.07 m

Baltimo

Brunswick

Fernandina Beach

Cedar Keys

Biloxi Pensacola

Galveston © 2008 Europa Technologies © 2008 Tele Allas Image NASA Image © 2008 TerraMetrics

42*34'34.62" N 95*04'11.11" W

San Diego

Fort Stephens

The North American ertical Datum of 1988 is referenced to a single tide gauge in Canada

Father's Point

Yarmouth

Halifax

Boston

Portland

Perth Amboy

Baltimore Annapolis Norfolk

Old Point Comfort

San Pedro

Prince Rupert

📩 Anacortes

San Diego

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Image NASA Image © 2008 TerraMetrics a class

Brunswick Fernandina Beach

St. Augustine

Cedar Keys

Biloxi Pensacola



National Geodetic Survey

VERTICAL DATUMS OF THE UNITED STATES Current Reference Systems

Federal Register Notice: Vol. 58, No. 120, June 24, 1993, pg. 34245 "Affirmation of Vertical Datum for Surveying and Mapping Activities" (INAVD 88)

American Samoa Vertical Datum of 2002 (ASVD 02)

Northern Marians Vertical Datum of 2003 (NMVD 03)

The Vertical Datum of 3001

Federal Register Notices for American Samoa, Guam and Northern Marians: Vol. 74, No. 13, January 22, 2009, pgs 3990 - 3991



National Geodetic Survey

HISTORICAL HORIZONTAL DATUMS OF THE UNITED STATES

Bessel Ellipsoid

New England Datum

U.S. Standard Datum

North American Datum

North American Datum of 1927

Puerto Rico Datum Old Hawaijan Datum

American Samoa Datum 1962

Guam Datum 1963

Barter Island Datum

Camp Colonna Datum

Flaxman Island Datum

Golofnin Bay Datum

Kripniyuk Datum

Point Barrow Datum

Port Clarence Datum

SE Alaska Datum

St. George Island Datum

St. Lawrence Island Datum

St. Michael Datum

St. Paul Island Datum

UnAlaska Datum

Valdez Datum

Yakutat Datum

Yukon Datum

Johnson Island 1961

Midway Astro 1961

Wake Island Astro 1952



NORTH AMERICAN DATUM OF 1983

Federal Register Notice: Vol. 54, No. 113, June 14, 1989, pg. 25318 "Affirmation of Datum for Surveying and Mapping Activities"

NAD 83 (1986) – 2D & passive ~ 1m national integrity (1986 – 1990)

NAD 83 (199x) – 3D & passive ~ 10 cm national integrity (1990 – 1997)

NAD 83 (CORS96) – 4D & active ~ 2 cm national integrity (1994 – Present)

NAD 83 (2007) – 3D & passive ~ 2 cm relative to CORS (2007 – Present)



National Geodetic Survey

Tectonic Motions



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International Earth Rotation and Reference System Service (IERS)

(http://www.iers.org)

The International Terrestrial Reference System (ITRS) constitutes a set of prescriptions and conventions together with the modeling required to define origin, scale, orientation and time evolution

ITRS is realized by the International Terrestrial Reference Frame (**ITRF**) based upon estimated coordinates and velocities of a set of stations observed by Very Long Baseline Interferometry (**VLBI**), Satellite Laser Ranging (**SLR**), Global Positioning System and GLONASS (**GNSS**), and Doppler Orbitography and Radio- positioning Integrated by Satellite (**DORIS**).

ITRF89, ITRF90, ITRF91, ITRF92, ITRF93, ITRF94, ITRF95, ITRF96, ITRF97, ITRF2000, ITRF2005, ITRF2008 (soon)



Goddard CORS GPS Station Coordinates

ITRF2014
GODDARD SPACE CTR (GODE), MARYLAND

Retrieved from NGS DataBase on 06/16/20 at 12:05:19.

Antenna Reference Point(ARP): GODDARD SPACE CTR CORS ARP

PID = AF9646

ITRF2014 POSITION (EPOCH 2010.0)

Published by the IGS in May 2020.

X =	1130773.681 m	latitude	= 39 01	18.21996	Ν
Y =	-4831253.619 m	longitude	= 076 49	36.59163	W
Z =	3994200.473 m	ellipsoid	height =	14.559	m

ITRF2014 VELOCITY

Published by the IGS in May 2020.

