NATRF and NAPGD 2022 and Effects on Land Surveying

(On or Near the Pacific Tectonic Plate)

CPP Geomatics Conference

Gregory A. Helmer, PLS

September 2024

CALIFOR
REFER

Public Reso

§ 8850-8861 Geod

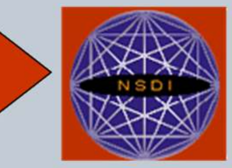
§ 8870-8880 Geodet

§ 8890-8902 Heights

§ 8801-8819 State Plane

2017.50 CSRN Adjustmen

ITRF14 Transformed to NAD83
Project Report, signed and sea
NAVD88 Calif. Orthometric Heig



Data Distribution

- Web Interface db
- Standards & Specifications
- Post-Processing Apps
- Real-Time Infrastructure

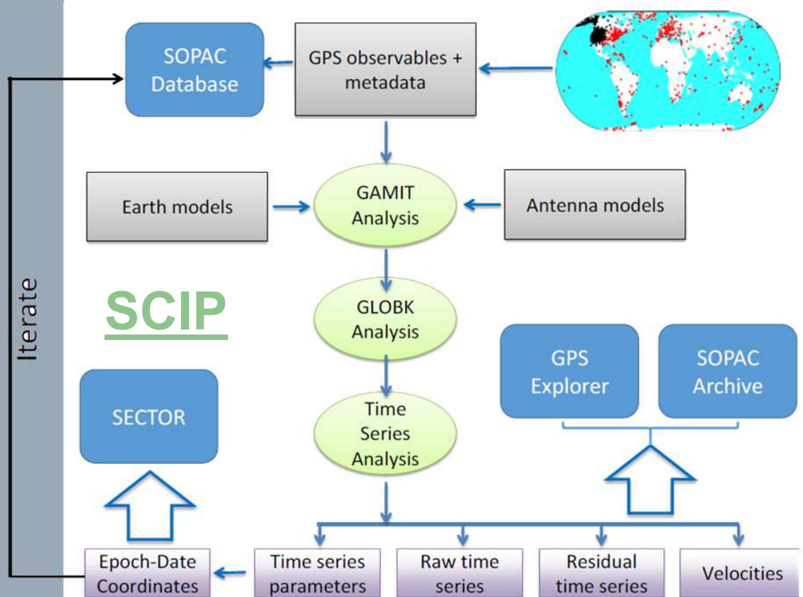
Public Outreach

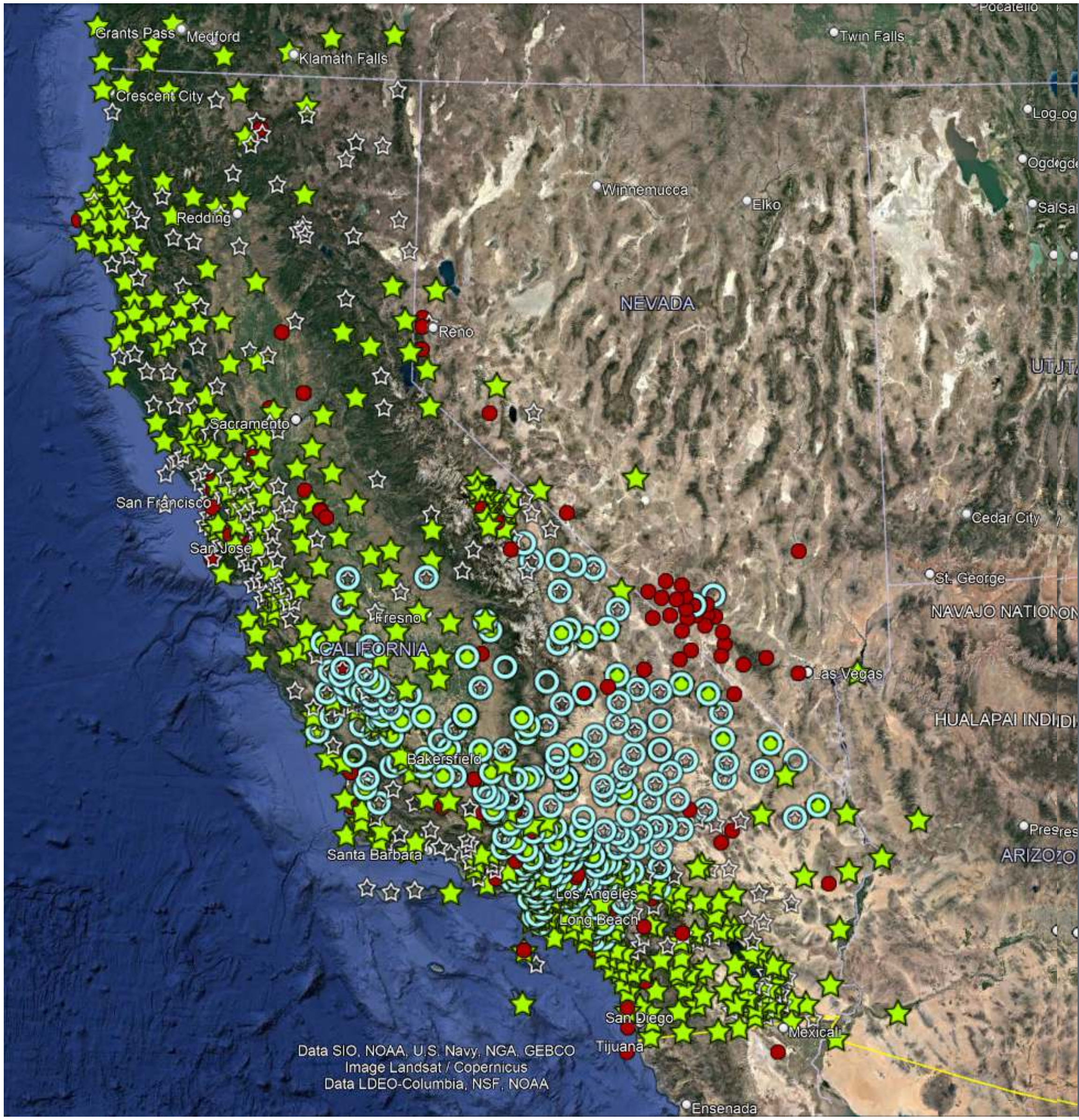
- Legislation
- Guidelines
- Education / Seminars
- Meetings & Forums

CSRN 2017.50

957 Network Stations

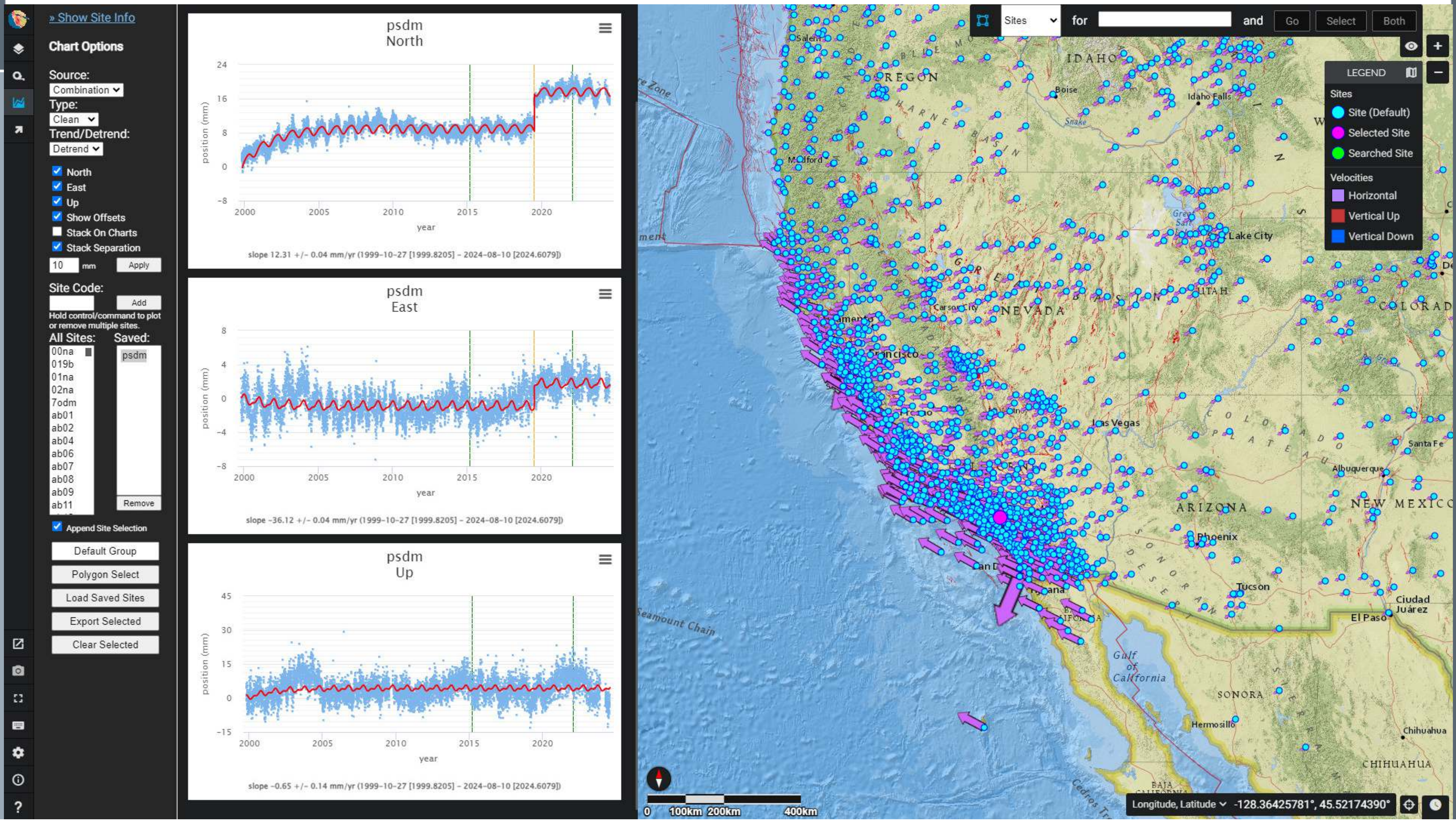
~400 IGS Global Stations



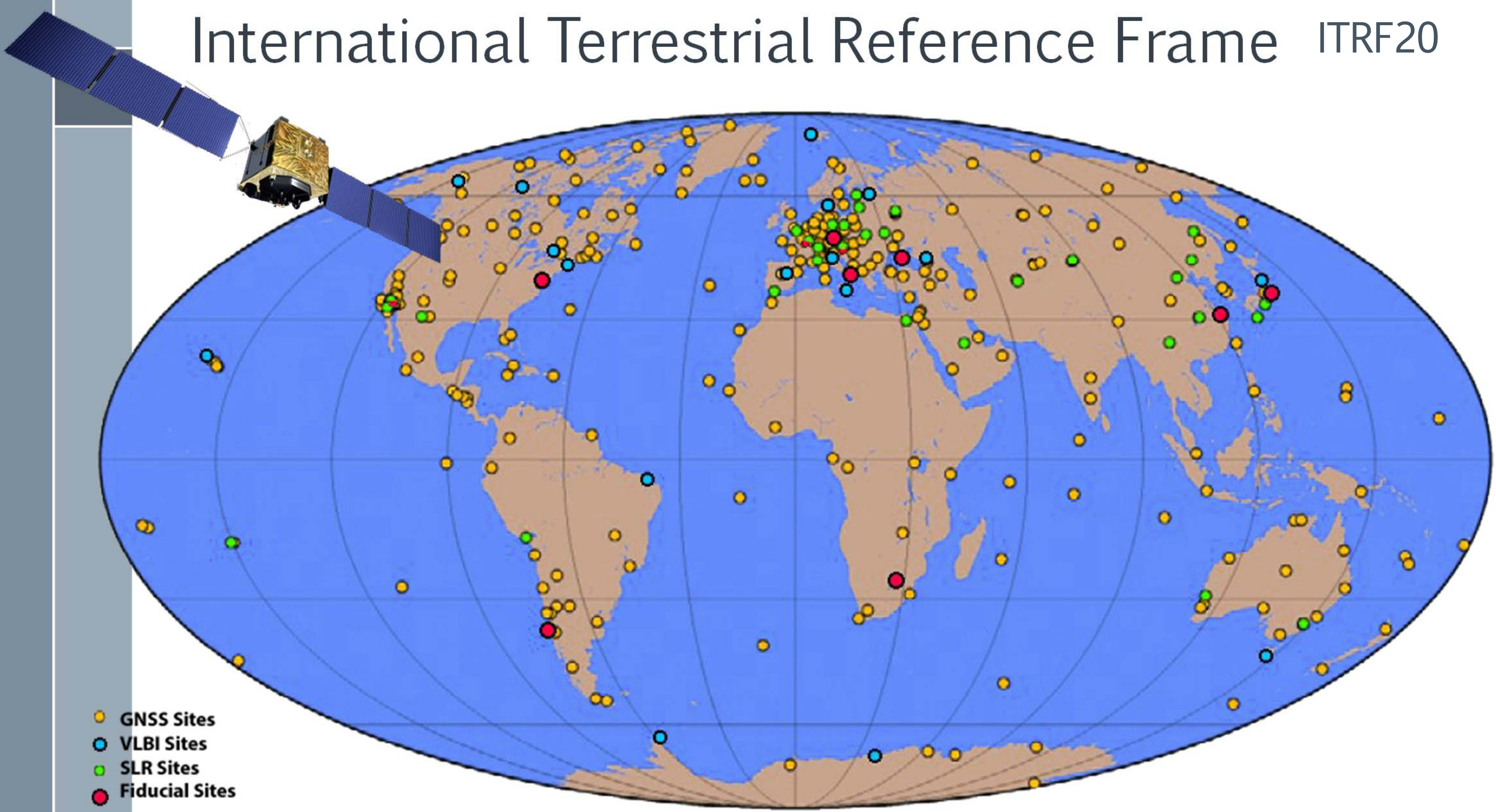


CSRN 2025.00

NAD83, NATRF2022, or both?



International Terrestrial Reference Frame ITRF20

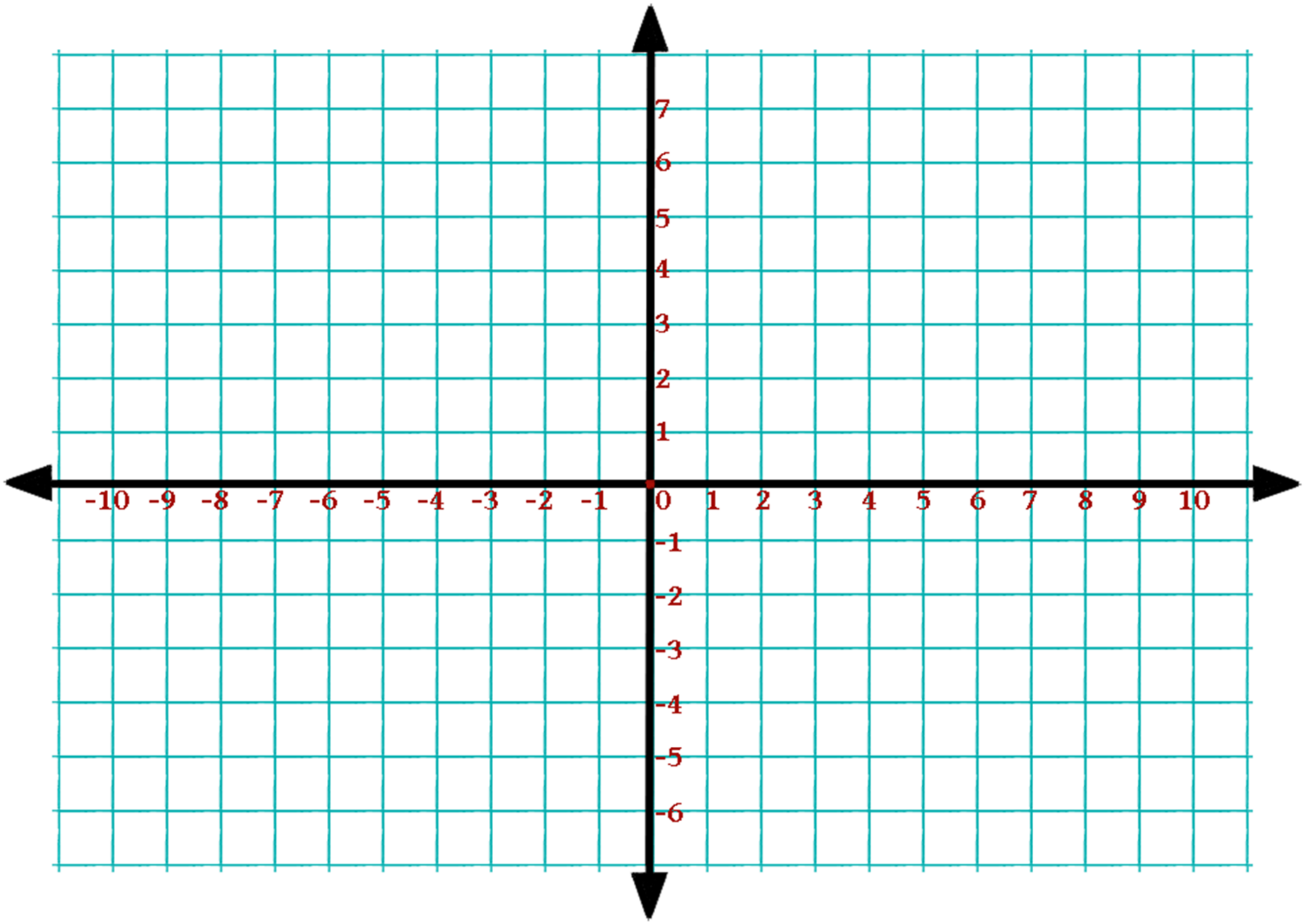


Geodesy Curriculum at SIO

SIO course number	Title	Instructor(s)
229	*Reference Frames and Global Gravity*	Borsa/Bock
239	*GNSS Geodesy (new in 2023)*	Haase
236	*Satellite Remote Sensing*	Fricker/Sandwell
237	*Space Geodesy Seminar*	Fialko/Haase/Sandwell
(new)	*Radar Interferometry*	Sandwell/Mellors
(new)	*Geodetic Field Work and Aircraft Gravity*	Greenbaum
239	*Seafloor Geodesy*	Zumberge/Sandwell
223 A/B	*Geophysical Data Analysis*	Agnew
210	*Introduction to Physical Oceanography*	Talley

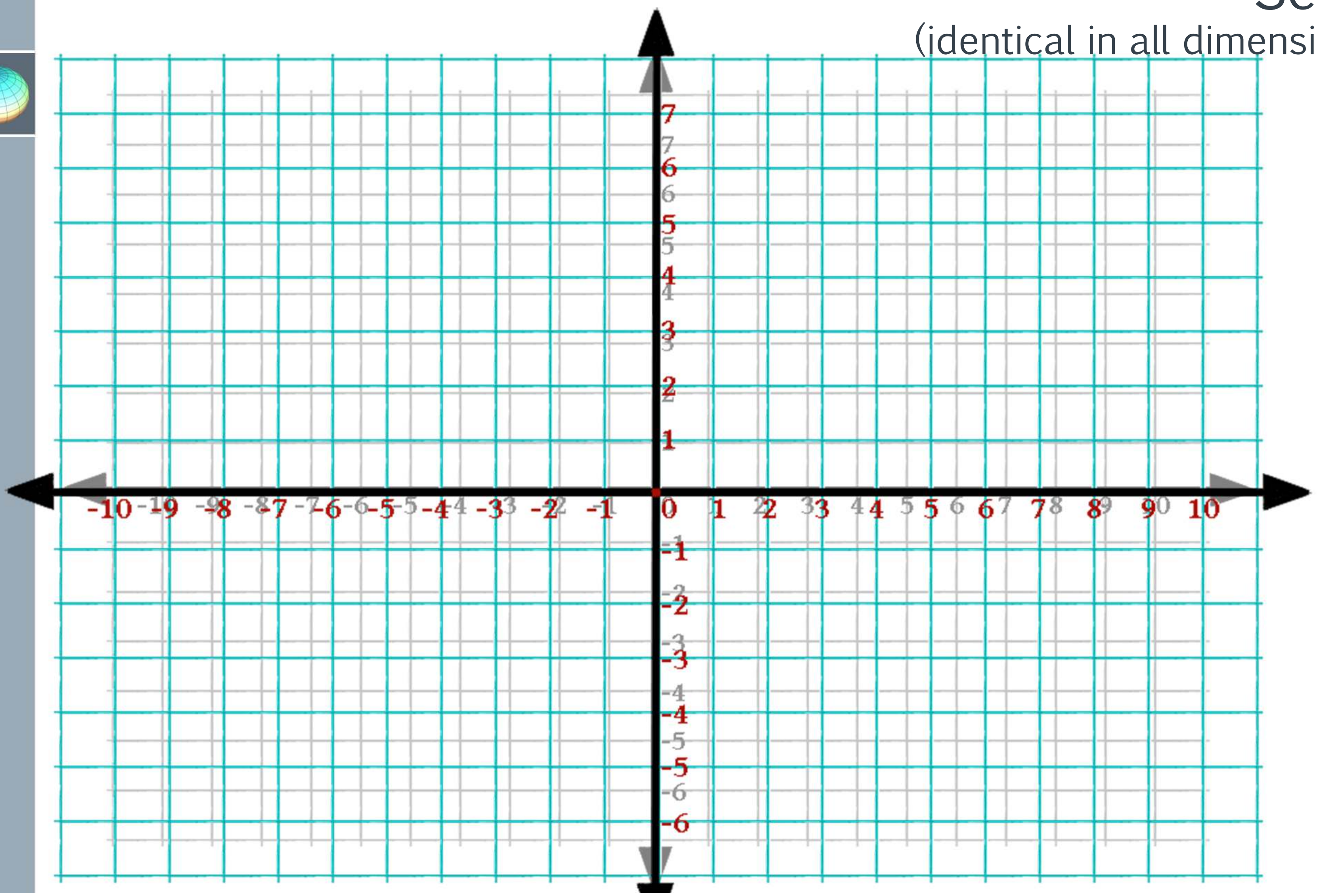
Curriculum will include 9 graduate courses including seven that are already offered in the Geophysics Curricular group and two more in development; includes support for five graduate students to enhance the nation's pool of geodetic scientists.