VX =	-0.0151 m/yr	northward =	0.0042 m/yr
VY =	0.0003 m/yr	eastward =	-0.0146 m/yr
VZ =	0.0024 m/yr	upward =	-0.0014 m/yr

 NAD_83 (2011) POSITION (EPOCH 2010.0)

 Transformed from ITRF2014 (epoch 2010.0) position in May 2020.

 X = 1130774.439 m

 latitude
 = 39 01 18.18970 N

 X = 4831355 072 m
 langitude

 076 10 26 57172 H

Y =	-4831255.072 m	longitude	= 076 49	36.57472	W
Z =	3994200.558 m	ellipsoid	height =	15.845	m

NAD_83 (2011) VELOCITY

Transformed from ITRF2014 velocity in May 2020.

VX	=	0.0015	m/yr	northward	=	-0.0007	m/yr
VY	=	0.0016	m/yr	eastward	=	0.0018	m/yr
VZ	=	-0.0019	m/yr	upward	=	-0.0021	m/yr



International Terrestrial Reference Frame 4 Global Independent Positioning Technologies



ARE NAD 83 & WGS 84 THE SAME?

IT DEPENDS

If requirements are greater than 3m then Yes

If requirements are less than 3m then No

Federal Register Notice: Vol. 60, No. 157, August 15, 1995, pg. 42146 "Use of NAD 83/WGS 84 Datum Tag on Mapping Products"



WORLD GEODETIC SYSTEM 1984

HOW MANY WGS 84s HAVE THERE BEEN????

DATUM = WGS 84 RELEASED - SEPTEMBER 1987 BASED ON DATUM = WGS 84(G730)



MORE TH Datum redefined with respect to the International STATIONS Terrestri DATUM = WGS 84(G873)

+/- 20 cm Datum redefined with respect to the International (Proceed Terrestrial Reference Frame of 1994 (ITRF94)

DATUM = WGS 84(G1150)

Datum redefined with respect to the International Terrestrial Reference Frame of 2000 (ITRF00)

+/- 2 cm in each component

(Proceedings of the ION GPS-02)

http://earth-info.nima.mil/GandG/sathtml/IONReport8-20-02.pdf



MY SOFTWARE SAYS I'M WORKING IN WGS-84

Unless you are doing autonomous positioning (point positioning +/- 6-10 meters) you're probably NOT in WGS-84

Project tied to WGS-84 control points obtained from the Defense Department -- Good Luck!

You're really working in the same reference frame as your control points -- NAD 83?



PLANE COORDINATE SYSTEMS

STATE PLANE AND UNIVERSAL TRANSVERSE MERCATOR GRID COORDINATES ARE A DIRECT MATHEMATICAL CONVERSION FROM LATITUDE AND LONGITUDE TO A CARTESIAN NORTHING AND EASTING (Y & X) COORDINATE SYSTEM, AND <u>MUST</u> MAINTAIN THE SAME DATUM TAG [e.g. NAD 27 or NAD 83] AS THE LATITUDE AND LONGITUDE)



So What Is A Projection

NORTHING

EASTING

•



National Geodetic Survey

MAP PROJECTIONS CONIC AND CYLINDRICAL







National Geodetic Survey

UTM ZONES







National Geodetic Survey STATE PLANE COORDINATE ZONES



To:

What Are State Plane Coordinates

 State plane coordinates are the projection of latitudes and longitudes from the GRS80 ellipsoid

A flat mapping surface that is usually defined by state law



STATE PLANE COORDINATE SYSTEM 1927

Developed by U.S. Coast and Geodetic Survey from a request in 1933 from the North Carolina Department of Transportation

Two basic map projections used:

Lambert Conformal Conic – States or parts of states that have a more East-West orientation Transverse Mercator – States or parts of states that have a more North-South orientation

Zone boundaries along International, State and county boundaries

Zones typically 154 miles wide – this limits the maximum geodetic to grid distance distortion to 1:10,000

All coordinate values in U.S. Survey Feet

Conversions to/from latitude & longitude calculated using tables (e.g. USC&GS Special Publication. 316 Plane Coordinate Projections Tables – New Jersey)

State Plane Coordinates by Automatic Data Processing (USC&GS 62-4)

STATE PLANE COORDINATE SYSTEM 1983

Geometric parameters of original SPC zones left unchanged unless requested by "the State"

All states get new false northing and false easting defined in meters.

All values in meters – conversions to feet defined by individual state legislation or Federal Register Notice

1 m = 3.28083333333. U.S. Survey Feet 1 m = 3.2808398950 International Feet





GOOD COORDINATION BEGINS WITH GOOD COORDINATES



GEOGRAPHY WITHOUT GEODESY IS A FELONY



What Developments are there?



- 2022 Terrestrial Reference Frame (Horizontal and Vertical)
 - Ellipsoid and Orthometric Height
 - Horizontal Change
 - Updated NAD83 and NAVD88
 - 4D (Horizontal, Vertical, and Time)
- Redesign of all State Plane Coordinate Systems by NGS
 - NGS has developed new suggested State Plane systems for each state.
 - Some states have asked for redesigns or changes in parallels.
 - Some states have asked for high accuracy areas
- MD will need legislative change to adopt new State Plane Coordinate system.

2022 Terrestrial Reference Frame Horizontal



- Similar change as from NAD27 to NAD 83
- Takes into account velocity of North American Plate
- New Name: NATRF2022
- Approx. Horizontal change from NAD83 to NATRF2022 is 1.2-1.3 meters across the State of Maryland



2022 Terrestrial Reference Frame Vertical



- Similar change vs. transition to NAVD88 from NGVD29
- Follows new modelled geopotential surface datum NAPGDP2022
- Will be combined with GEOID 2022 and regional deflection models
- Approx. Vertical changes:
 - Ellipsoid: -1.3M
 - Orthometric : -0.4M
 - GEOID will more closely match Global Sea Level.
- Ellipsoid will be held constant until a new threshold is defined (Important for MD and Sea Level Rise)



Draft Vertical Comparisons



NW Corner of Garrett county:						
39 43 16	-79 28 36 WGS84		708.94m NAVD88			
NGVD29:	Ellipsoid Ht: 709.076m					
NAVD88:	Ellipsoid Ht: 708.94m	Geoid height: -31.655m	Orthometric Height: 740.595 m			
NAPGD2022	Ellipsoid Ht: 707.696m	Geoid Height: -32.459	Orthometric Height: 740.155 m	Ortho Change: -0.440m		
Deltimente						
Baltimore						
391/51	-/6365/ WG884		30.08m NAVD88			
NGVD29:	Ellipsoid Ht: 30.365m					
NAVD88:	Ellipsoid Ht: 30.08m	Geoid height: -32.702m	Orthometric Height: 62.782 m			
NAPGD2022	Ellipsoid Ht:28.801m	Geoid Height: -33.627	Orthometric Height: 62.428 m	Ortho Change: -0.354m		
SE Assateagu	e Island					
38 01 39	-75 14 30 WGS84		0.0m NAVD88			
NGVD29:	Ellipsoid Ht: 0.244m					
NAVD88:	Ellipsoid Ht: 0.0m	Geoid height: -36.422m	Orthometric Height: 36.422 m			
NAPGD2022	Ellipsoid Ht: -1.327m	Geoid Height: -37.444m	Orthometric Height: 36.117 m	Ortho Change: -0.305m		
Point of Origi	n (SPCS2022)					
38 51 00	-77 00 00 NATRF22		45.73m NAVD88			
NGVD29:	Ellipsoid Ht: 45.977m					
NAVD88:	Ellipsoid Ht: 45.73m	Geoid height: -32.209m	Orthometric Height: 77.939 m			
NAPGD2022	Ellipsoid Ht: 44.440m	Geoid Height: -33.132m	Orthometric Height: 77.572 m	Ortho Change: -0.367m		
	-	2	5	C C		

State Plane 1983 (Existing Law)





State Plane 2022 (No Current Legal Authority)





SPCS 2022???



- Still a Lambert Conformal Conic Projection
- Changes from 2 Standard Parallels to 1 standard Parallel
- Decreases total range of distortion errors and halves the median distortion error throughout the State.
- Based on NATRF2022
- Can be either <u>INTERNATIONAL FOOT</u> or Meters.
- Has no legal change in Maryland unless there is legislative adoption.
- Vendors (ESRI, Trimble, Topcon, AutoCad, Woolpert, etc.) are tracking this change and will add datum, projection, system to software and hardware.