SIO Faculty: David Sandwell, Jennifer Haase, Yehuda Bock, Adrian Borsa, Yuri Fialko, Jamin Greenbaum, Matthew Mazloff, Mark Merrifield, Mark Zumberge, Helen Fricker, Robert Mellors
Collaborators: Humberto Gallegos, East Los Angeles City College, Caltrans, DWR

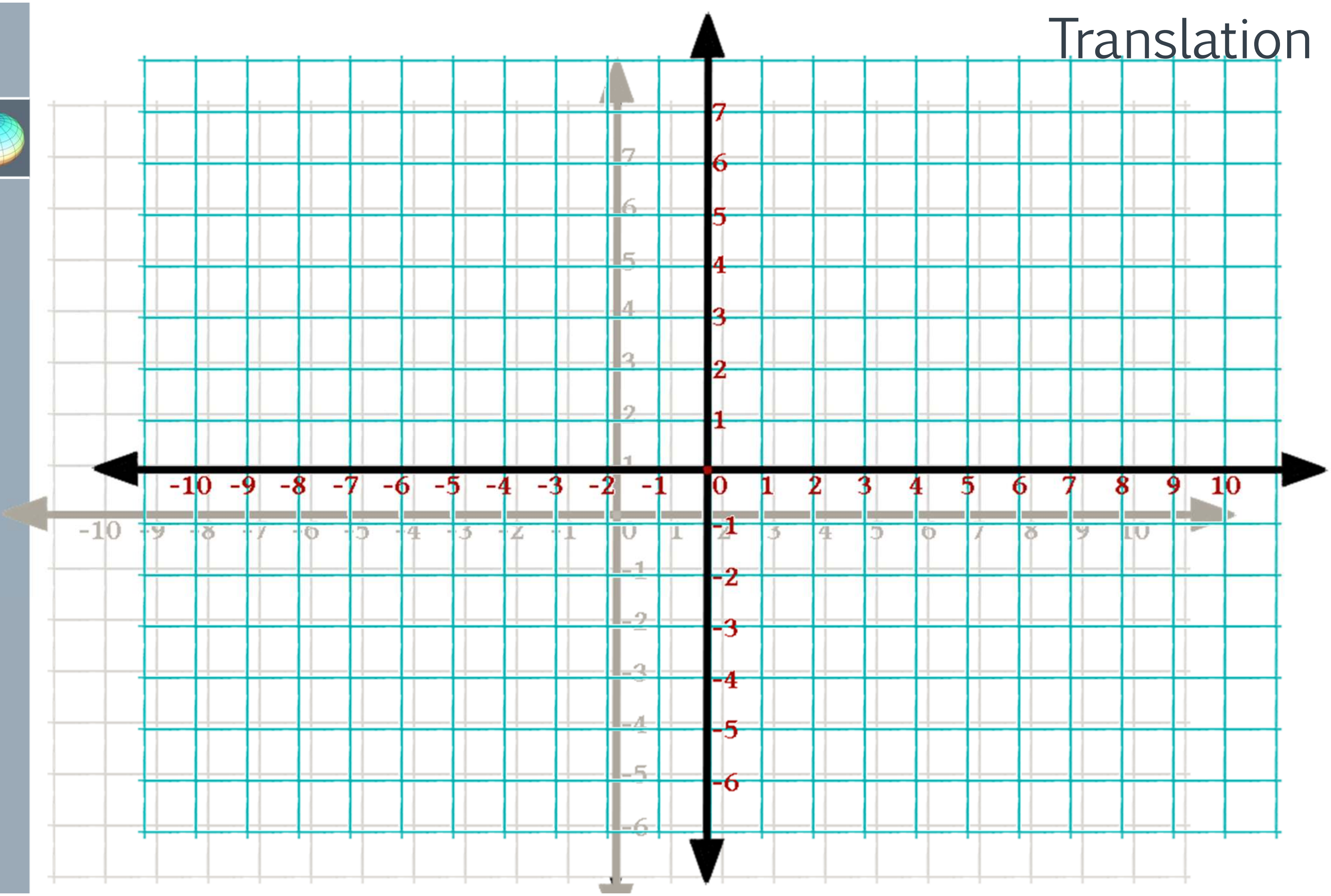

-10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10
7
6
5
4
3
2
1
-1
-2
-3
-4
-5
-6

Scale

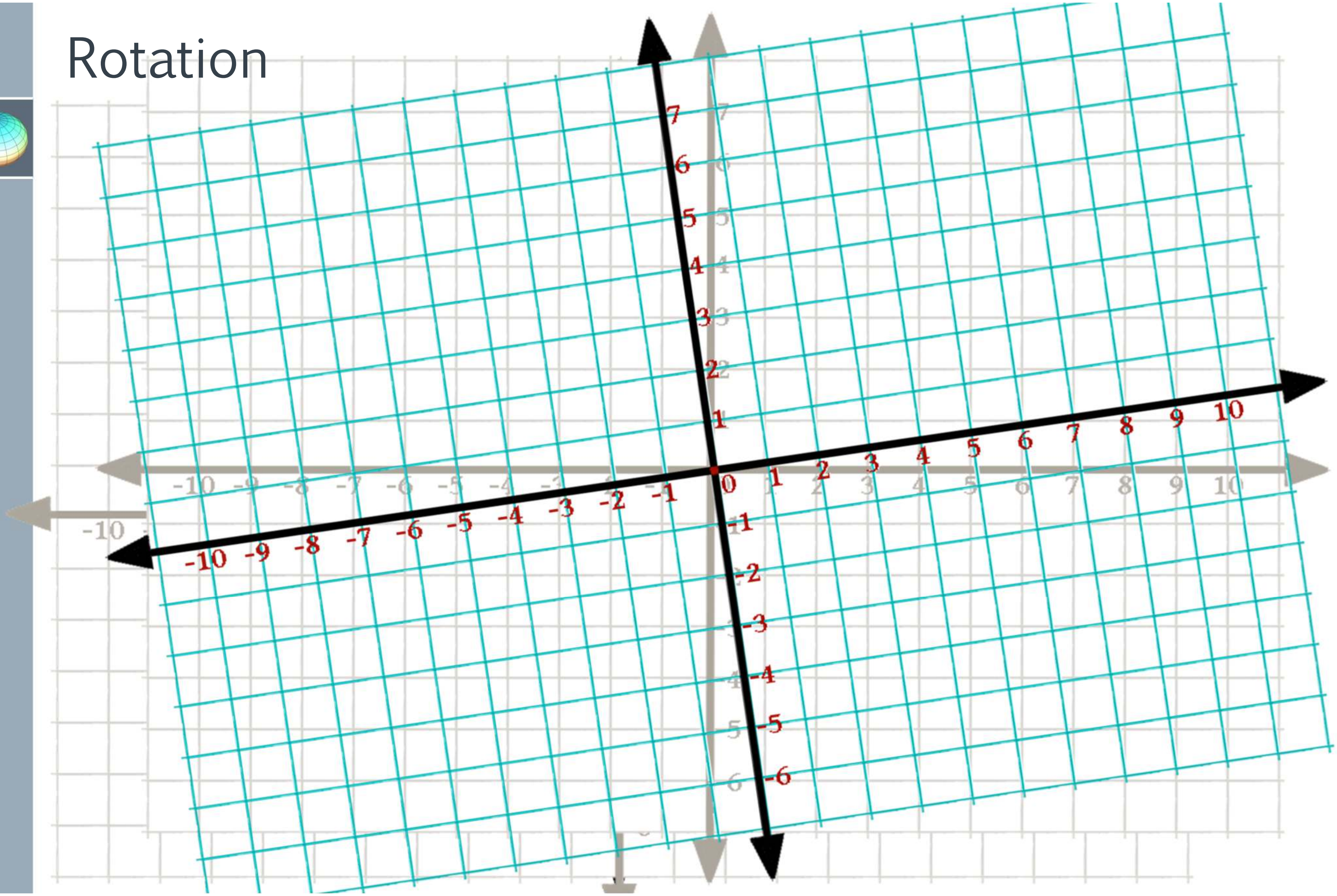
(identical in all dimensions)



Translation

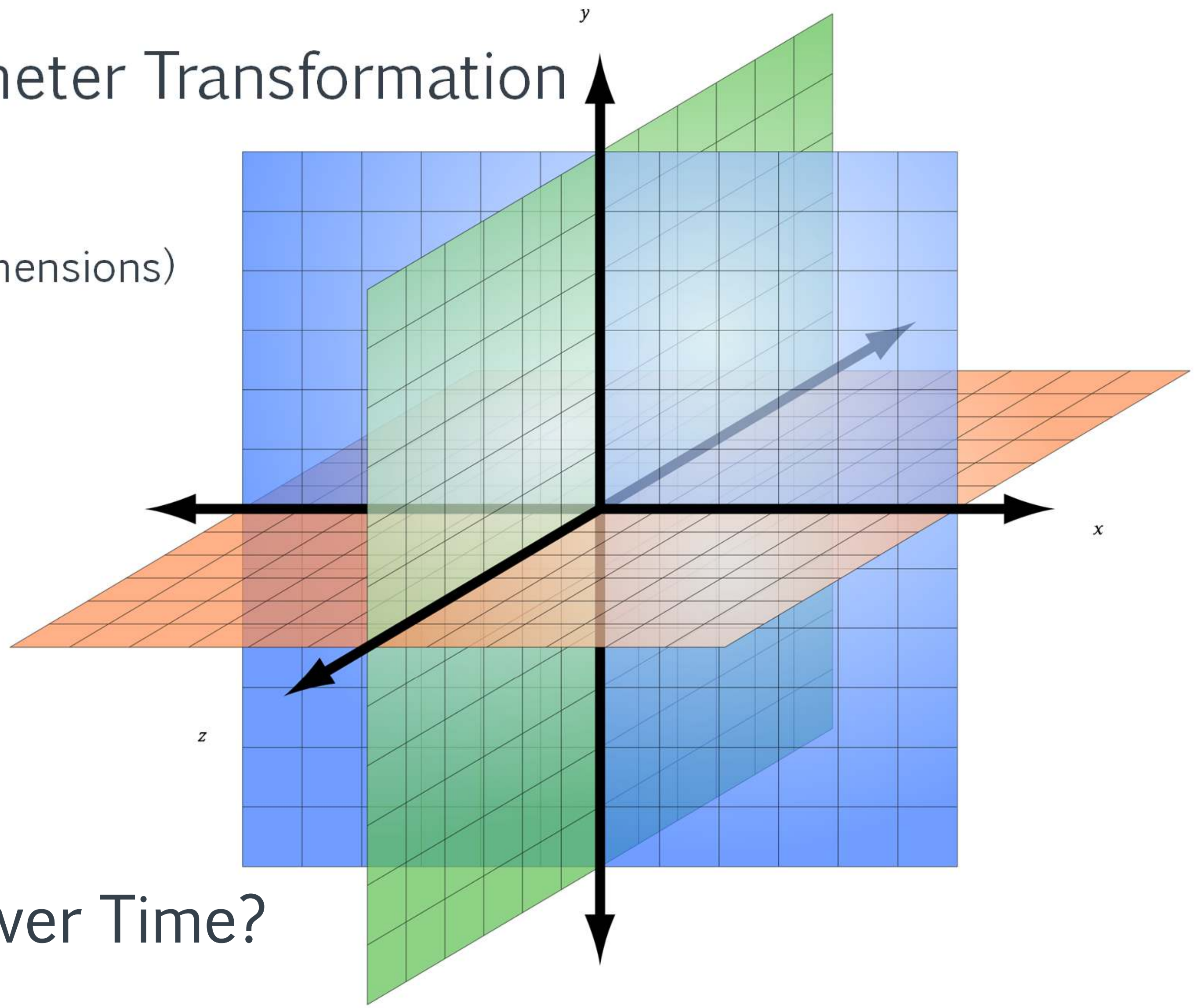


Rotation



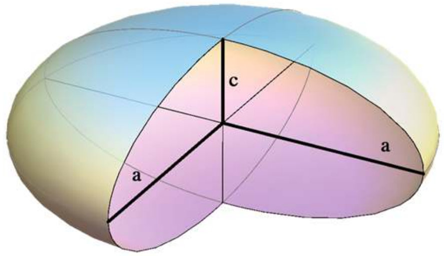
Seven-Parameter Transformation

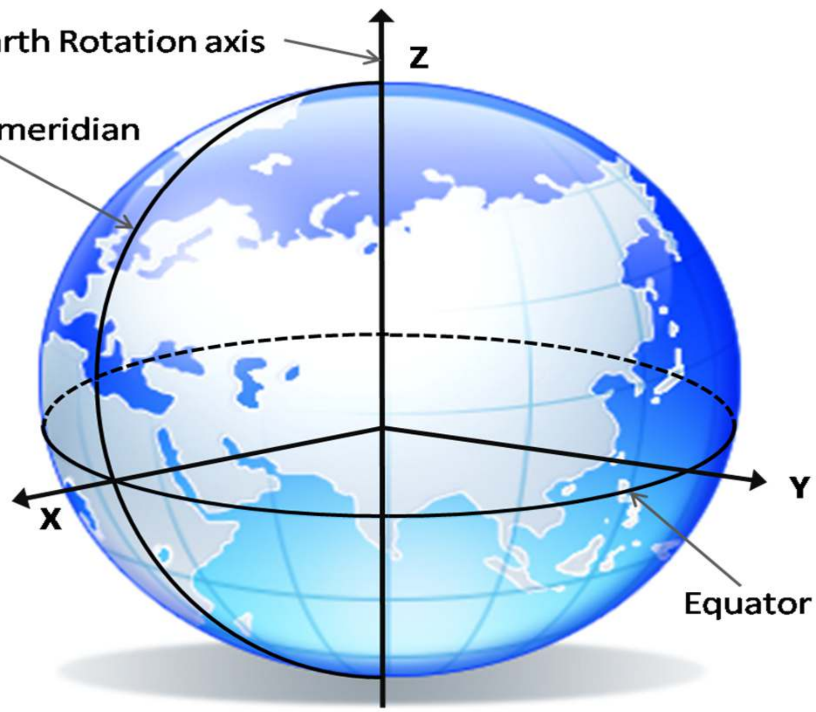
Scale
(identical in all dimensions)
Translations
(in X, Y & Z)
Rotations
(about X, Y & Z)



4d Change over Time?

Ellipsoid
(GRS80)



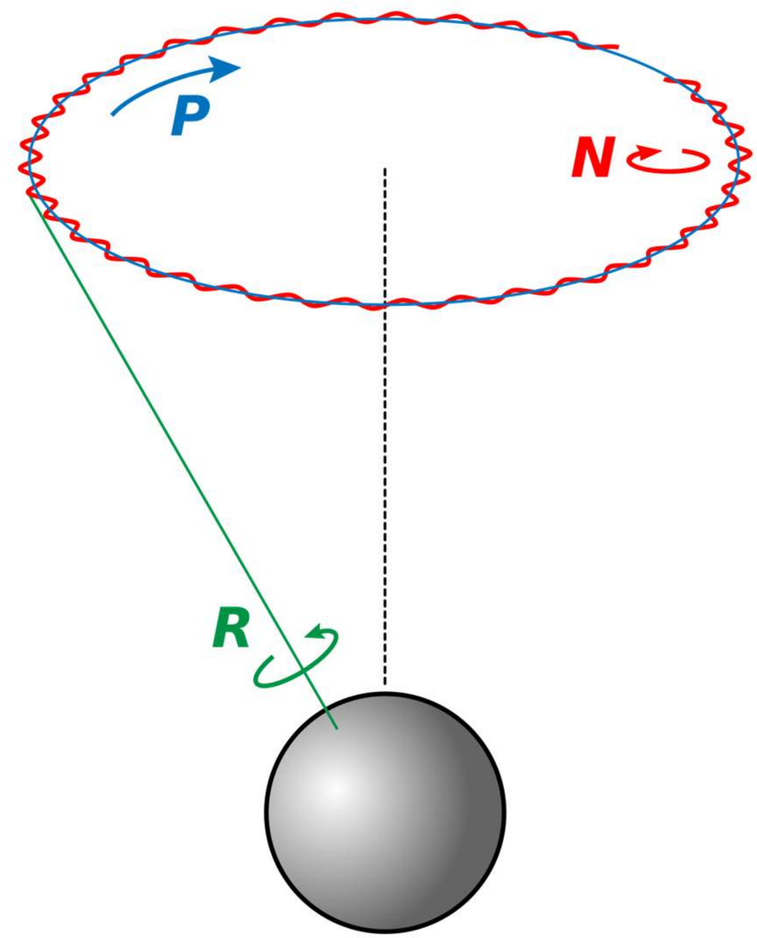


Major Axis 6,378,137 m
Flattening 1/298.257 222 101
Center of Mass

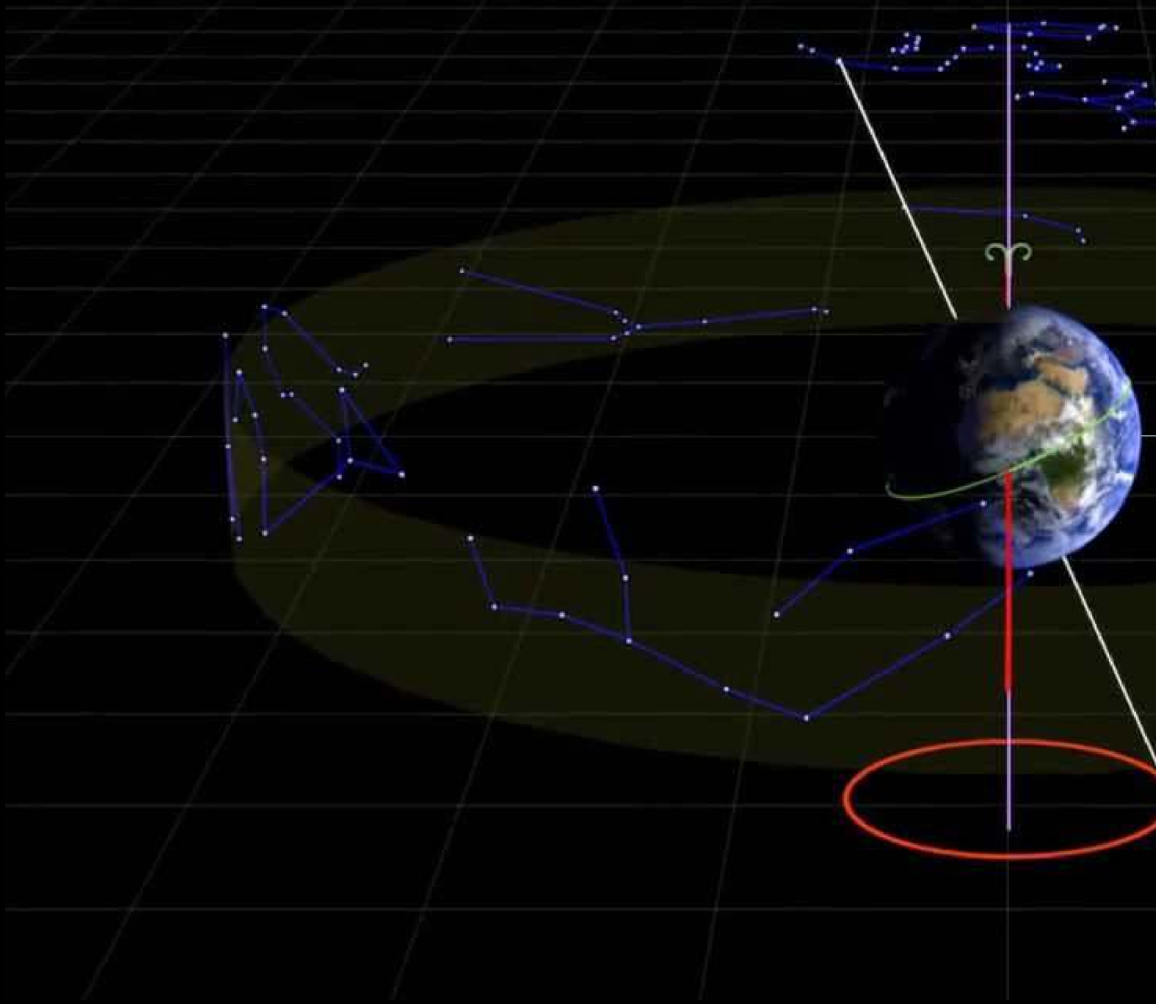
Gravity as a Function of Latitude
Rotation Period (86,164 seconds)

Precession
26,000 Years, 1.38°/Century

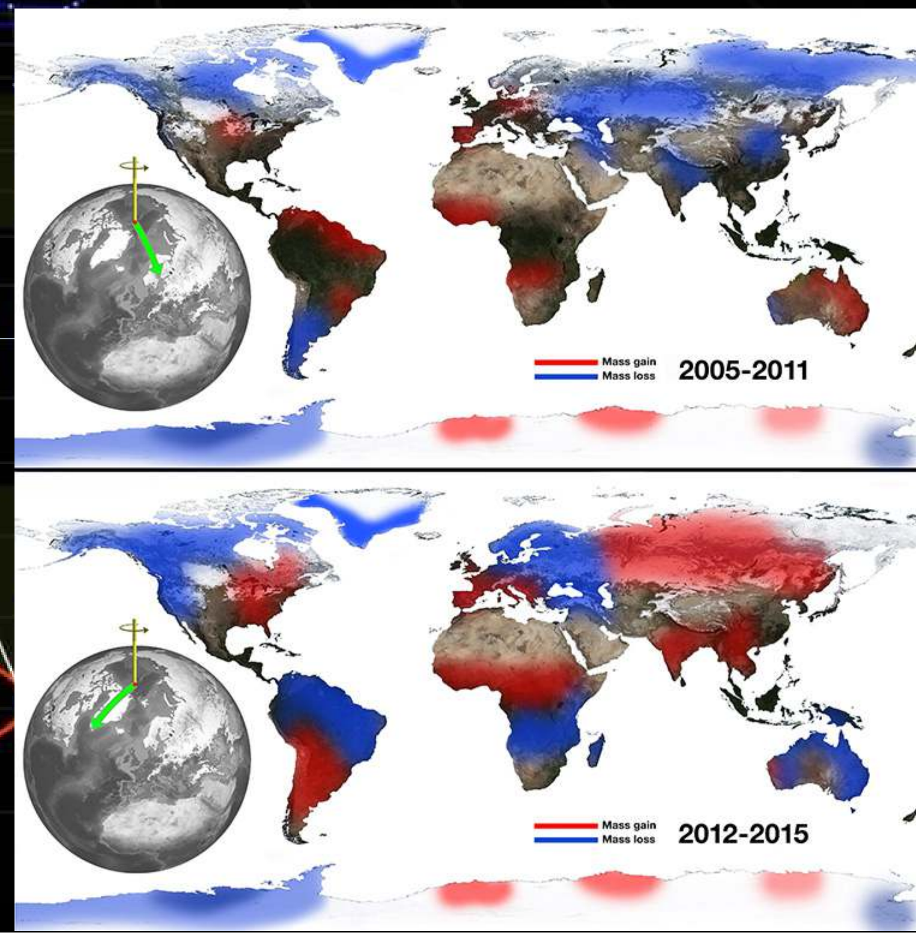
Nutation
17”x 9” / 18.6 Years



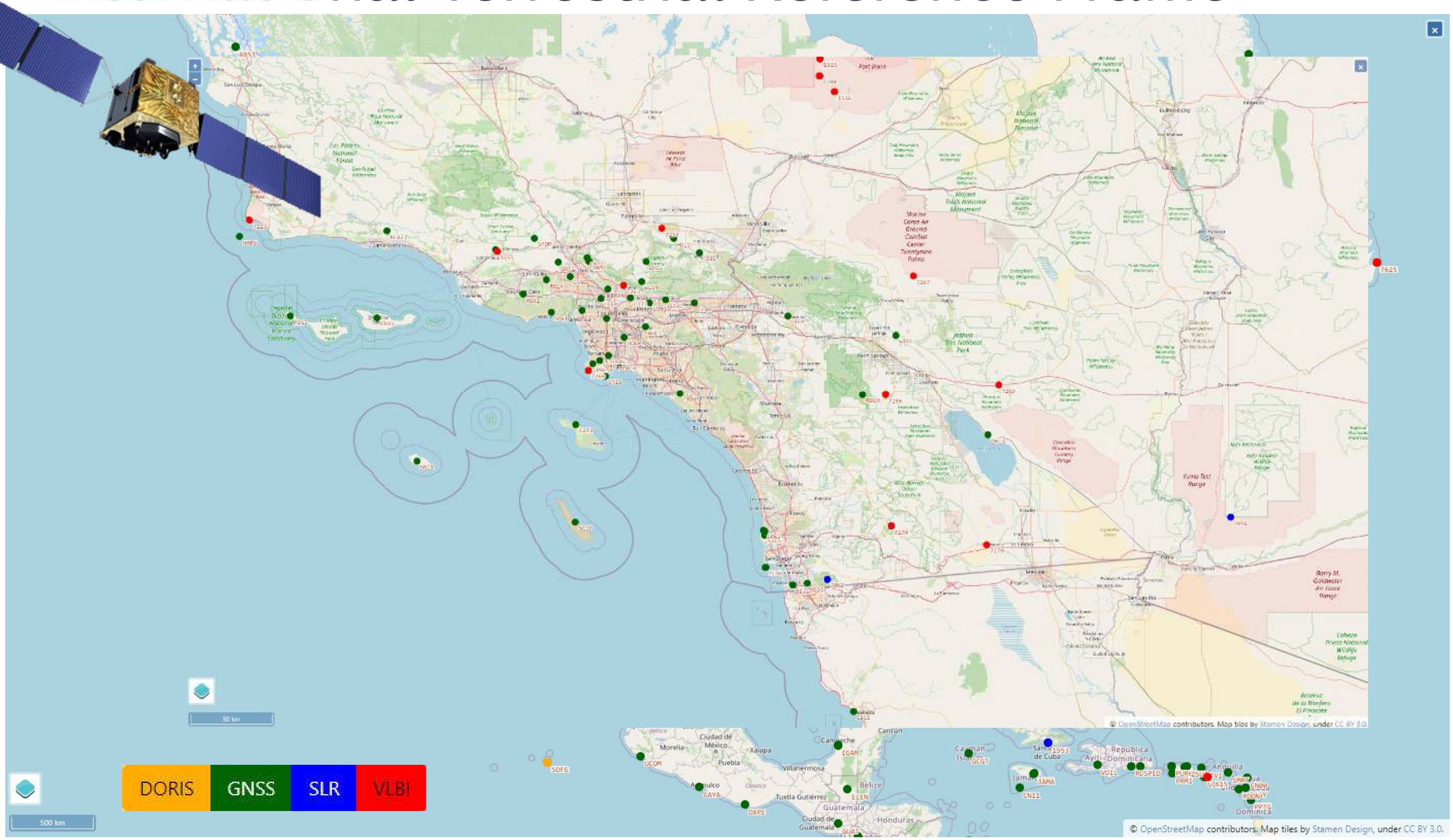
Orientation within Inertial Celestial Space



2016 NASA-JPL Study Changing
Mass Distribution

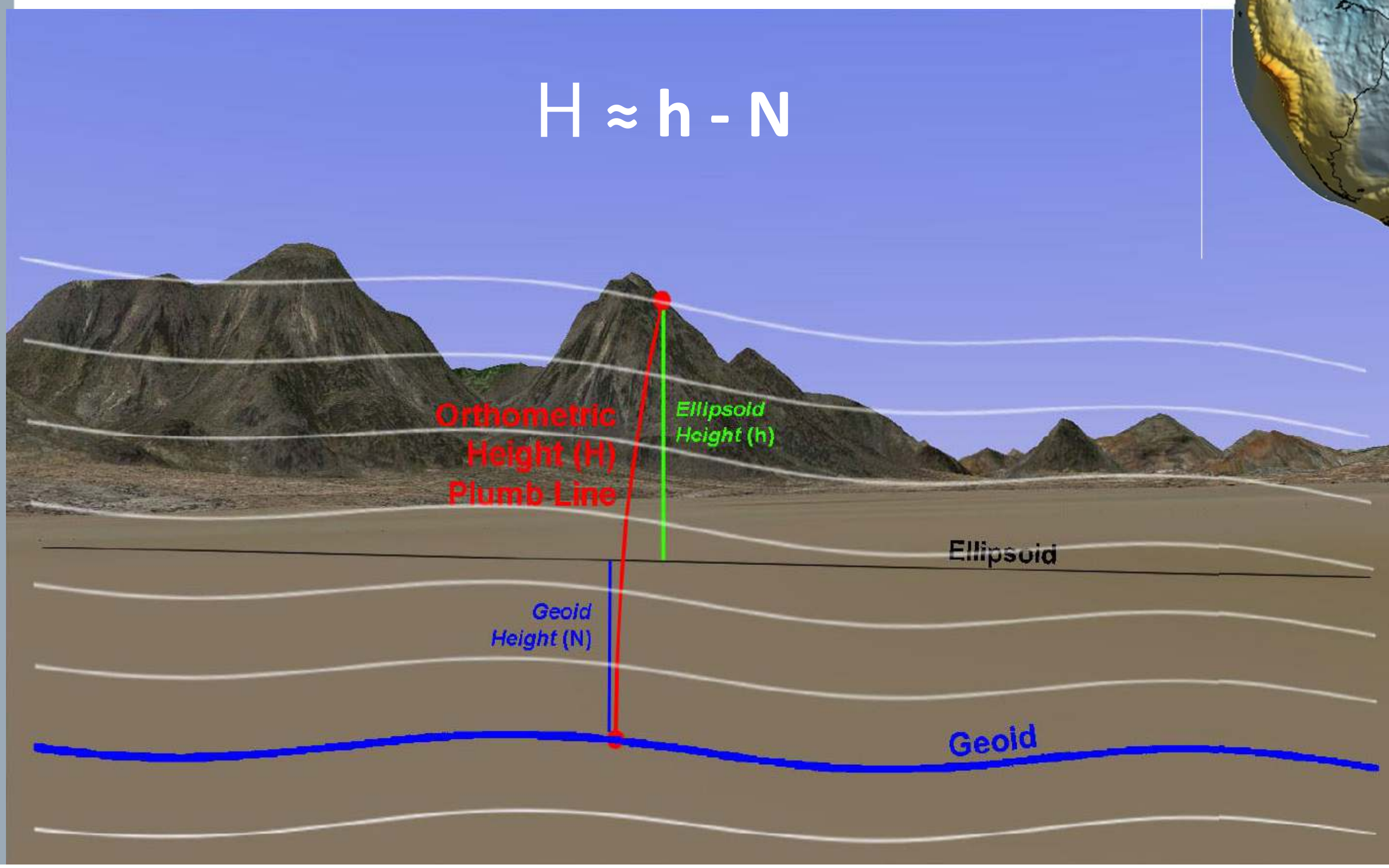


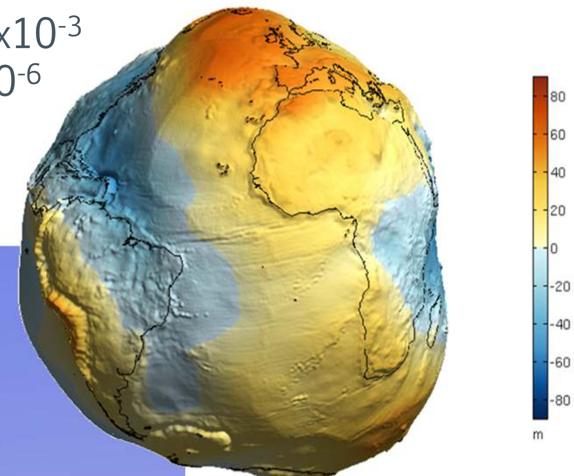
International Terrestrial Reference Frame



Force and Potential

Strong Nuclear = 1
Electromagnetic = $7x10^{-3}$
Weak Nuclear = $1x10^{-6}$
Gravity = $6x10^{-39}$



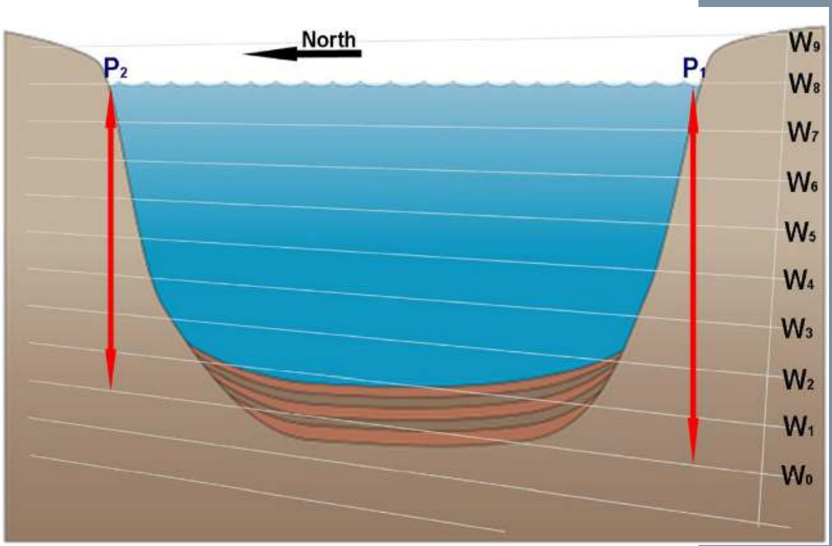


Geoid Definition
Equipotential Surface
not Equal Gravity
Work ~ Energy

NAPG2022
Zero Elevation W_0 =
62,636,856.00 m^2/s^2

IAG GGOS
62,636,853.4 m^2/s^2

Orthometric Height Conundrum

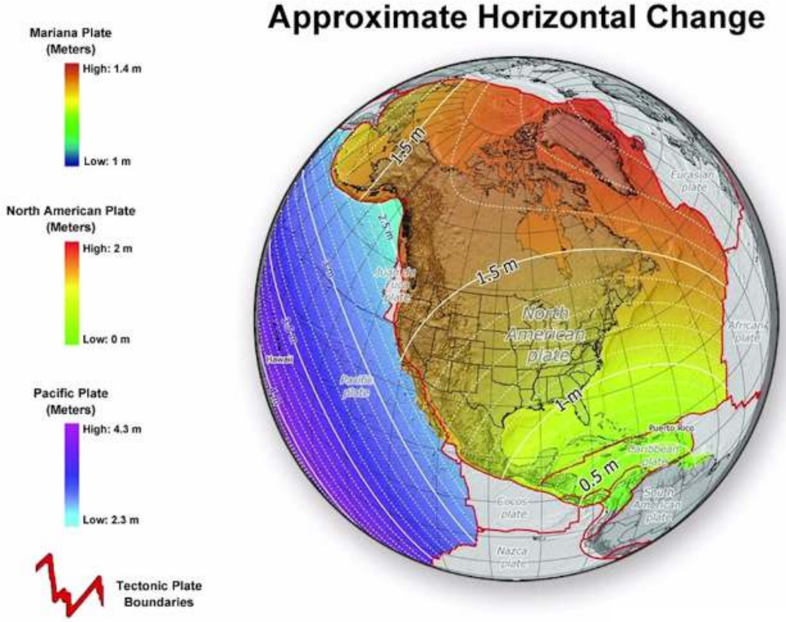


The lines W_i are equipotential surfaces with W_0 being the geoid or datum surface. The orthometric height at Points P_1 and P_2 are the distances along the plumb line between W_0 the datum and W_8 the equipotential surface of the lake, and are properly computed by the formula:

$H_1 = (W_8 - W_0) / g'_1$
$H_2 = (W_8 - W_0) / g'_2$
Where g'_i = the mean gravity along the respective plumb line

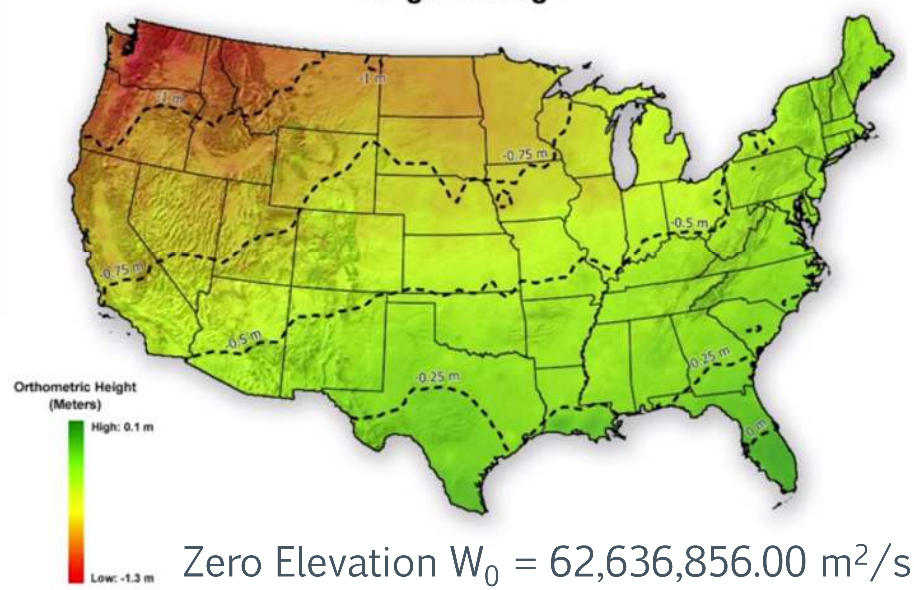
Since equipotential surfaces converge to the north in the northern hemisphere, due to the decrease in centrifugal force, $H_1 > H_2$.

North American Terrestrial Reference Frame of 2022



ITRF20, Epoch 2020.00

North American-Pacific Geopotential Datum of 2022 (NAPGD2022)



Zero Elevation $W_0 = 62,636,856.00\ m^2/s^2$

NSRS Modernization Delay

Operational, workforce retention and other issues have delayed NSRS Modernization

SPCS2022 zones will be finalized in 2024 but will not be rolled out until all of the NSRS is modernized.

Beta rollout planned for 2025, full rollout in 2026

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

Credit: Brian Shaw, NGS 2024-05-21

Why Modernize the NSRS

Current models built on old technology

- NAD 83 not truly Geocentric (~2.2m)
- NAVD 88 relies on marks in the ground and is not easily maintained
- Today's technology needs better accuracy

Credit: Brian Shaw, NGS 2024-05-21

Main Benefits of Modernized NSRS

Fast, Accurate, Consistent Elevations Everywhere

Improved Public Safety

- Flood Plain Maps
- Emergency Route Planning

Accurate Positioning

- Autonomous vehicles, BIMs, Smart Cities

Credit: Brian Shaw, NGS 2024-05-21

Best ways to determine coordinates in Modernized NSRS

1. **Resurvey**: Return to the field and collect new observations, relying upon geodetic control that has coordinates in the new datum
2. **Readjust**: Using existing observations, re-compute new coordinates based upon geodetic control (CORS) that has been defined in the new datum
3. **Transform**: Take finished products which have coordinates in the old datum and use transformation software to estimate coordinates in the new datum

Credit: Brian Shaw, NGS 2024-05-21

Preparing for the Modernized NSRS

1. For all control points and checkpoints, store the raw observation data files (for example, RINEX observation files), so that they can be reprocessed later relative to the modernized NSRS
2. For all data deliverables (and possibly important intermediate products), store versions with geodetic coordinates (latitudes, longitudes, and ellipsoid heights) relative to the current NSRS (e.g., NAD 83(2011) epoch 2010.00), even if the project deliverables call for, say, SPCS83 northings, eastings, and NAVD88 heights.
3. Ensure that all metadata for all archived data (not just final deliverables) is complete and correct with reference frames, coordinate epochs, units, geoid models applied (e.g., GEOID18), and acquisition dates.
4. Document project workflows with particular attention to any coordinate transformations
5. Work with software manufacturers for all steps in your end-to-end project workflow to ensure they are aware of and preparing for NSRS modernization

Credit: Brian Shaw, NGS 2024-05-21

Preparing for the Modernized NSRS

Metadata about the datums and geoid used will be essential.

LiDar – NGS processes everything to the ellipsoid. This enables different geoid models to be applied and will make it easier to transform products to the Modernized NSRS rather than from NAVD88.

GCPs – if you keep the original occupations you can process them in the Modernized NSRS and then align the data into the new system.