Approximate Horizontal Comparisons



Northing (Foot)	Easting (East)	Northing (Motors)	Easting (Motors)	SDCS		
Northing (Feet)	Easting (Feel)	Northing (Meters)	Easting (weters)	3603		
NW Corner of Garrett	county (MD/WV/PA	Border)				
Lat: 39 43 16 Long: -79	28 36	WGS84	Elevation:	708.94m NAVD88		
696954	103274	212432m	31477m	SPCS27		
757694	615693	230946m	187664m	SPCS83		
982913	1928030	299592m	587664m	SPCS2022		
Baltimore (Washington	n Monument)					
Lat: 39 17 51 Long: -76	36 57	WGS84	Elevation:	30.08m NAVD88		
533418	908636	162586m	276953m	SPCS27		
594168	1421054	181103m	433138m	SPCS83		
819382	2733394	249748m	833139m	SPCS2022		
SE Assateague Island	(MD/VA Border)					
Lat: 38 01 39 Long: -75	14 30	WGS84	Elevation:	0.0m NAVD88		
75544	1306405	23026m	398193m	SPCS27		
136291	1818830	41541m	554381m	SPCS83		
361504	3131168	110187m	954380m	SPCS2022		
Point of Origin (SPCS2022)						
Lat: 38 51 00 Long: -77 00 00		NATRF22	Elevation:	45.73m NAVD88		
370205	799914	112839m	243814m	SPCS27		
430954	1312333	131355m	400000m	SPCS83		
656168	2624672	200000m	800000m	SPCS2022		

Current Law -SPCS



2013 Maryland Code REAL PROPERTY

§ 14-405 - Standards of Maryland Coordinate System

(a) For the purpose of more precisely defining the Maryland Coordinate System, the standards of the National Geodetic Survey set out in this section are adopted.

(b) (1) The Maryland Coordinate System is a Lambert conic conformal projection of the Geodetic Reference System of 1980, having standard parallels at north latitudes 38 degrees 18' and 39 degrees 27', along which parallels the scale shall be exact.

(2) The origin of coordinates is at the intersection of the meridian 77 degrees 00' west longitude and the parallel 37 degrees 40' north latitude.

(3) This origin is given the coordinates: Easting=400,000 meters and northing=0 meters.

(c) For the Maryland Coordinate System, the unit used to convert feet to meters is the United States survey foot, which is 39.37/12 feet for each meter.

(d) The position of the Maryland Coordinate System shall be as marked on the ground by triangulation or traverse stations established in conformity with the standards adopted by the National Geodetic Survey for first-order and second-order work, whose:

(1) Geodetic positions have been rigidly adjusted on the North American Datum of 1983; and

(2) Plane coordinates have been computed in accordance with this section.

Future MD SPCS



- Maryland State Legislature must change COMAR to change Maryland's accepted current SPCS to the new NGS designed system.
- NGS has distributed legislative language that will allow States to match NGS changes.
- Currently, Maryland Society of Surveyors is developing legislative language.
- Small working group within State included: SHA, MGS, DOIT, DOP
- Technical -- A latitude/longitude of origin must be decided. *Current* proposed is 38 51'N, 77 00' W.
- Technical -- An offset must be decided upon. It is desirable and expected that these offsets will be large and will be obvious so as to not confuse SPCS2022 with any previous coordinate system. *Current proposed is 200,000M Northing and 800,000M Easting at origin.*



References:

https://geodesy.noaa.gov/datums/newdatums/delayed-release.shtml

https://www.ngs.noaa.gov/datums/newdatums/delayed-release.shtml Delayed Release of the Modernized

NSRS

Written and Verbal Comms: Scott Loken, William Stone, National Geodetic Survey (NGS) Regional Coordinators; Michael Dennis, SPCS Coordinator

Maryland Society of Surveyors, verbal and written comms, draft legislative review.

[FR Doc. 2020-16068 Filed 7-23-20; 8:45 am] Upcoming Changes to the National Spatial Reference System

https://www.esri.com/about/newsroom/arcuser/moving-from-static-spatial-reference-systems-in-2022/

Summary



- The current multiple versions of NAD83 will be replaced with NATRF2022. This is true for all coordinate systems (UTM, Geographic, SPCS, etc.). The anticipated horizontal change is about 1.2 to 1.3 meters in Maryland.
- NAVD88 will be superseded by NAPGPD2022 and GEOID22 for elevations.
- SPCS83 is proposed to change to SPCS2022.
- Current MD Law will need to be updated to make SPCS 2022 enacted in Maryland.