Credit: Brian Shaw, NGS 2024-05-21

The Future Reference Frames

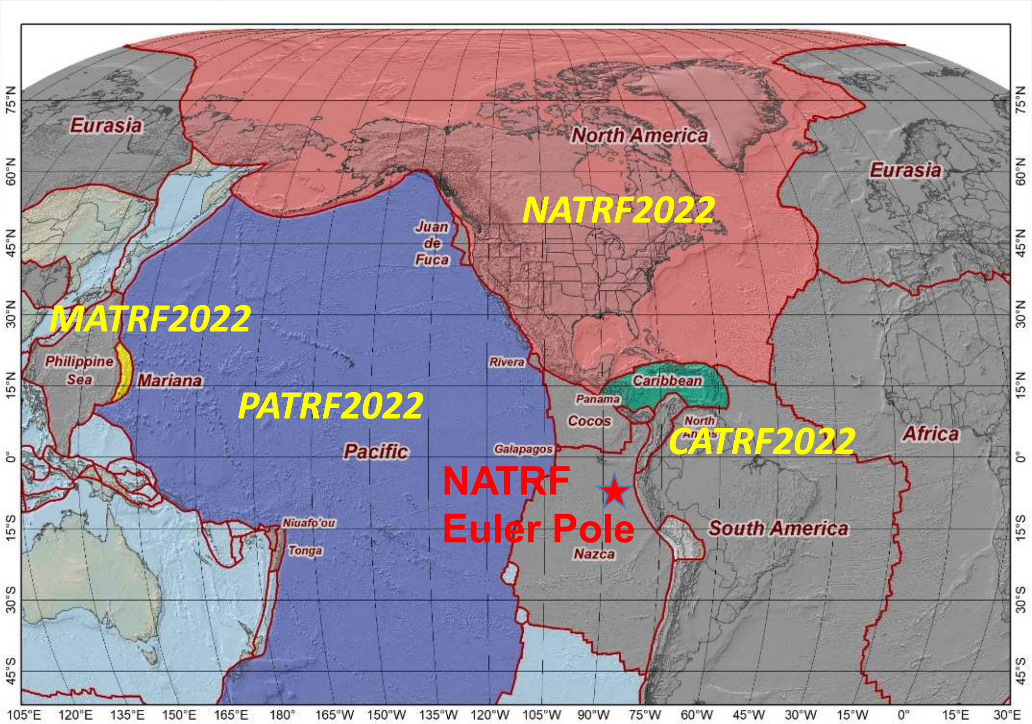
Tectonic Plate based

Each Plate is based on the same densified ITRF model

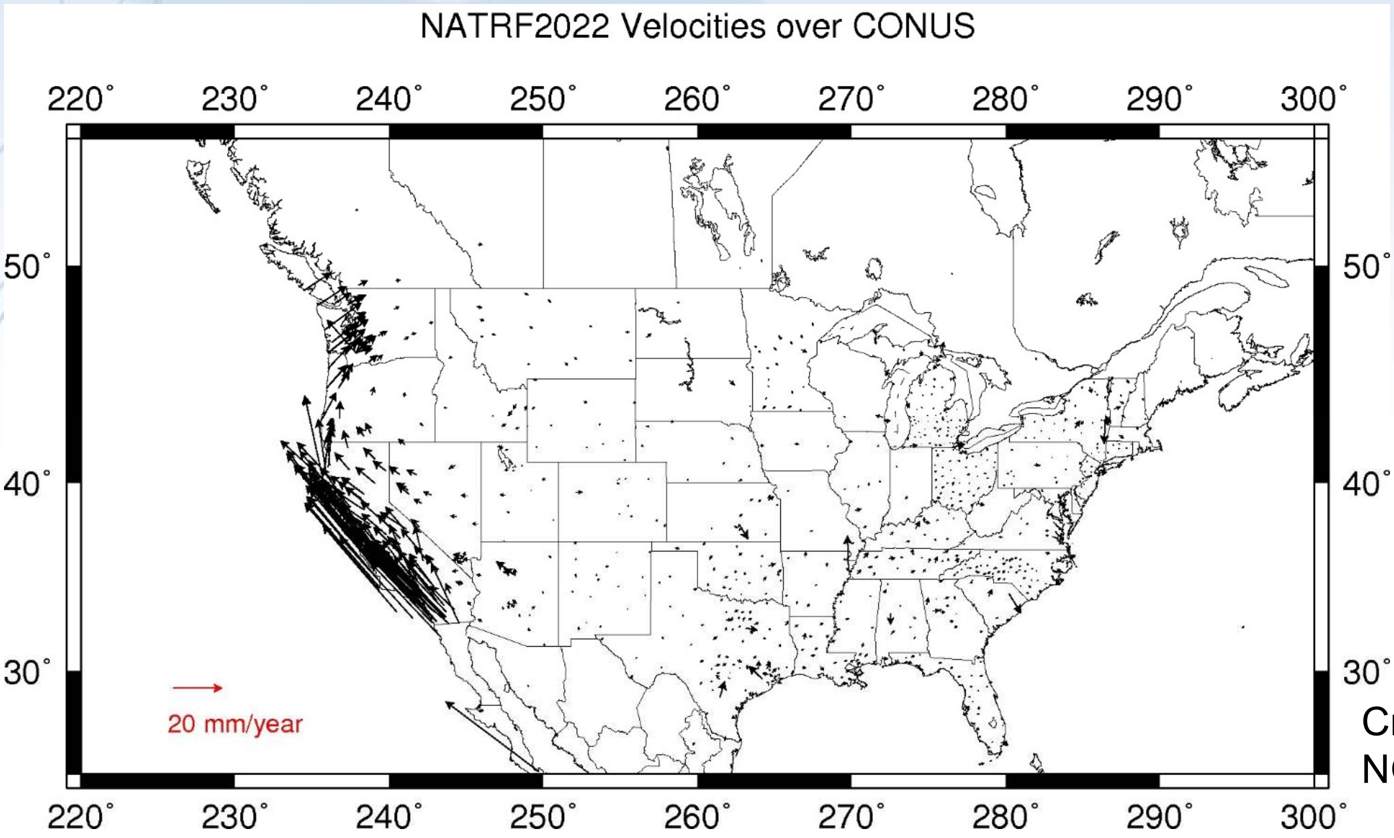
North America	NATRF
Caribbean	CATRF
Pacific	PATRF
Mariana	MATRF

Credit: Brian Shaw, NGS 2024-05-21

The tectonic plates "fixed" for the 2022 Terrestrial Reference Frames

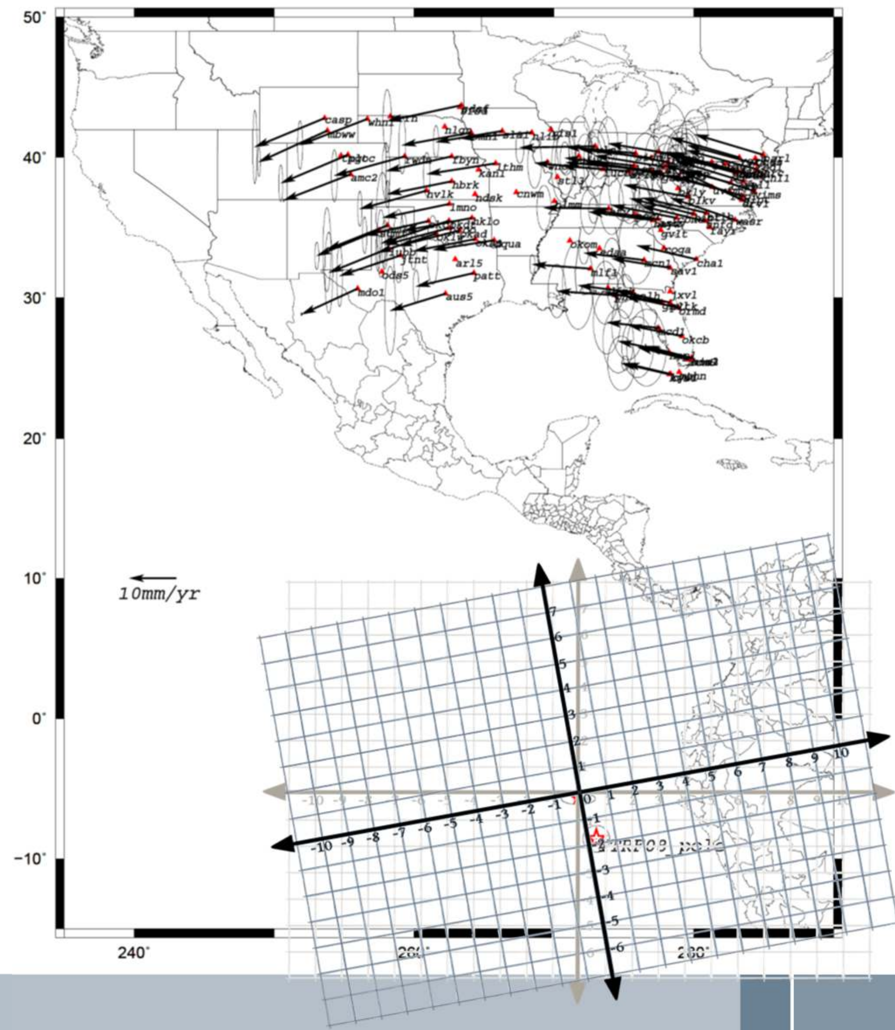


Residual Velocities – NATRF2022/CONUS

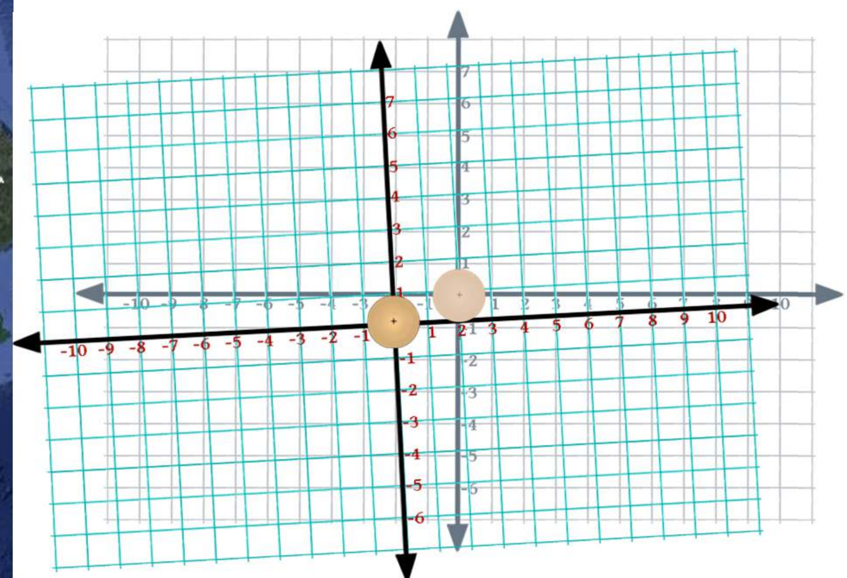


Credit: Keith A. Kohl, NGS 2024-07-30

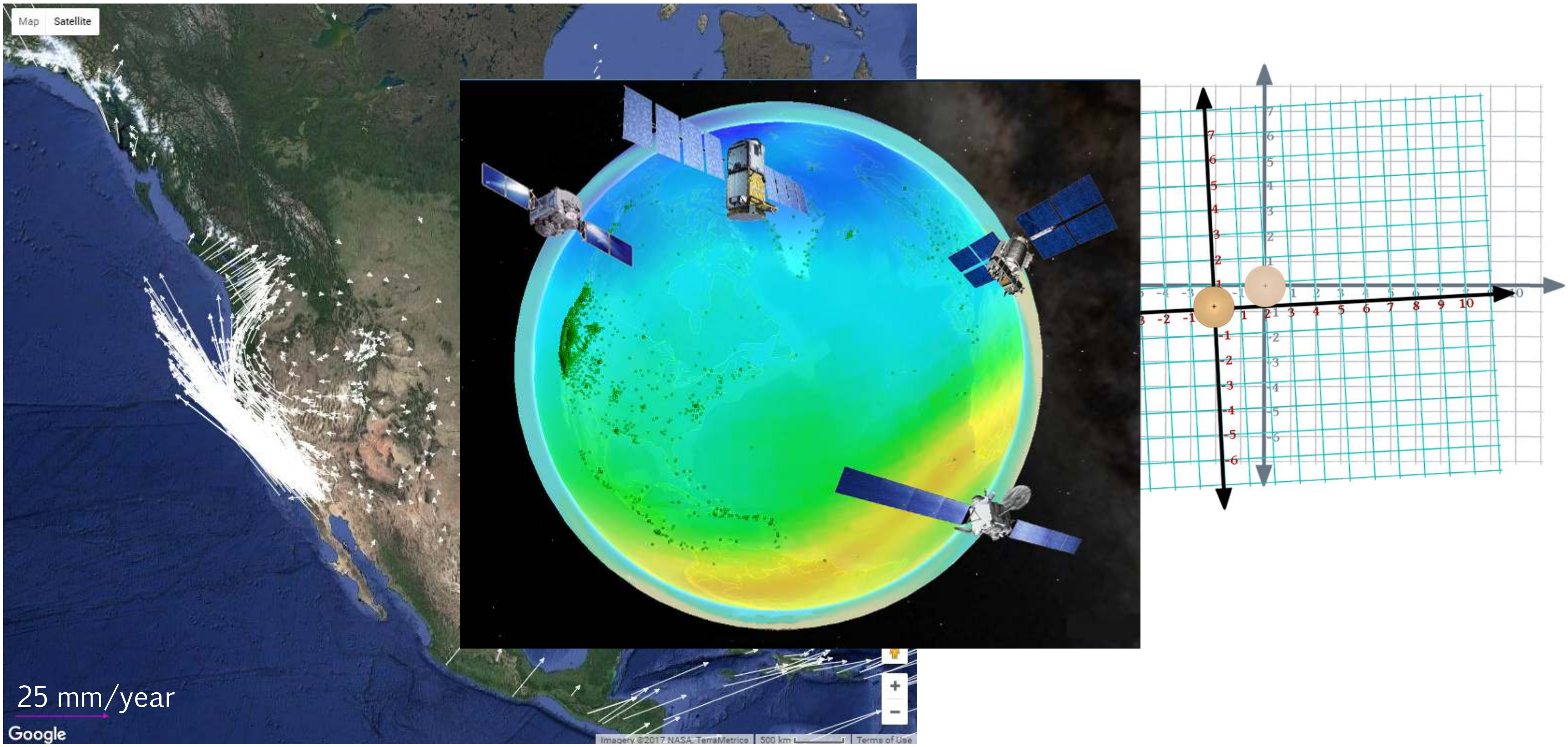
ITRF20 Velocity Field



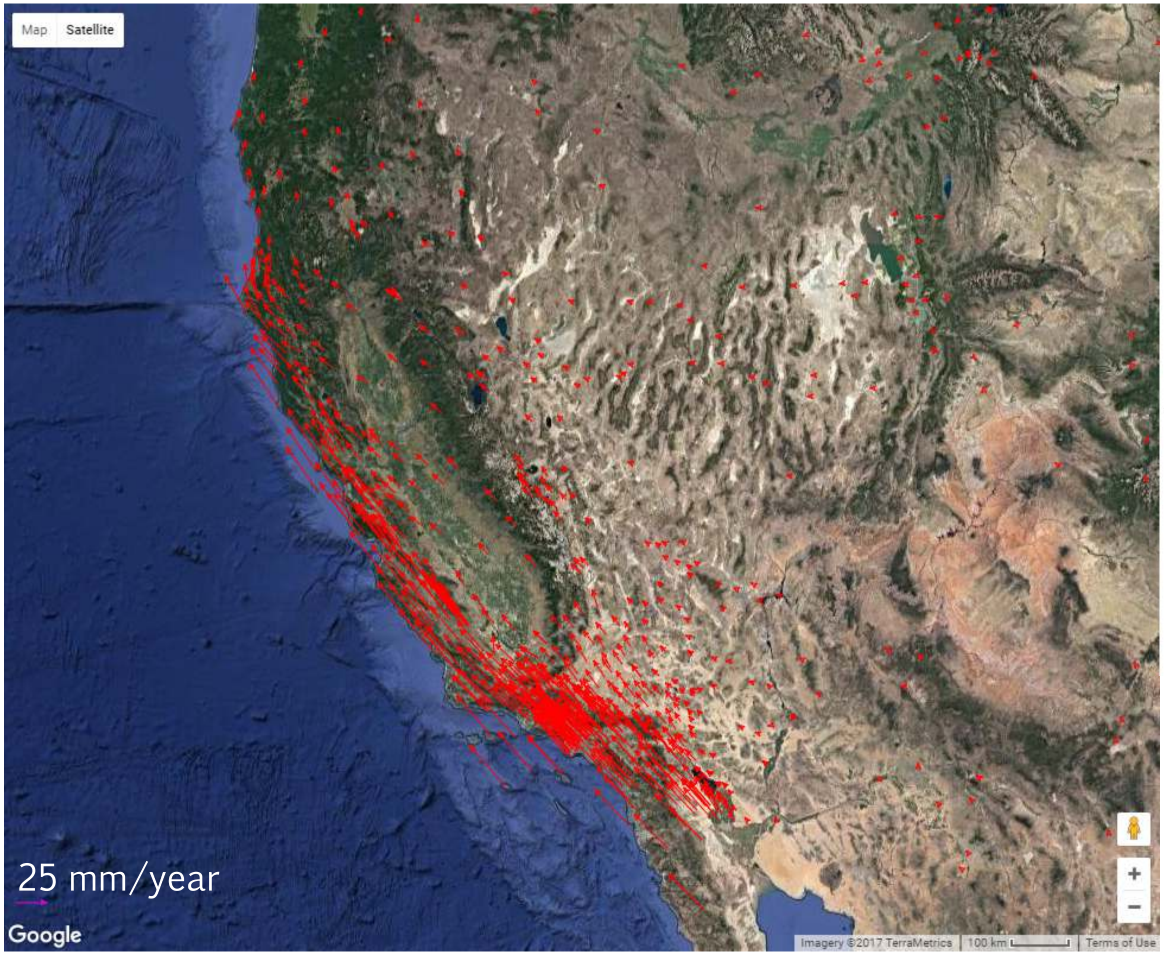
NATRF2022 Residual Velocity Field

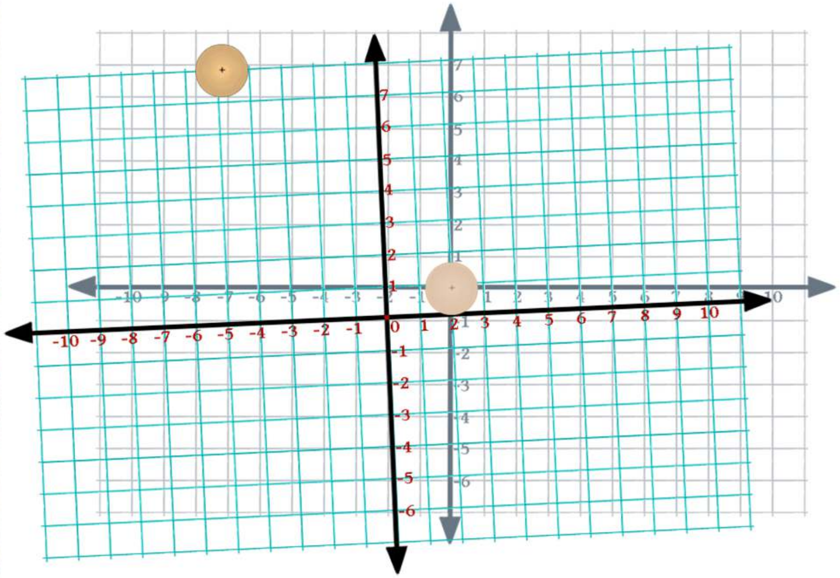


NATRF2022 Residual Velocity Field

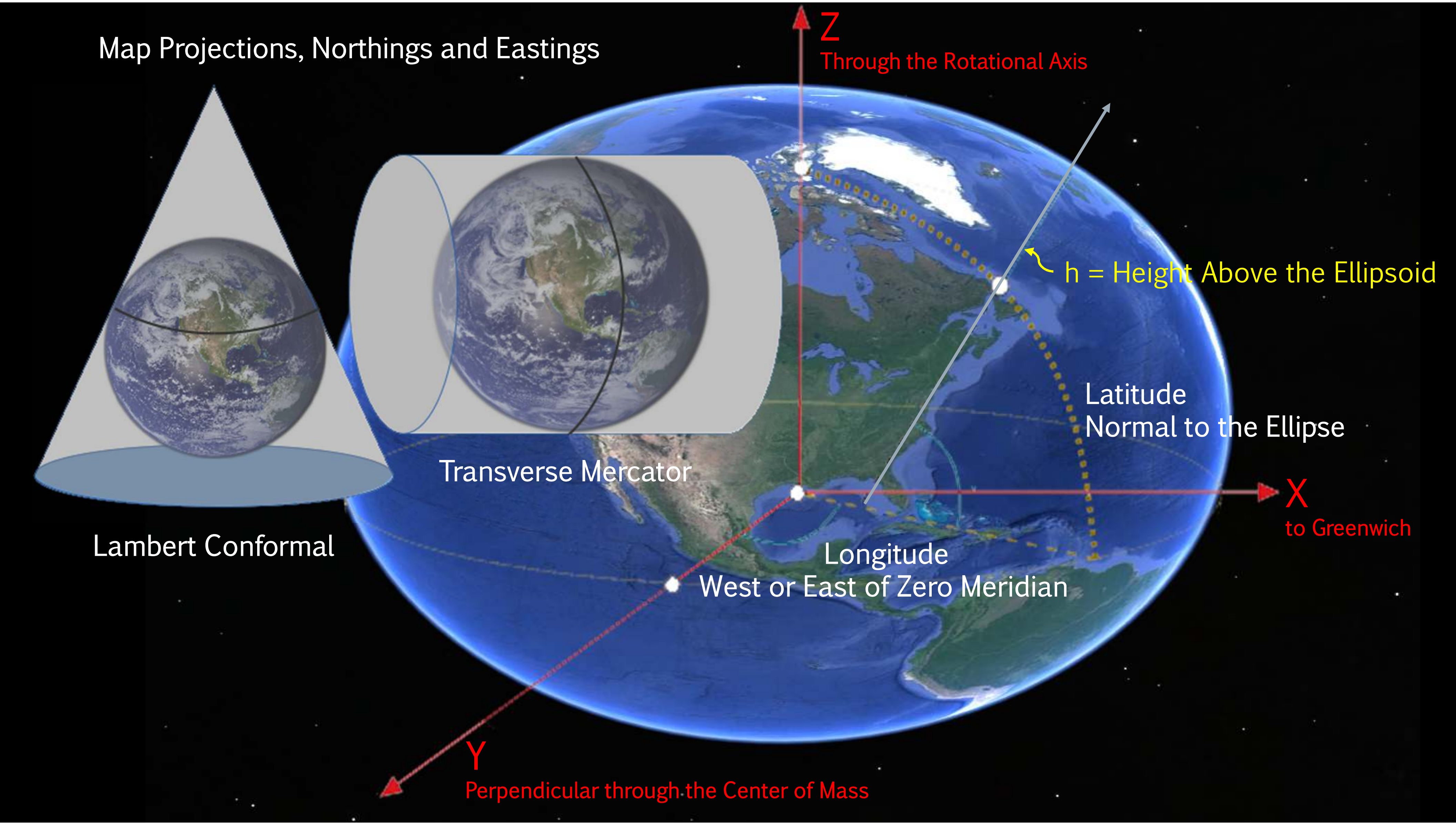


Intra-Plate Deformation Zone



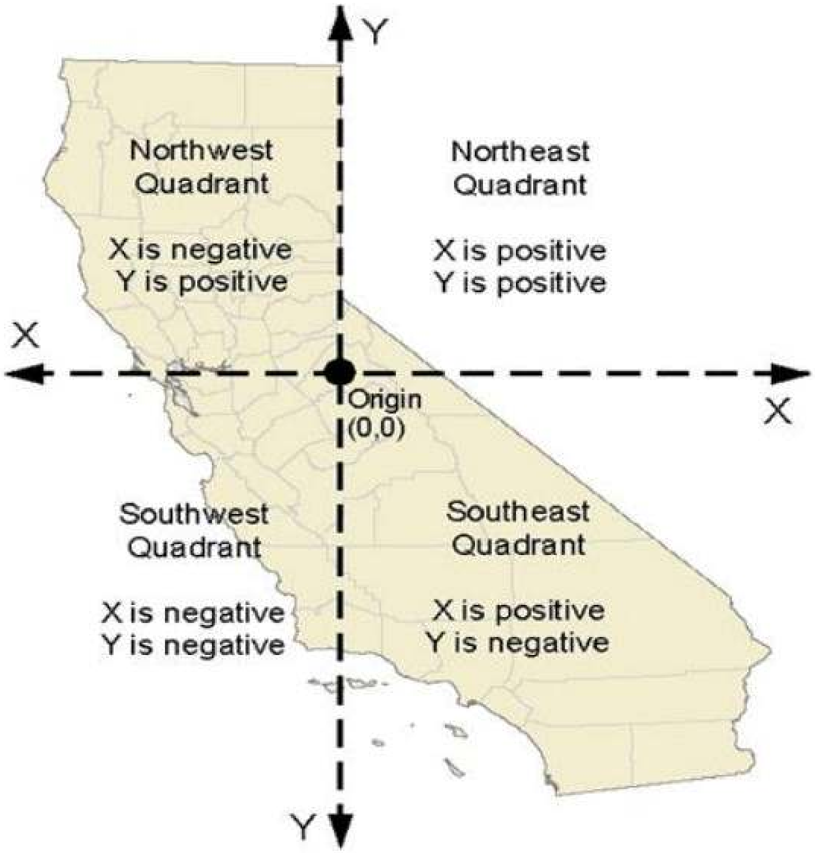


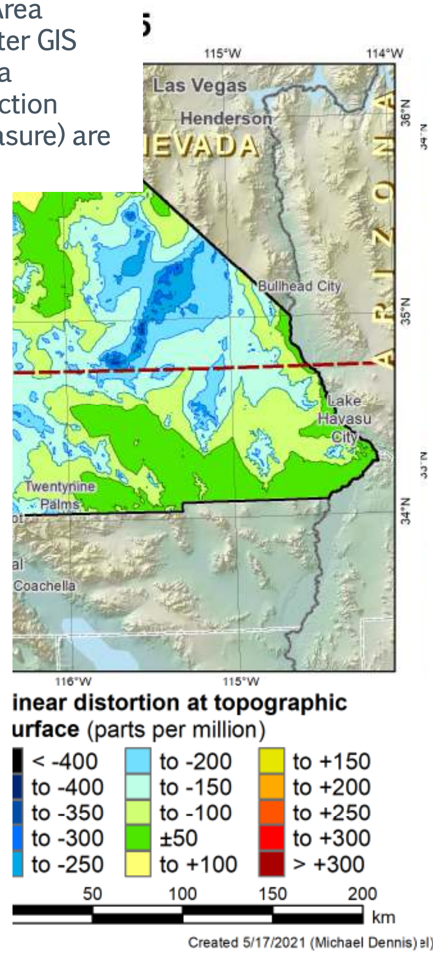
0.5 cm – 5.0 cm per year

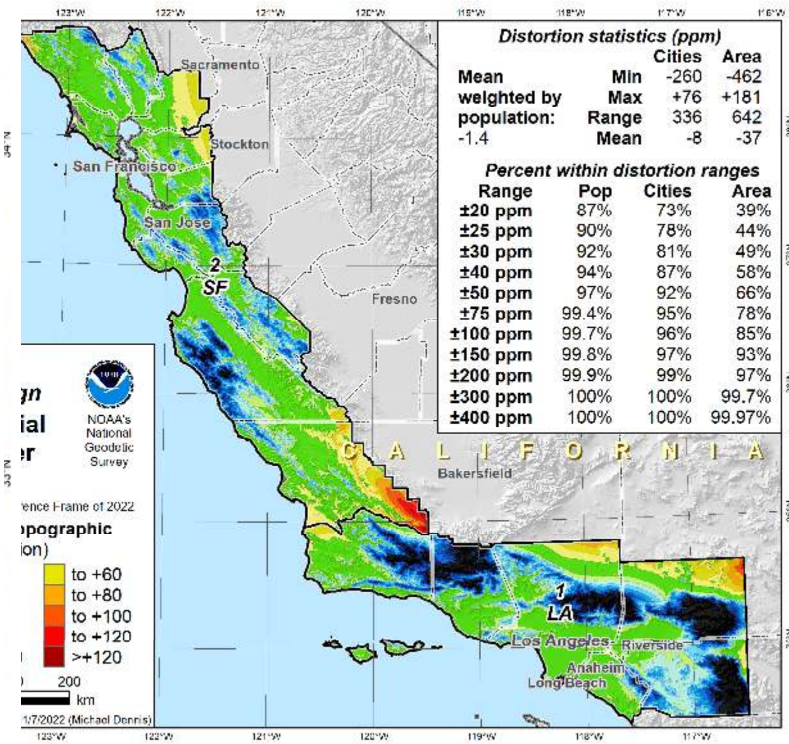

Map Projections, Northings and Eastings
Z
Through the Rotational Axis
h = Height Above the Ellipsoid
Latitude
Normal to the Ellipse
Transverse Mercator
X
to Greenwich
Lambert Conformal
Longitude
West or East of Zero Meridian
Y
Perpendicular through the Center of Mass

New State Plane Coordinate Zones

California (Teale) Albers is an adaptation of the Albers Conical Equal Area projection as defined by the former State of California Teale Data Center GIS Solutions Group. It is a California-specific projection optimized for area calculations, making it popular to map statewide resources. The projection divides California into four quadrants. Coordinate values (units of measure) are in meters from the origin (0, 0) near the center of the state.

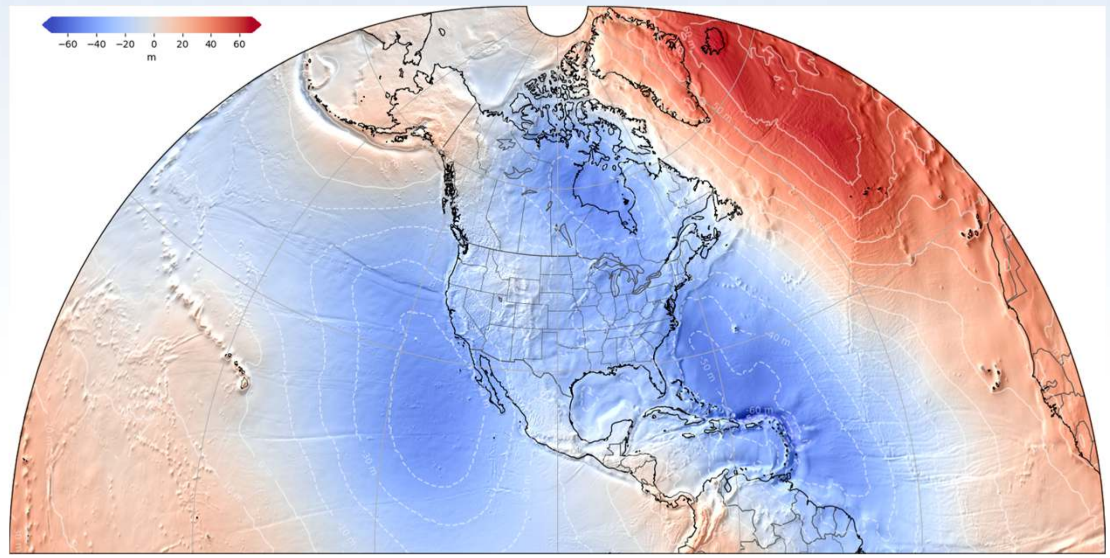






NAPGD2022 Geopotential Datum

- Defined from satellite, airborne, & terrestrial gravity observations, along with satellite altimetry
- Models include:
  - Geopotential
  - Geoid
  - Deflection of Vertical
  - Gravity
- Primary access to datum will be via GNSS
- Unified datum for off-shore, near-shore & on-shore
- Consistent access to the same datum for all US and territories



Geoid undulations from the alpha GEOID2022 model

https://alpha.ngs.noaa.gov/GEOID2022/

Credit: Keith A. Kohl, NGS 2024-07-30

Why Modernize? NAVD 88 and Heights

	The Old:	The New:
Orthometric Heights	NAVD 88	The North American-Pacific ***Geopotential Datum*** of 2022 (NAPGD2022)
Normal Orthometric Heights	PRVD 02 VIVD09 ASVD02 NMVD03 GUVD04	Will include:
Dynamic Heights	IGLD 85	DEM2022
Gravity	IGSN71	GRAV2022
Geoid Undulations	GEOID18	GEOID2022
Deflections of the Vertical	DEFLEC18	DEFLEC2022

A HUGE component of this effort is GRAV-D:

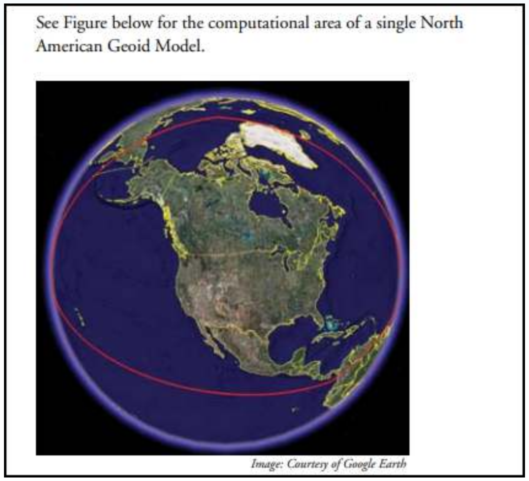
Gravity for the Redefinition of the American Vertical Datum

One Vertical Datum; Pole-to-Equator!

Credit: Keith A. Kohl, NGS 2024-07-30

GRAV-D Improves Gravity Models

- Airborne gravimeter flown at 20,000 feet.
- Measured the Earth's gravity field with sufficient density and accuracy to create a geoid model over ¼ of the Earth
  - Covers the US and *all* its Territories.



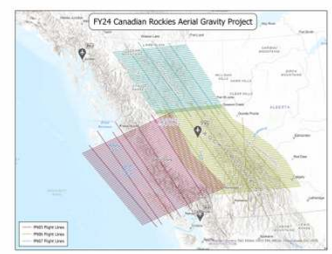
Credit: Keith A. Kohl, NGS 2024-07-30

https://www.ngs.noaa.gov/GRAV-D/pubs/GRAV-D_v2007_12_19.pdf

GRAV-D is Completed Throughout the US

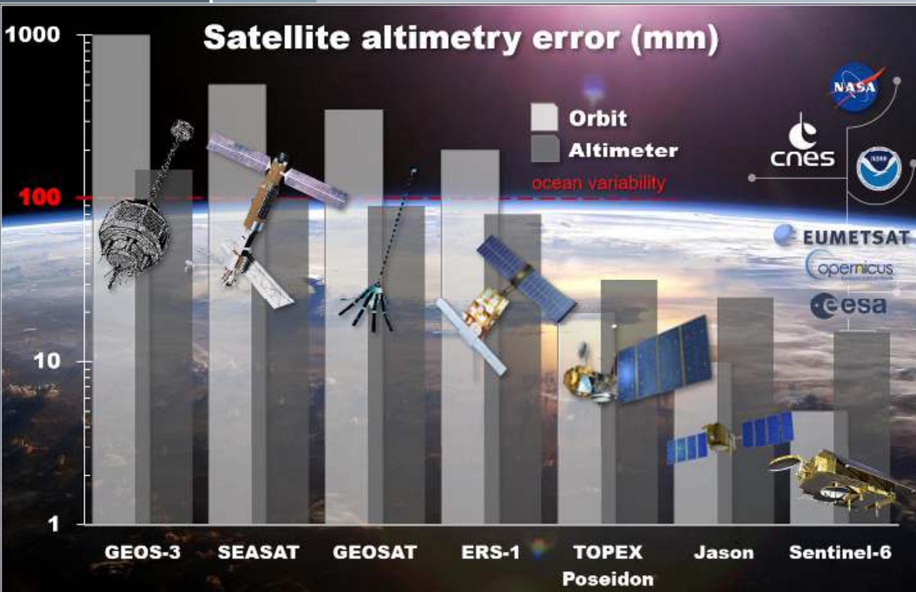
Entire US and all its territories

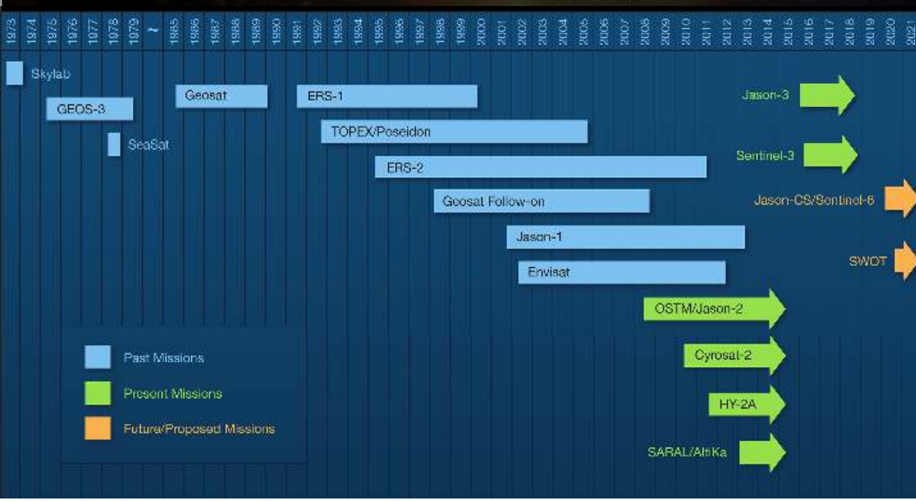
- Total Square Kilometers: 15.6 million
  - That's 3,854,843,950.9 acres
- Critical for NAPGD2022 Development
- ~200 km buffer around territory or shelf break if possible

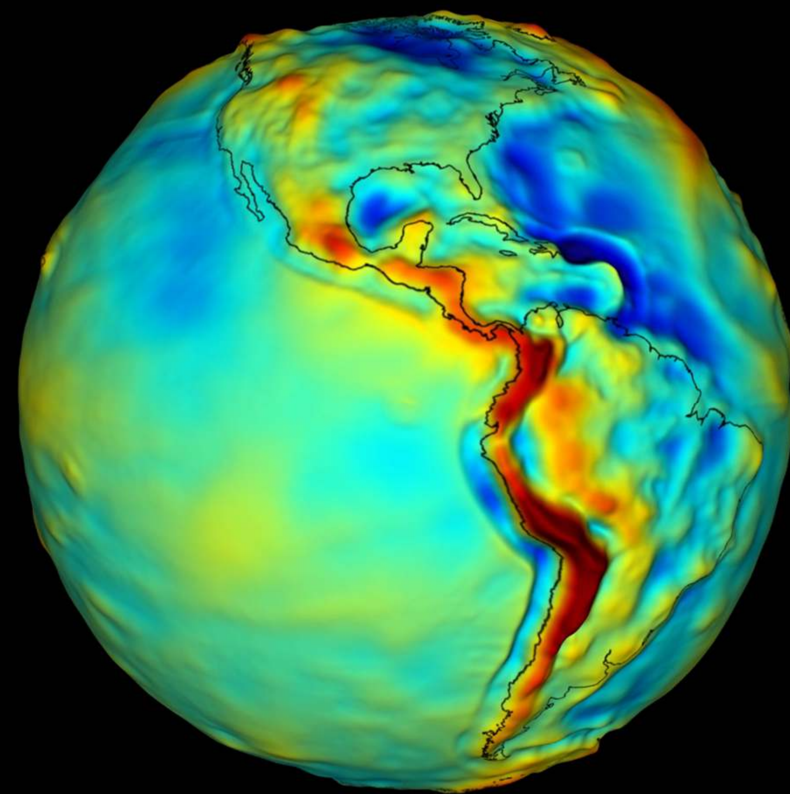


Credit: Keith A. Kohl, NGS 2024-07-30

Satellite Altimetry and Marine Geoid

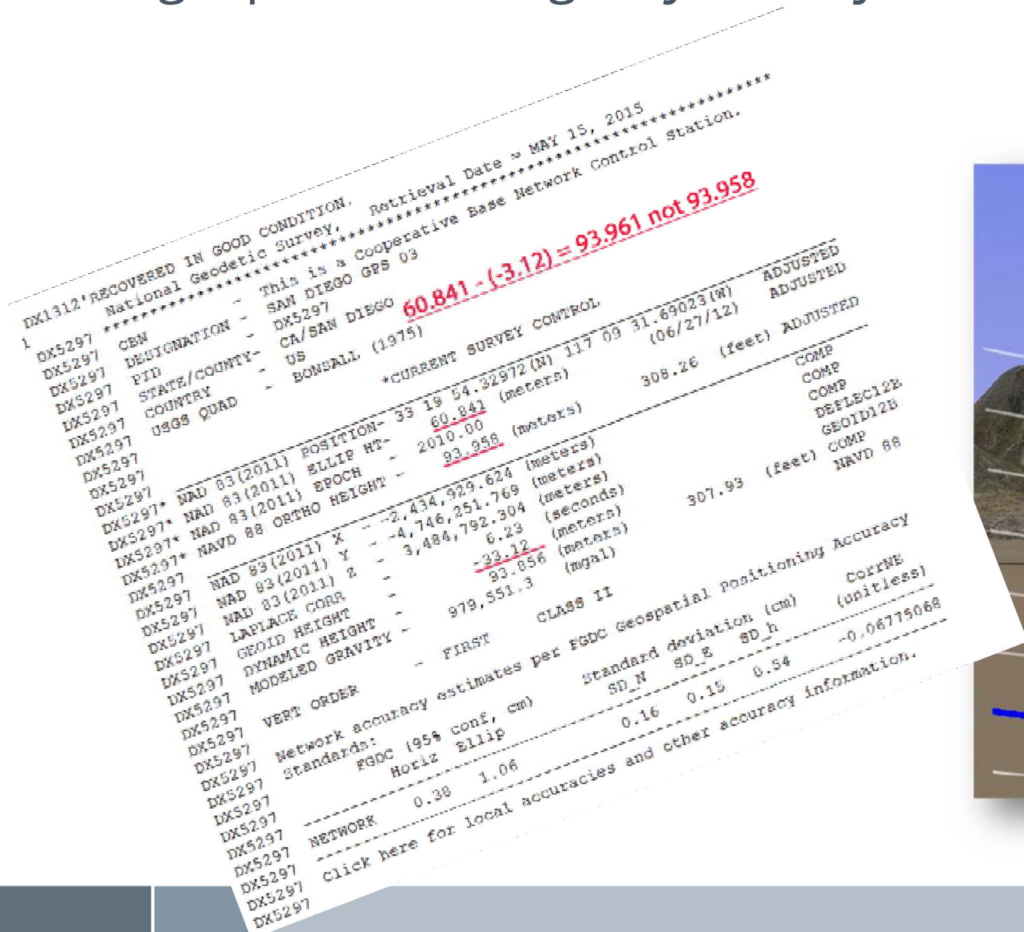


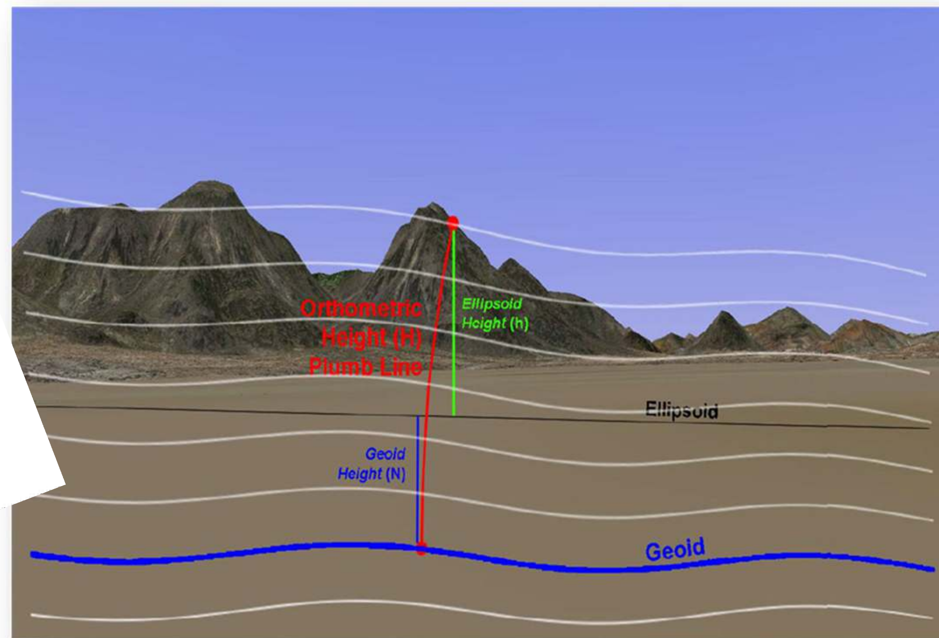




Unified Horizontal and Vertical – NAPGD2022

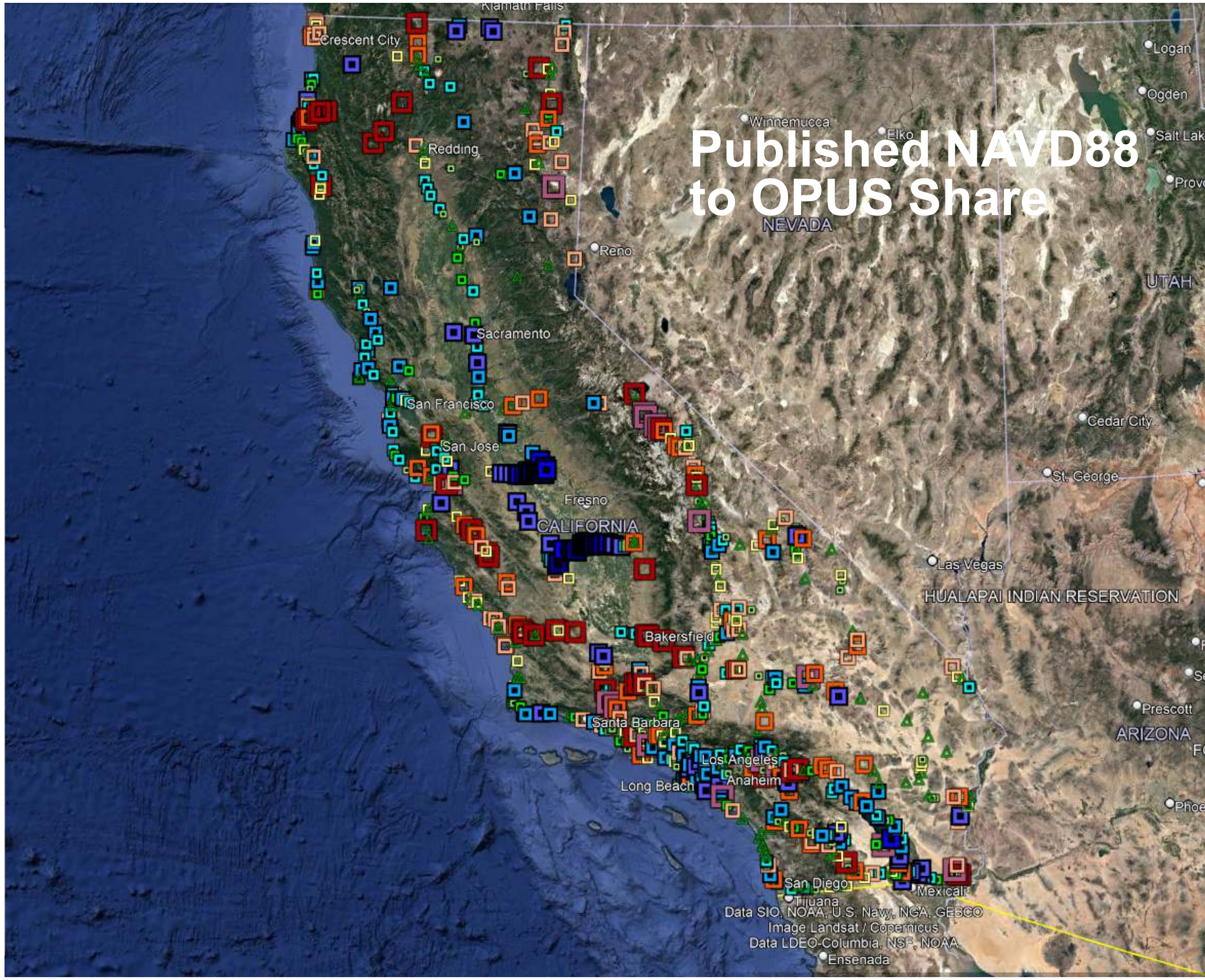
2022 geopotential height system by definition equals ellipsoid height + model(s)

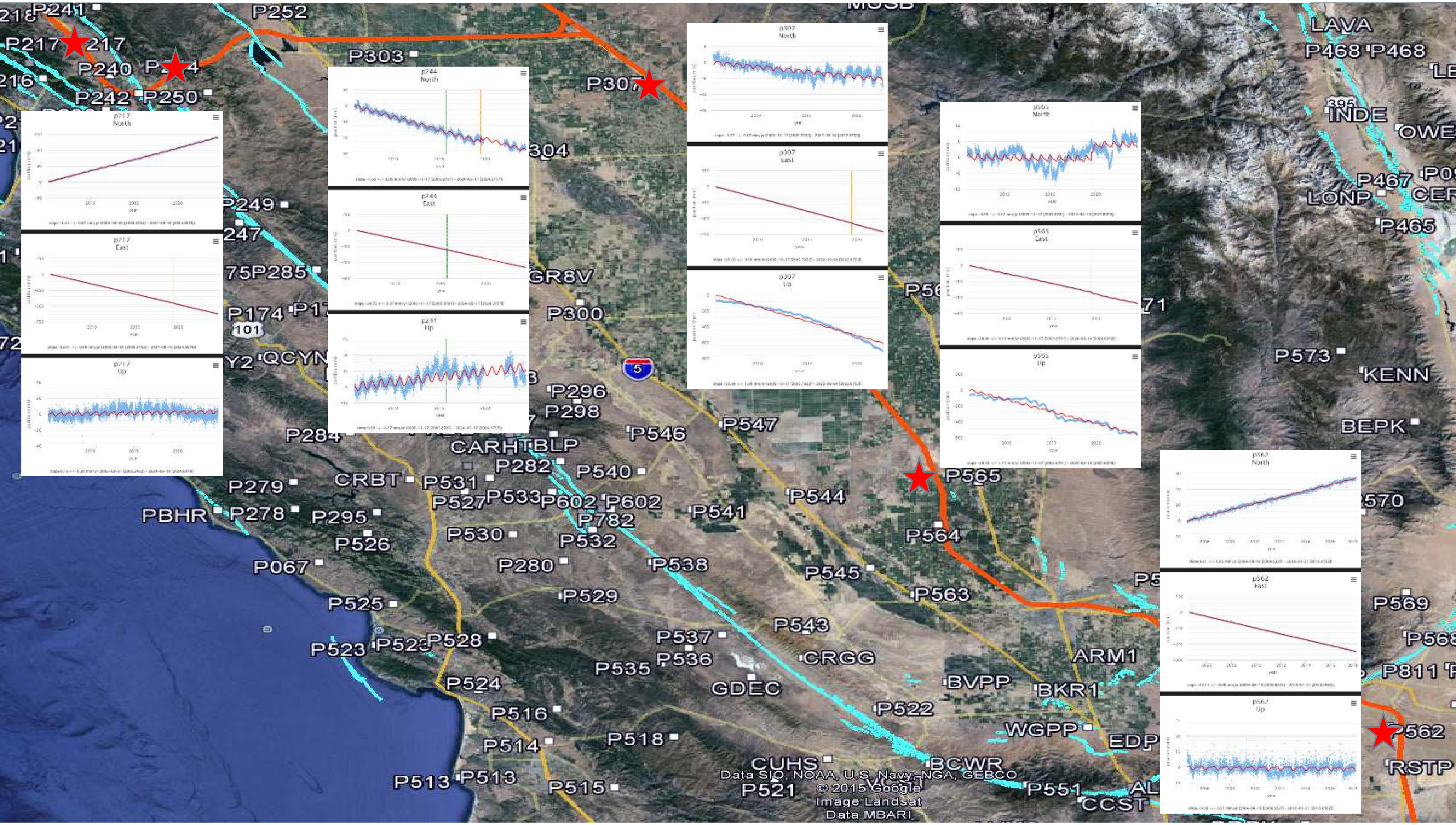

```
DX1312'RECOVERED IN GOOD CONDITION.
 1        National Geodetic Survey,          Retrieval Date = MAY 15, 2015
 DX5297 ***********************************************************************
 DX5297  CBN            -  This is a Cooperative Base Network Control Station.
 DX5297  DESIGNATION    -  SAN DIEGO GPS 03
 DX5297  PID            -  DX5297
 DX5297  STATE/COUNTY-  CA/SAN DIEGO
 DX5297  COUNTRY        -  US
 DX5297  USGS QUAD      -  BONSALL (1975)
 DX5297
 DX5297                         *CURRENT SURVEY CONTROL
 DX5297  ______________________________________________________________________
 DX5297* NAD 83(2011) POSITION- 33 19 54.32972(N) 117 09 31.69023(W)   ADJUSTED
 DX5297* NAD 83(2011) ELLIP HT-    60.841  (meters)        (06/27/12)   ADJUSTED
 DX5297* NAD 83(2011) EPOCH   -  2010.00
 DX5297* NAVD 88 ORTHO HEIGHT -    93.958  (meters)     308.26  (feet) ADJUSTED
 DX5297  ______________________________________________________________________
 DX5297  NAD 83(2011) X  -  -2,434,929.624 (meters)                    COMP
 DX5297  NAD 83(2011) Y  -  -4,746,251.769 (meters)                    COMP
 DX5297  NAD 83(2011) Z  -   3,484,792.304 (meters)                    COMP
 DX5297  LAPLACE CORR    -            6.23  (seconds)                   DEFLEC12B
 DX5297  GEOID HEIGHT    -          -33.12  (meters)                    GEOID12B
 DX5297  DYNAMIC HEIGHT  -          93.856  (meters)    307.93  (feet) COMP
 DX5297  MODELED GRAVITY -       979,551.3  (mgal)                      NAVD 88
 DX5297
 DX5297  VERT ORDER      -  FIRST     CLASS II
 DX5297
 DX5297  Network accuracy estimates per FGDC Geospatial Positioning Accuracy
 DX5297  Standards:
 DX5297         FGDC (95% conf, cm)     Standard deviation (cm)      CorrNE
 DX5297           Horiz  Ellip           SD_N   SD_E   SD_h        (unitless)
 DX5297  -------------------------------------------------------------------
 DX5297  NETWORK   0.38   1.06           0.16   0.15   0.54       -0.06775068
 DX5297  -------------------------------------------------------------------
 DX5297  Click here for local accuracies and other accuracy information.
 DX5297
```

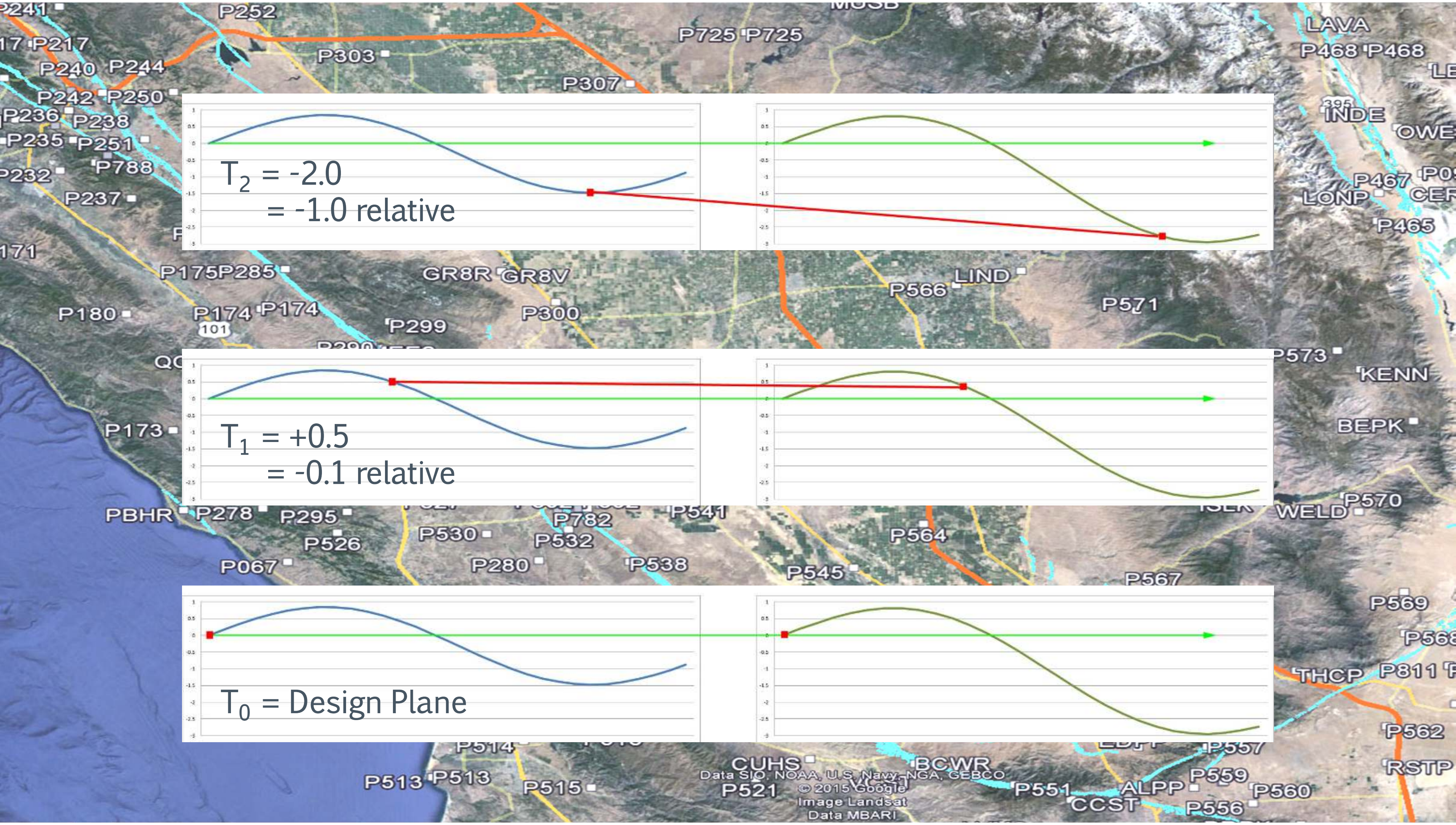
Adjusted NAVD88 to GPS Derived

- -240 to -100 cm
- -90 to -50 cm
- -50 to -10 cm
- -10 to -5 cm
- -5 to -3 cm
- -3 to -2 cm
- -2 to -1 cm
- -1 to +1 cm
- +1 to +2 cm
- +2 to +3 cm
- +3 to +5 cm
- +5 to +10 cm
- +10 to +19 cm

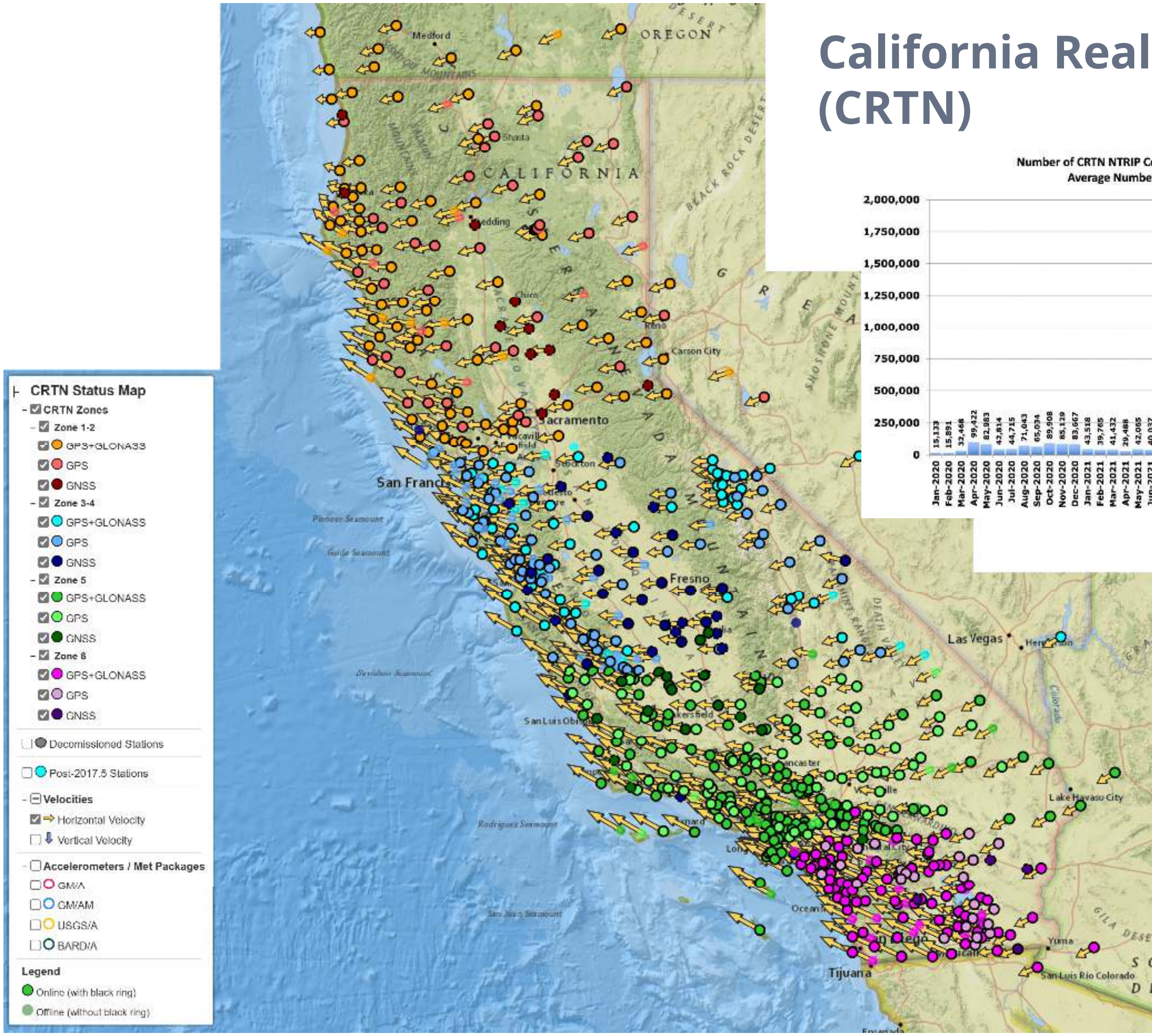


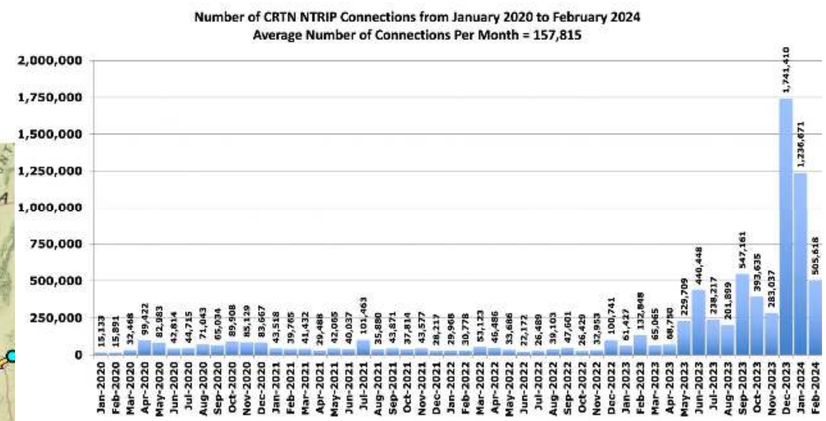


P241
P252
P217
P240
P242
P250
P303
P307
LAVA
P468
P468
INDE
p217 North
p217 East
p217 Up
p244 North
p244 East
p244 Up
p307 North
p307 East
p307 Up
p565 North
p565 East
p565 Up
p562 North
p562 East
p562 Up
P249
P285
GR8V
P300
P174
101
QCYN
5
P296
P298
P546
P547
CARH
TBLP
P284
P282
P540
P279
CRBT
P531
P527
P533
P602
P602
P782
P541
P544
P565
PBHR
P278
P295
P526
P530
P532
P538
P564
P067
P280
P545
P525
P529
P563
P543
P537
P523
P528
CRGG
P535
P536
ARM1
GDEC
P524
BVPP
BKR1
P522
P516
WGPP
P514
P518
CUHS
BCWR
P513
P513
P515
P521
P551
CCST
P467
LONP
P465
P573
KENN
BEPK
P569
P811
P562
RSTP
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2015 Google
Image Landsat
Data MBARI


T2 = -2.0
= -1.0 relative
T1 = +0.5
= -0.1 relative
T0 = Design Plane

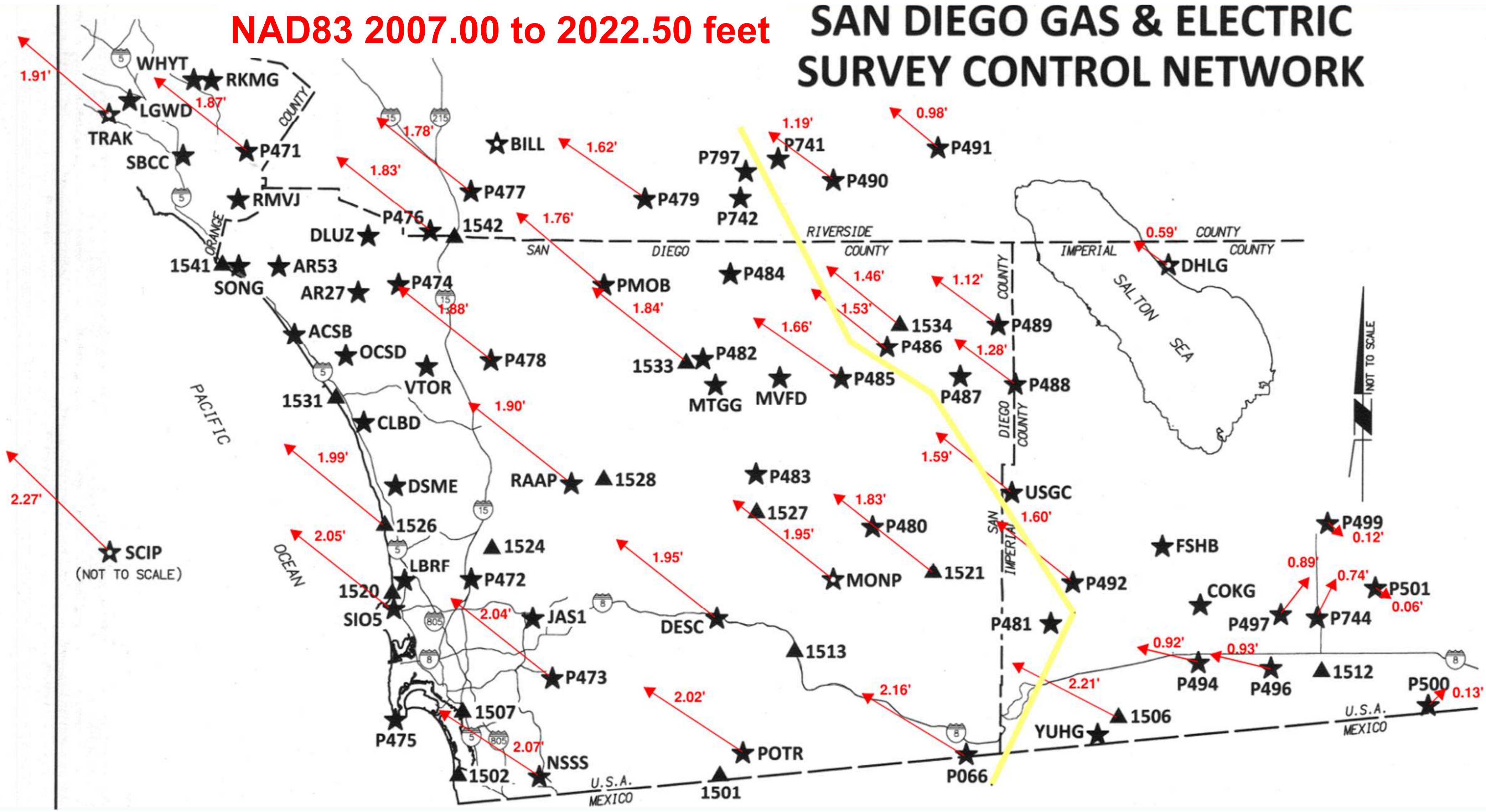
California Real Time Network (CRTN)





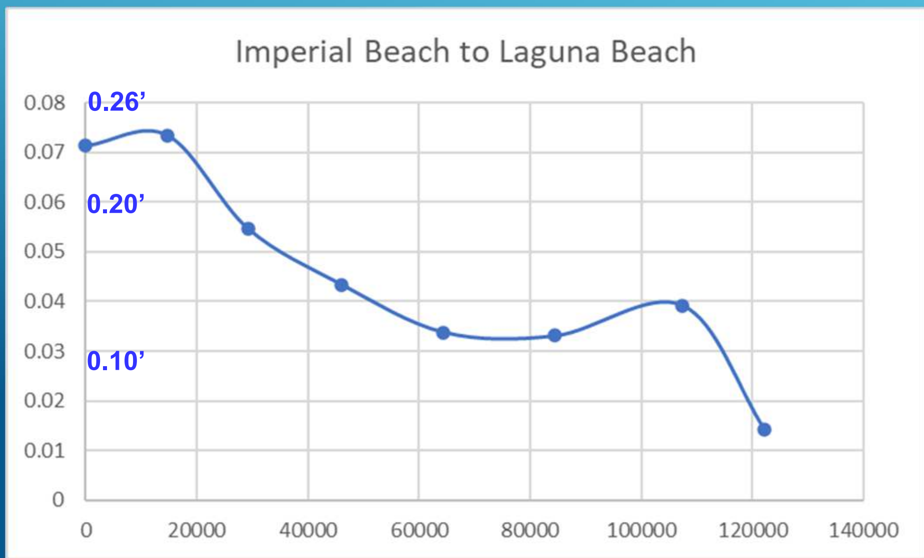
PRC Compliant
CSRN Epoch 2017.50
Single-User Accounts
Consortium Membership

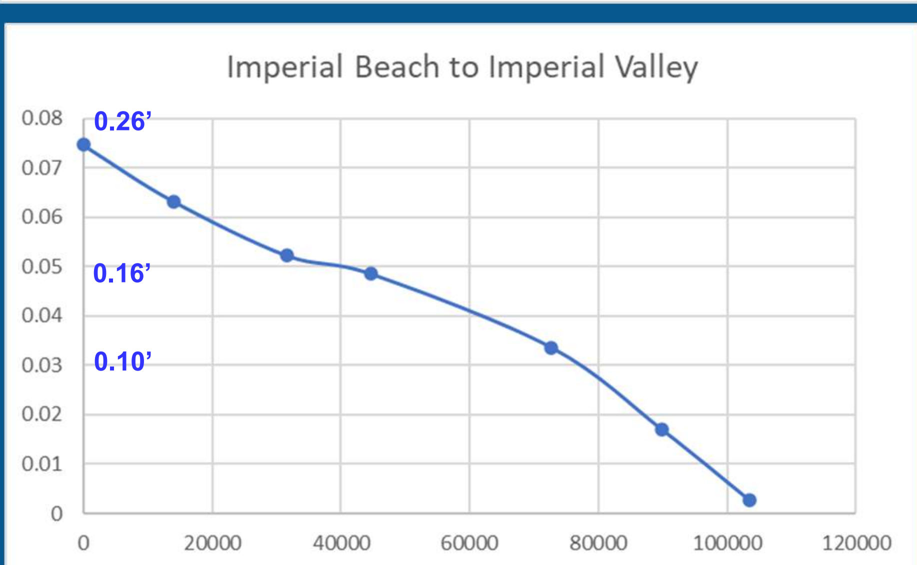
Stay Tuned:
Dynamic Datum Delivery

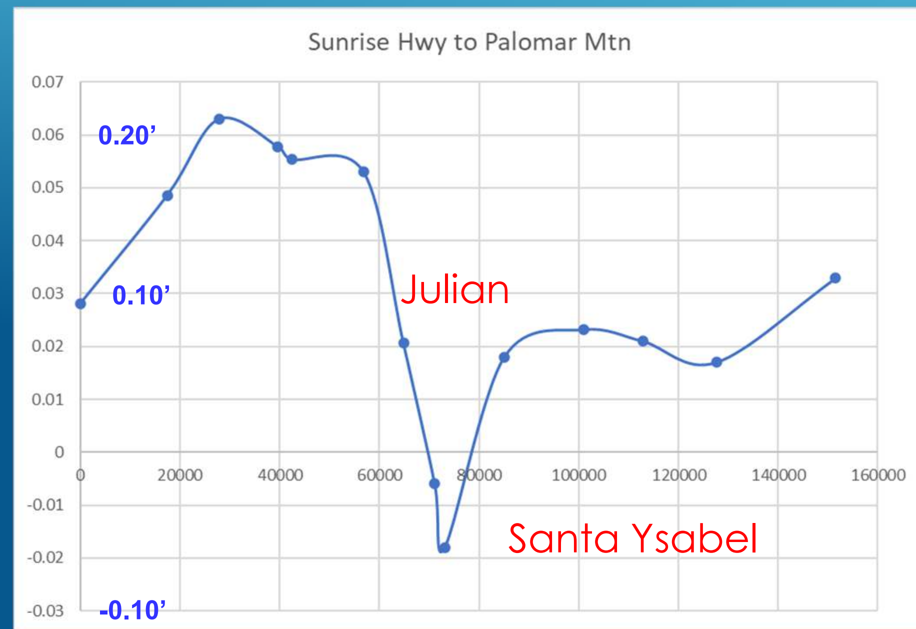

NAD83 2007.00 to 2022.50 feet
SAN DIEGO GAS & ELECTRIC
SURVEY CONTROL NETWORK
WHYT
RKMG
LGWD
TRAK
SBCC
P471
RMVJ
DLUZ
P476
1542
P477
BILL
P479
P797
P741
P490
P491
P742
1541
SONG
AR53
AR27
P474
PMOB
P484
1534
P489
P486
DHLG
ACSB
OCSD
VTOR
P478
1533
P482
MTGG
MVFD
P485
P487
P488
1531
CLBD
PACIFIC
OCEAN
DSME
RAAP
1528
P483
USGC
1526
1527
P480
1524
MONP
1521
P492
FSHB
P499
P501
COKG
P497
P744
SCIP
(NOT TO SCALE)
LBRF
1520
SIO5
P472
JAS1
DESC
1513
P481
P494
P496
1512
P473
1507
P475
NSSS
1502
1501
POTR
P066
YUHG
1506
P500
RIVERSIDE
COUNTY
SAN
DIEGO
IMPERIAL
SALTON
SEA
U.S.A.
MEXICO
NOT TO SCALE
1.91'
1.87'
1.78'
1.83'
1.62'
1.19'
0.98'
1.76'
0.59'
1.46'
1.12'
1.88'
1.84'
1.53'
1.66'
1.28'
1.90'
1.59'
1.99'
2.27'
1.83'
1.60'
2.05'
1.95'
1.95'
0.12'
0.89'
0.74'
0.06'
2.04'
0.92'
0.93'
2.21'
2.02'
2.16'
2.07'
0.13'

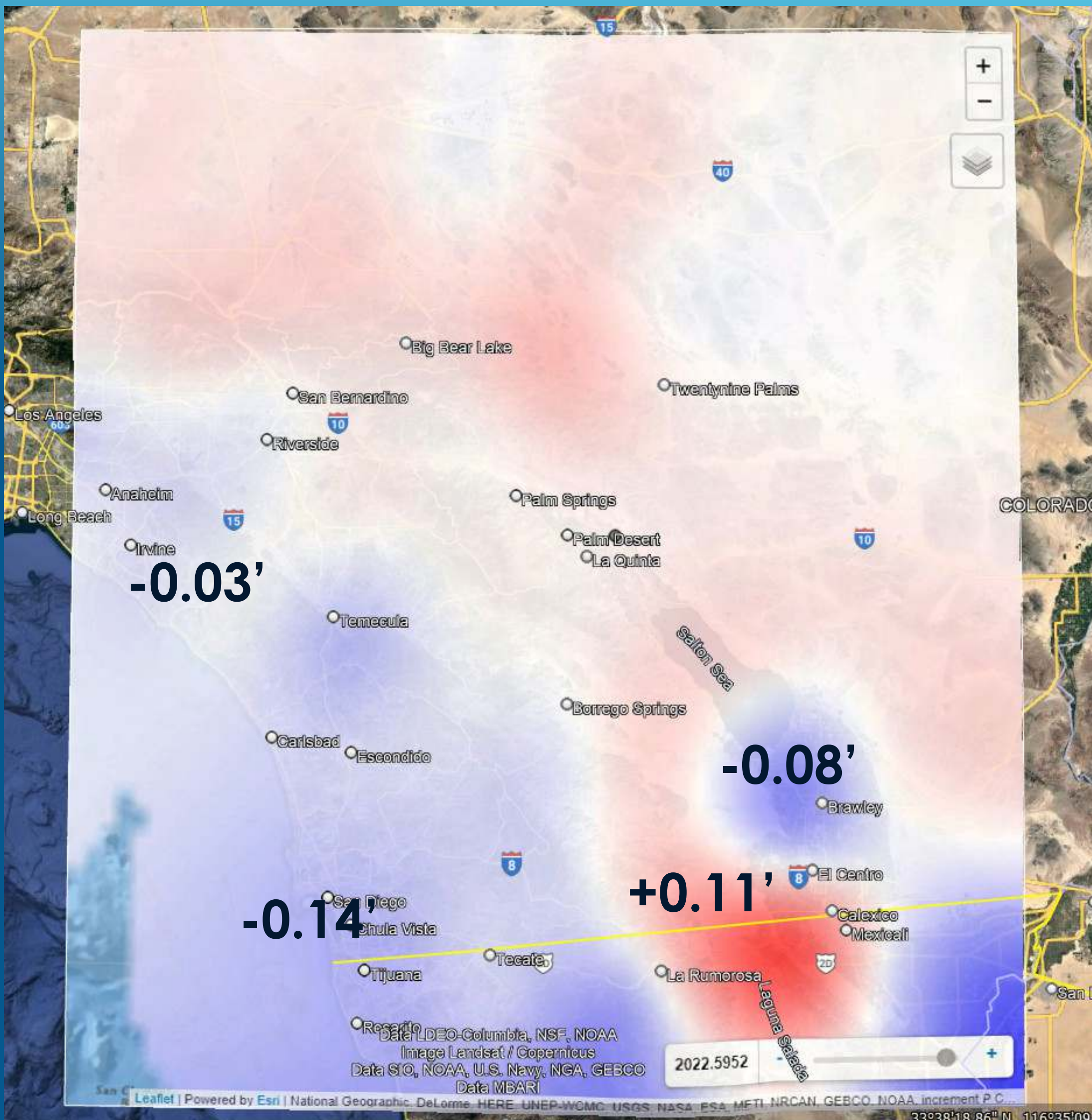
Corrector Surface Cross-Sections (meters)

(Feet)





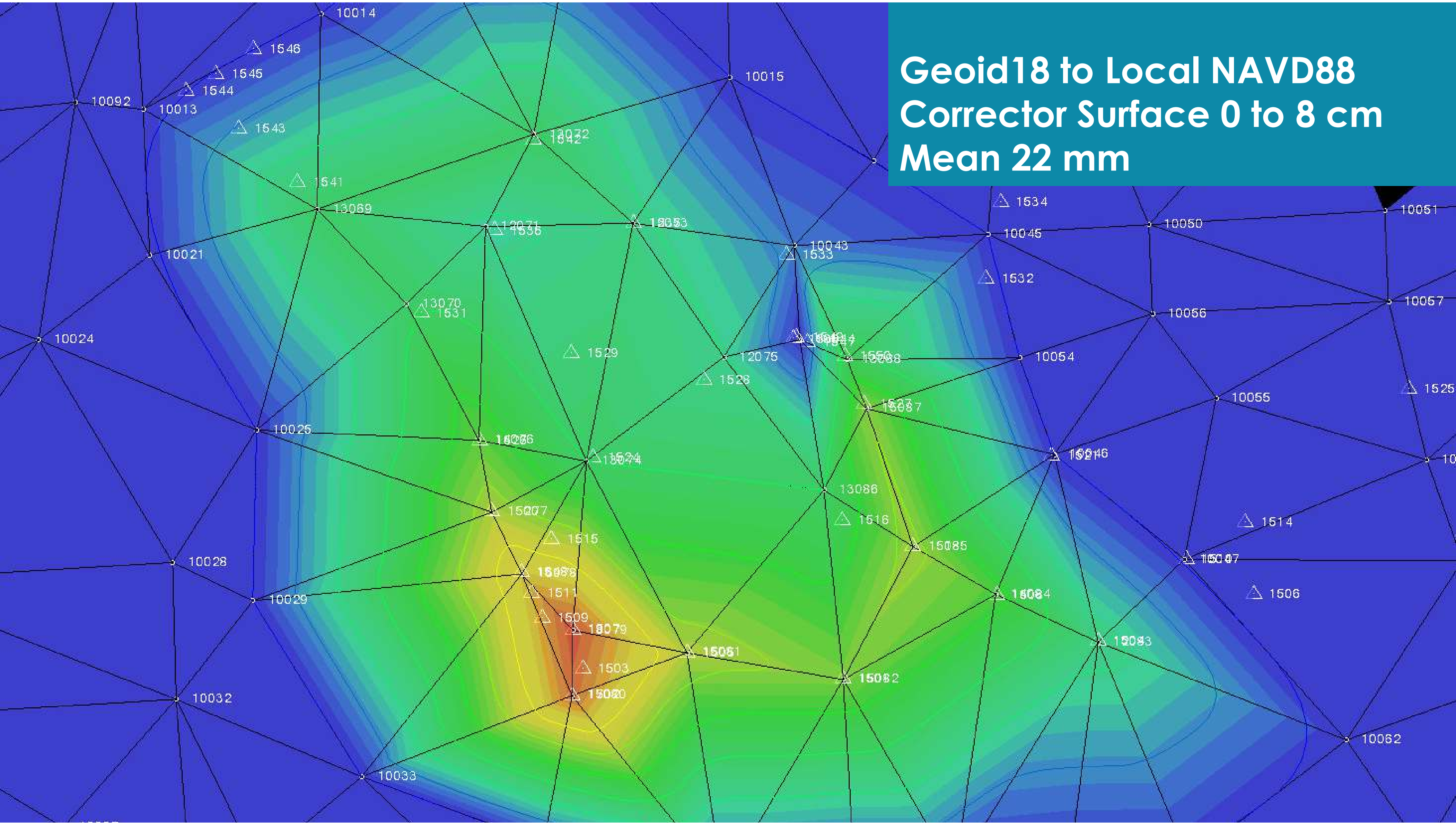




SCIP Velocity Model Vertical 2010 – 2022.50

NAVD88 ≈ 1991

Geoid18 to Local NAVD88 Corrector Surface 0 to 8 cm Mean 22 mm



RECORD OF SURVEY 24647

SHEET 39 OF 42 SHEETS

CALIFORNIA ORTHOMETRIC HEIGHTS NAVD88

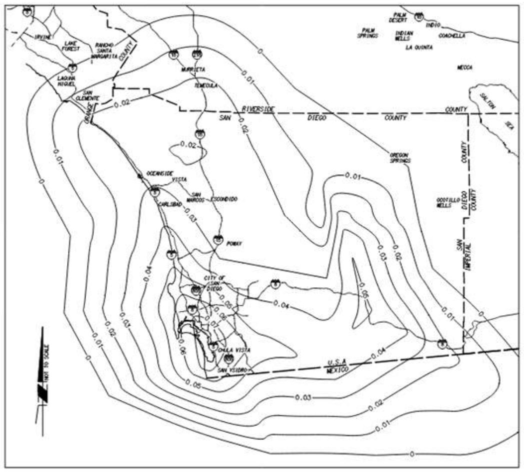
ESTABLISHMENT OF ELEVATIONS FOR THE SDG&E 2022 NETWORK WAS GUIDED BY A GOAL TO PUBLISH CALIFORNIA ORTHOMETRIC HEIGHTS ON THE NAVD88 DATUM IN ACCORDANCE WITH THE PUBLIC RESOURCES CODE §§ 8890-8896 THAT WOULD SUPPORT MODERN GNSS SURVEYING METHODS AND ACCURACIES WHILE MIMICKING RESULTS OF LOCAL CONTROL SURVEYING TIED TO LOCAL NGS PUBLISHED BENCH MARKS. THE NAVD88 DATUM WAS ORIGINALLY ESTABLISHED THROUGH SAN DIEGO COUNTY IN 1991 WITH PRECISE LEVELING GENERALLY ALONG THE LOSAN RAILROAD COASTAL CORRIDOR TO IMPERIAL BEACH THEN EASTERLY IN THE VICINITY OF THE INTERNATIONAL BORDER INTO IMPERIAL COUNTY. AN ORIGINAL LEVELING LINE FOLLOWED THE STATE ROUTE 76 CORRIDOR FROM OCEANSIDE TO SANTA YSABEL AND BORREGO SPRINGS. FOLLOWING PUBLICATION OF THE ORIGINAL NAVD88 DATUM, ADDITIONAL DIFFERENTIAL AND TRIGONOMETRIC LEVELING DATA WAS READJUSTED INTO THE NATIONAL DATUM. SOME OF THIS ADDITIONAL DATA INCLUDED PRECISE LEVELING FROM 1978. THESE READJUSTED LEVELING LINES CONVERGE IN SANTA YSABEL.

TO FURTHER THE GOAL OF MIMICKING LOCAL CONTROL SURVEYING, A CORRECTOR SURFACE WAS INTERPOLATED FROM OBSERVED ELLIPSOID HEIGHTS AND PUBLISHED NAVD88 HEIGHTS ON 30 NGS BENCH MARKS IN ACCORDANCE WITH §§ 8896. THIS CORRECTOR SURFACE, DEPICTED IN THE ONE CENTIMETER CONTOUR MAP SHOWN HEREON, CORRECTS FOR APPROXIMATELY EIGHT CENTIMETERS (0.26') OF SLOPE ALONG THE SAN DIEGO COUNTY COASTAL CORRIDOR AND FIVE CENTIMETERS (0.16') OF UNDULATION ALONG STATE ROUTE 79 TO SANTA YSABEL. NGS GPS-ON-BENCHMARKS ELEVATIONS FROM OPUS SHARE SOLUTIONS WERE USED TO CORROBORATE THE CORRECTOR ESTIMATES.

WHILE LOCAL SUBSIDENCE MAY ACCOUNT FOR SOME OF THE REGIONAL ANOMALIES IN NAVD88 (TIME SERIES AT CGNSS SITE NSSS NEAR BROWN FIELD IN OTAY MESA INDICATES -2 CM OF VERTICAL DISPLACEMENT IN THE LAST 20 YEARS.), THIS CORRECTOR SURFACE ACCOUNTS FOR LIMITATIONS IN THE ORIGINAL NAVD88 LEVELING AND GRAVITY DATA, THE COMPUTATION CAPABILITIES AT THE TIME, TOGETHER WITH BROAD AREAS OF VERTICAL DEFORMATION AND ANY REMAINING DEFICIENCIES IN THE CURRENT REGIONAL GEOID MODEL (GEOID18). NEW DIFFERENTIAL LEVELING WAS NOT PERFORMED FOR THIS PROJECT.

CALIFORNIA ORTHOMETRIC HEIGHTS ON THE NAVD88 DATUM WERE ESTABLISHED FROM A CONSTRAINED LEAST SQUARES NETWORK ADJUSTMENT HOLDING FIXED GEOID18, THE ABOVE DESCRIBED CORRECTOR SURFACE AND THE FOLLOWING NGS BENCH MARKS:

POINT ID	NAME	NGS PID	PUBLISHED NAVD88 METERS	ACCURACY	SOURCE	ESTABLISHED BY
1507	SD 241	DC0759	3.573	FIRST I	NGS	DIFFERENTIAL LEVELING 1991
1510	OCOTILLO	DC0110	145.377	FIRST I	NGS	DIFFERENTIAL LEVELING 1994
1512	C 16	DB1206	-4.275	FIRST I	NGS	DIFFERENTIAL LEVELING 1994
1526	LJ 106	DC1239	4.8	FIRST I	NGS	DIFFERENTIAL LEVELING 1995
1531	H 131	DX1222	12.435	FIRST I	NGS	DIFFERENTIAL LEVELING 1991
1544	K 783 RESET	DX1627	15.946	FIRST I	NGS	DIFFERENTIAL LEVELING 1991
1504	Y 612	DC0166	853.656	FIRST II	NGS	DIFFERENTIAL LEVELING 1991
1505	T 891	DC0384	156.133	FIRST II	NGS	DIFFERENTIAL LEVELING 1991
1520	BOCK	DR6852	18.115	FIRST II	NGS	DIFFERENTIAL LEVELING 2021
1536	SD 6 36	DX5538	52.826	FIRST II	NGS	DIFFERENTIAL LEVELING 1993
1542	SD 6 23	DX5516	349.571	FIRST II	NGS	DIFFERENTIAL LEVELING 1993
1546	3EE-22-91	OCS_1488	183.52	N/A	OCS	DIFFERENTIAL LEVELING 1999
1548	E 1415	DC1434	6.577	FIRST II	NGS	DIFFERENTIAL LEVELING 1991
1501	JUNCTIO CADH AZ MK 1974	DC2029	562.79	THIRD	NGS	BENCH MARK TIE 1994
1516	SAN DIEGO GPS 21	DC2131	1096.93	THIRD	NGS	BENCH MARK TIE 1994
1521	SD PR 2	AF9877	294.349	THIRD	NGS	DIFFERENTIAL LEVELING 2000
1530	SY 119	DX0246	911.125	THIRD	NGS	DIFFERENTIAL LEVELING 1993
1533	HPGN CA 11 08	DX5292	873.611	THIRD	NGS	DIFFERENTIAL LEVELING 2000
1534	11 AAR	DX0471	188.052	THIRD	NGS	DIFFERENTIAL LEVELING 2000
1535	PMT 66	DX0515	254.551	THIRD	NGS	DIFFERENTIAL LEVELING 2000
1549	T 521	DX0245	891.068	THIRD	NGS	DIFFERENTIAL LEVELING 2000
1550	SAN DIEGO GPS 15	DX5300	1281.51	THIRD	NGS	BENCH MARK TIE 1994
1502	941 0120 O TIDAL	DC1338	7.304	R ADJ	NGS	READJUSTED 1993
1508	R 1252	DC0198	1240.803	R ADJ	NGS	READJUSTED 1993
1513	ML 48 SD CO	DC0397	1057.42	R ADJ	NGS	READJUSTED 1993
1524	PITCH	DC1128	142.866	R ADJ	NGS	READJUSTED 1993
1527	CY 77 SD CO	DC0538	1420.708	R ADJ	NGS	READJUSTED 1993
1528	RA 157	DX0304	466.625	R ADJ	NGS	READJUSTED 1993
1532	X 1326	DX3529	309.946	R ADJ	NGS	READJUSTED 1993
1547	F 308 RESET	DX0239	1016.771	R ADJ	NGS	DIFFERENTIAL LEVELING 1993



CORRECTOR SURFACE CONTOUR MAP

NOT TO SCALE
CONTOUR ELEVATIONS ARE IN METERS

SDGE

RECORD OF SURVEY 24647

SHEET 42 OF 42 SHEETS

CALIFORNIA ORTHOMETRIC HEIGHTS NAVD88

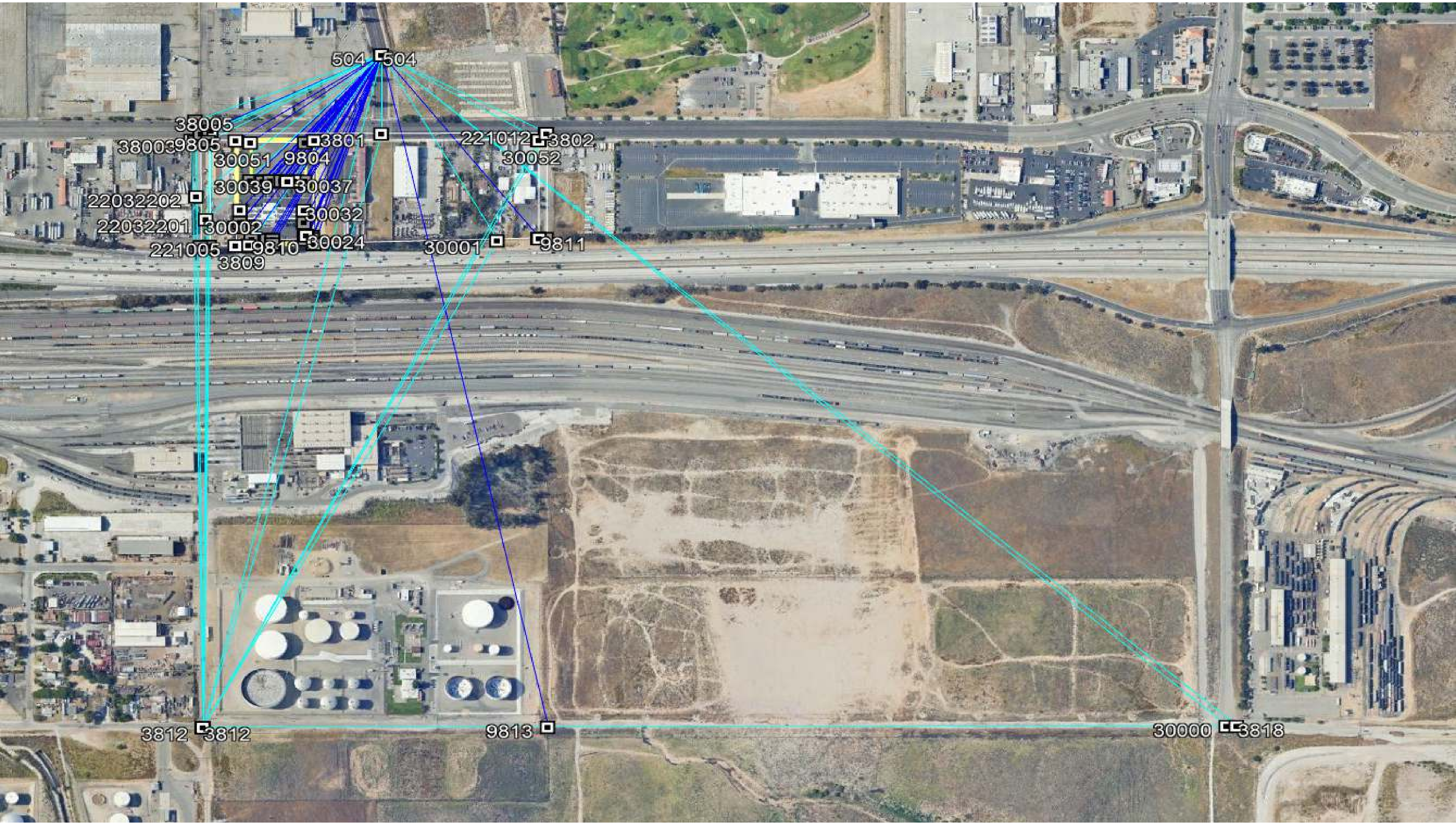
STATION ID	STATION NAME	GEOID18 METERS	GEOID CORRECTOR METERS	ELEVATION METERS	ELEVATION FEET	95% CONFIDENCE METERS
	H 131	-34.750	0.030	12.435	40.80	0.020
	X 1326	-32.828	0.002	309.946	1016.88	0.020
	HPGN CA 11 08	-31.740	0.008	873.611	2866.17	0.020
	11 AAR	-32.889	0.001	188.052	616.97	0.020
	PMT 66	-32.191	0.020	254.551	835.14	0.020
	SD 6 36	-33.550	0.016	52.826	173.31	0.020
	IGRIFT & BASILONE	-34.061	0.020	26.184	85.91	0.022
	5-63.59 2011	-34.639	0.028	46.423	152.31	0.021
	SILONE LAS PULGAS	-34.089	0.027	80.800	265.09	0.022
	B CP 3046 2007	-34.245	0.028	117.101	384.19	0.020
	L 1415	-34.782	0.024	10.133	33.24	0.020
	SD 6 23	-32.700	0.031	349.571	1146.88	0.020
	HPGN-12-02	-34.878	0.011	7.206	23.64	0.023
	K 783 RESET	-34.941	0.003	15.946	52.32	0.020
	7 8 21	-34.661	0.000	94.770	310.92	0.021
	3EE-22-91	-34.285	0.000	183.520	602.10	0.020
	F 308 RESET	-31.688	0.005	1016.771	3335.86	0.020
	E 1415	-34.998	0.067	6.577	21.58	0.020
	T 521	-31.716	0.001	891.068	2923.45	0.020
	N DIEGO GPS 15	-31.603	0.034	1281.510	4204.42	0.020
	ISOCREEKCA2013	-34.695	0.028	23.125	75.87	0.020
	EA_27_CPCA2013	-33.825	0.023	66.872	219.40	0.020
	EA_53_CPCA2013	-34.236	0.026	146.013	479.04	0.020
	LAKE SKINNER	-32.398	0.013	503.196	1650.90	0.020
	RLCANNONCA2011	-34.576	0.033	55.926	183.48	0.020
	COOKS RANCH	-34.435	0.000	-11.689	-38.35	0.020
	SCANSO DETENTI	-31.863	0.032	989.921	3247.77	0.020
	DURWID HILL	-33.758	-0.001	-48.521	-159.19	0.021
DLUZ	DLUZHEIGHTCA2011	-33.314	0.027	246.787	809.67	0.020
DSME	DANA SEQUIN MEMO	-34.559	0.038	91.446	300.02	0.020
FSHB	FORT SCOTTY HUB	-34.259	0.001	170.046	557.89	0.020
JAS1	GILLESPIE FIELD	-33.747	0.038	132.049	433.23	0.020
LBRF	GEISEL_LIBRARY_REFERENCE	-34.836	0.050	92.059	302.03	0.020
LGWD	LAGUNAWOODCA2011	-34.518	0.002	123.922	406.57	0.020
LKHG	LAKE HENSHAW GPS	-31.711	0.010	855.755	2807.59	0.020
MONP	MONUMENT PEAK	-31.838	0.042	1875.194	6152.20	0.020
MTGG	MATAGUAY SCOUT C	-31.662	0.014	1099.145	3606.11	0.020
MVFD	MONTEZUMA VALLEY	-31.754	0.009	1222.602	4011.15	0.020
NSSS	NAVAL SPACE SURV	-34.506	0.054	158.871	521.23	0.020
OCSD	OCEANSIDE_CA2012	-34.365	0.026	78.011	255.94	0.020
P066	JACUMBAAP_CS2004	-32.637	0.022	856.290	2809.34	0.020
P471	SANJUANCRKCS2005	-33.864	0.005	209.344	686.82	0.020
P472	CAMPELLIOTCS2004	-34.143	0.039	172.764	566.81	0.020
P473	JAMACHA_LFCS2004	-33.847	0.046	223.180	732.22	0.020
P474	FALLBROOK_CS2004	-33.415	0.024	217.072	712.18	0.020
P475	POINT_LOMACS2007	-35.501	0.057	11.222	36.82	0.020
P476	SANTAMARGACS2005	-32.854	0.028	343.357	1126.50	0.020
P477	TEMECULAVHCS2005	-32.633	0.023	367.847	1206.84	0.020
P478	VALLEYCNTRCS2004	-32.863	0.024	405.191	1329.36	0.020
P479	COWBOYCTRYCS2005	-31.508	0.000	1126.083	3694.49	0.020

CALIFORNIA ORTHOMETRIC HEIGHTS NAVD88

STATION ID	STATION NAME	GEOID18 METERS	GEOID CORRECTOR METERS	ELEVATION METERS	ELEVATION FEET	95% CONFIDENCE METERS
P480	VALLECITO_CS2004	-32.587	0.010	469.379	1539.95	0.020
P481	CARRIZOMTNCS2007	-33.739	0.005	645.408	2117.48	0.020
P482	LAKHENSHAWCS2004	-31.728	0.008	911.193	2989.47	0.020
P483	JULIANBIN_CS2004	-31.633	0.035	1407.970	4619.31	0.020
P484	SKYOAKSBFSCS2005	-31.349	0.002	1414.582	4641.01	0.020
P485	TUBBCANYONCS2006	-32.414	0.003	405.309	1329.75	0.020
P486	BORREGOAIRCS2004	-32.949	-0.004	159.944	524.75	0.020
P487	CUT_ACROSSCS2007	-33.358	-0.001	124.352	407.98	0.020
P488	OCOTILLOWECS2007	-33.657	0.000	96.138	315.41	0.020
P489	CALCITEMINCS2007	-33.283	0.003	324.359	1064.17	0.020
P490	TORO_PEAK_CS2006	-31.214	0.012	2654.399	8708.64	0.020
P491	LA_QUINTA_CS2005	-32.853	-0.004	37.848	124.17	0.021
P492	CRZOBADLNDCS2007	-33.919	0.000	103.518	339.63	0.020
P494	WESTSIDEESCS2005	-34.368	0.000	-9.140	-29.99	0.020
P496	MCCABE_UESCS2005	-34.590	0.000	-4.697	-15.41	0.020
P497	IMPERIALAPCS2005	-34.614	-0.001	-15.610	-51.21	0.020
P498	SPRECKLESSCS2005	-34.566	0.000	-22.700	-74.47	0.020
P499	SDSUCENTERCS2005	-34.422	-0.001	-39.028	-128.04	0.020
P500	ALLAMERICNCS2005	-34.740	-0.001	14.924	48.96	0.020
P501	HOLTVILLECCS2005	-34.526	0.000	-20.389	-66.89	0.020
P741	SANTARO86GCS2006	-31.158	0.002	1403.188	4603.63	0.020
P742	FORDRA087GCS2006	-31.292	-0.001	1174.695	3853.98	0.020
P744	IMPERIALVCCS2007	-34.627	0.000	-17.325	-56.84	0.020
P797	SAGEBRUSH_CA2010	-31.170	0.004	1435.721	4710.36	0.020
PMOB	PALOMAR OBSERVAT	-31.446	0.019	1694.730	5560.13	0.020
POTR	POTRERO PARK	-32.464	0.048	763.521	2504.99	0.020
RAAP	RAMONA AIRPORT	-32.729	0.024	428.507	1405.86	0.020
RKMG	RAMAKRISHNA MONA	-33.755	-0.001	412.059	1351.90	0.020
RMVJ	RANCHOMISSCA2012	-34.244	0.014	171.354	562.18	0.020
SBCC	SBCC_SCGN_CS1999	-34.492	0.002	123.875	406.41	0.020
SCIP	SAN CLEMENTE ISL	-37.003	0.005	490.544	1609.39	0.021
SIO5	SCRIPPS 5 - MT.	-35.011	0.059	221.313	726.09	0.020
SONG	SAN_ONOFRECA2012	-34.703	0.024	32.492	106.60	0.020
TRAK	BOMMER CANYON	-34.703	0.000	150.936	495.20	0.020
USGC	USGC_SCGN_CS1998	-33.666	-0.001	167.862	550.73	0.020
VTOR	VISTA_TWINCA2012	-33.563	0.024	414.230	1359.02	0.020
WHYT	WHITING REGIONAL	-33.929	0.000	300.053	984.42	0.020
YUHG	YUHA DESERT GPS	-33.681	-0.001	187.036	613.63	0.020

SDGE

CALIFORNIA ORTHOMETRIC HEIGHTS NAVD88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38003
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9804
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30039
30037
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30000
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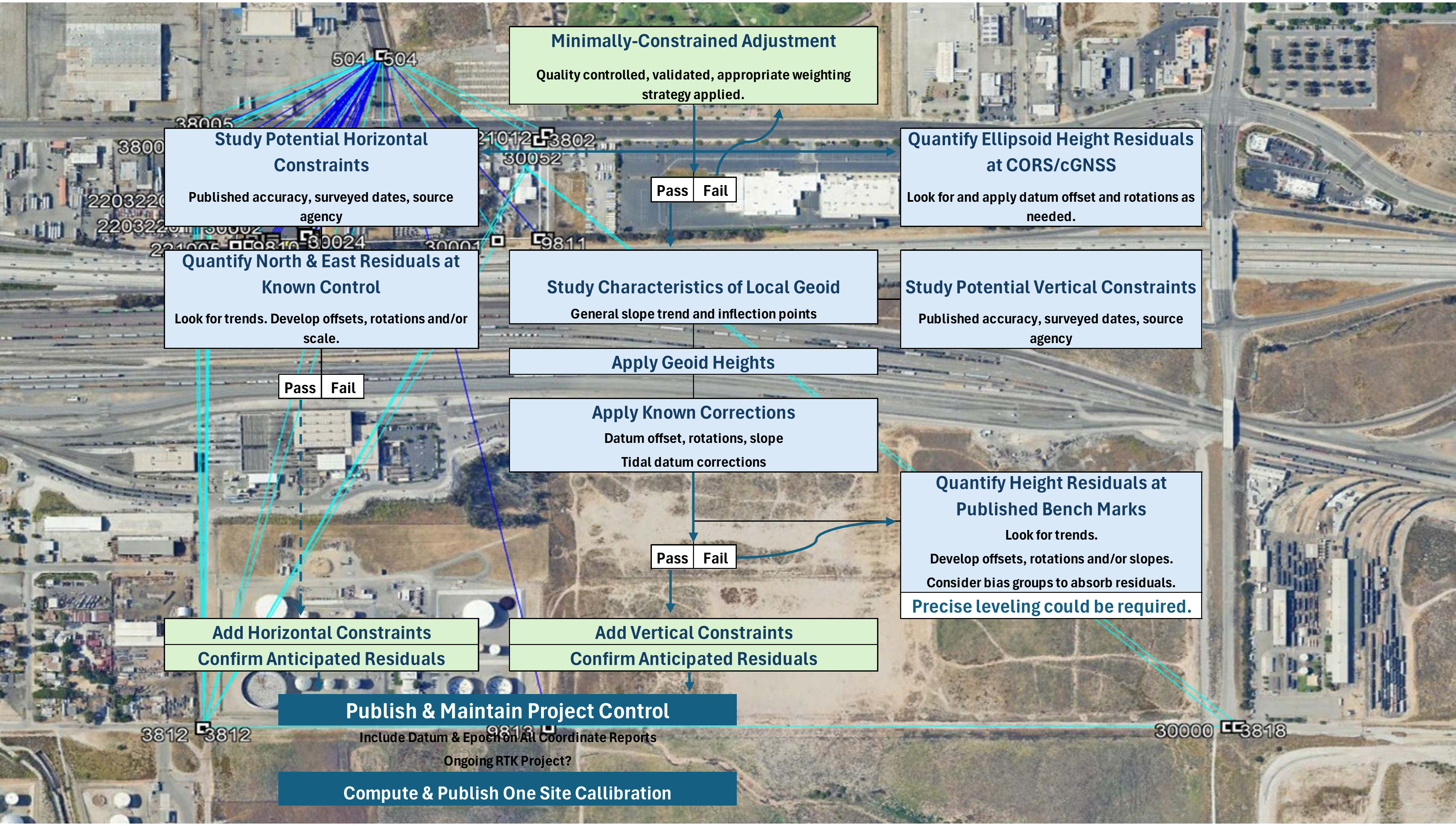

Minimally-Constrained Adjustment
Quality controlled, validated, appropriate weighting strategy applied.
Pass
Fail
Study Potential Horizontal Constraints
Published accuracy, surveyed dates, source agency
Quantify Ellipsoid Height Residuals at CORS/cGNSS
Look for and apply datum offset and rotations as needed.
Quantify North & East Residuals at Known Control
Look for trends. Develop offsets, rotations and/or scale.
Study Characteristics of Local Geoid
General slope trend and inflection points
Study Potential Vertical Constraints
Published accuracy, surveyed dates, source agency
Apply Geoid Heights
Pass
Fail
Apply Known Corrections
Datum offset, rotations, slope
Tidal datum corrections
Quantify Height Residuals at Published Bench Marks
Look for trends.
Develop offsets, rotations and/or slopes.
Consider bias groups to absorb residuals.
Precise leveling could be required.
Pass
Fail
Add Horizontal Constraints
Confirm Anticipated Residuals
Add Vertical Constraints
Confirm Anticipated Residuals
Publish & Maintain Project Control
Include Datum & Epoch on All Coordinate Reports
Ongoing RTK Project?
Compute & Publish One Site Callibration
504
38005
3800
3802
30052
30024
30001
9811
3812
30000
3818