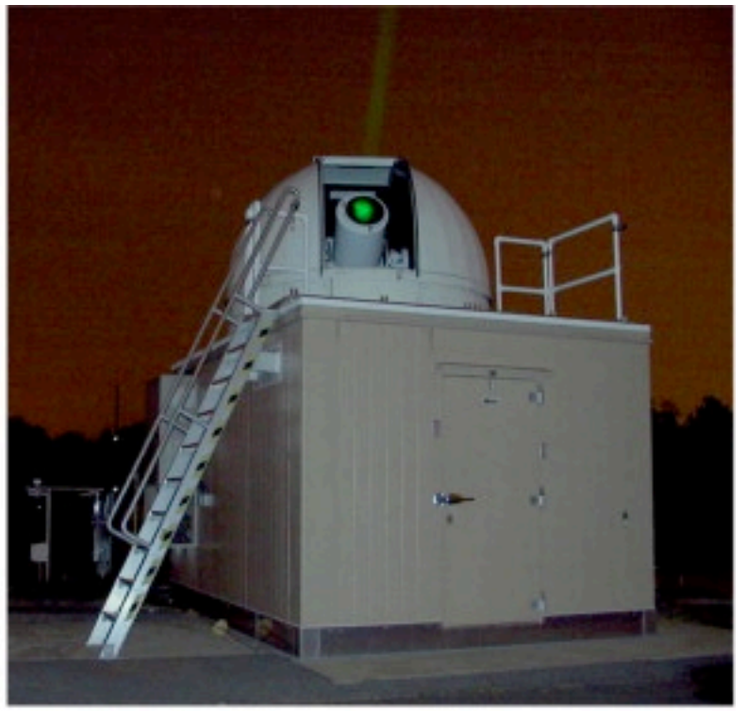
Class 16: Latest NAD83, ITRF and WGS84 implementations



DORIS, SLR and LLR, GPS, and VLBI

GISC3325
25 March 2013

Class Updates

- **Exam 2 during class period 1 April 2013**
- Lab 5 due 27 March 2013
- Last day to drop a class is 12 April 2013
- Oral reports start 15 April 2013

Datum

- Theoretical reference surface
- Geometric model of the Earth

  Reference ellipsoid
  - Semi-major axis (equatorial radius)
  - Semi-minor axis (polar radius)
  - Aligned with coordinate system

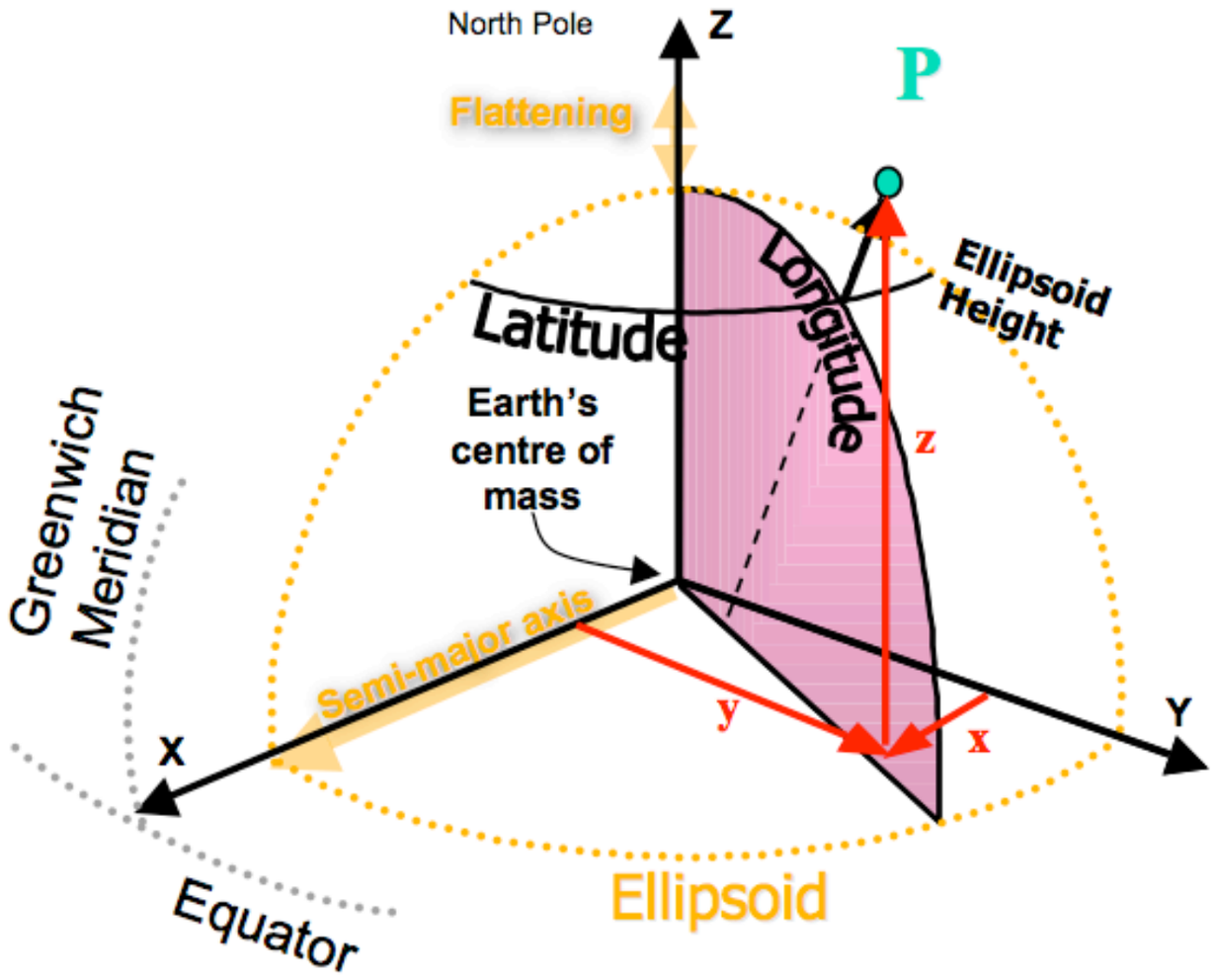
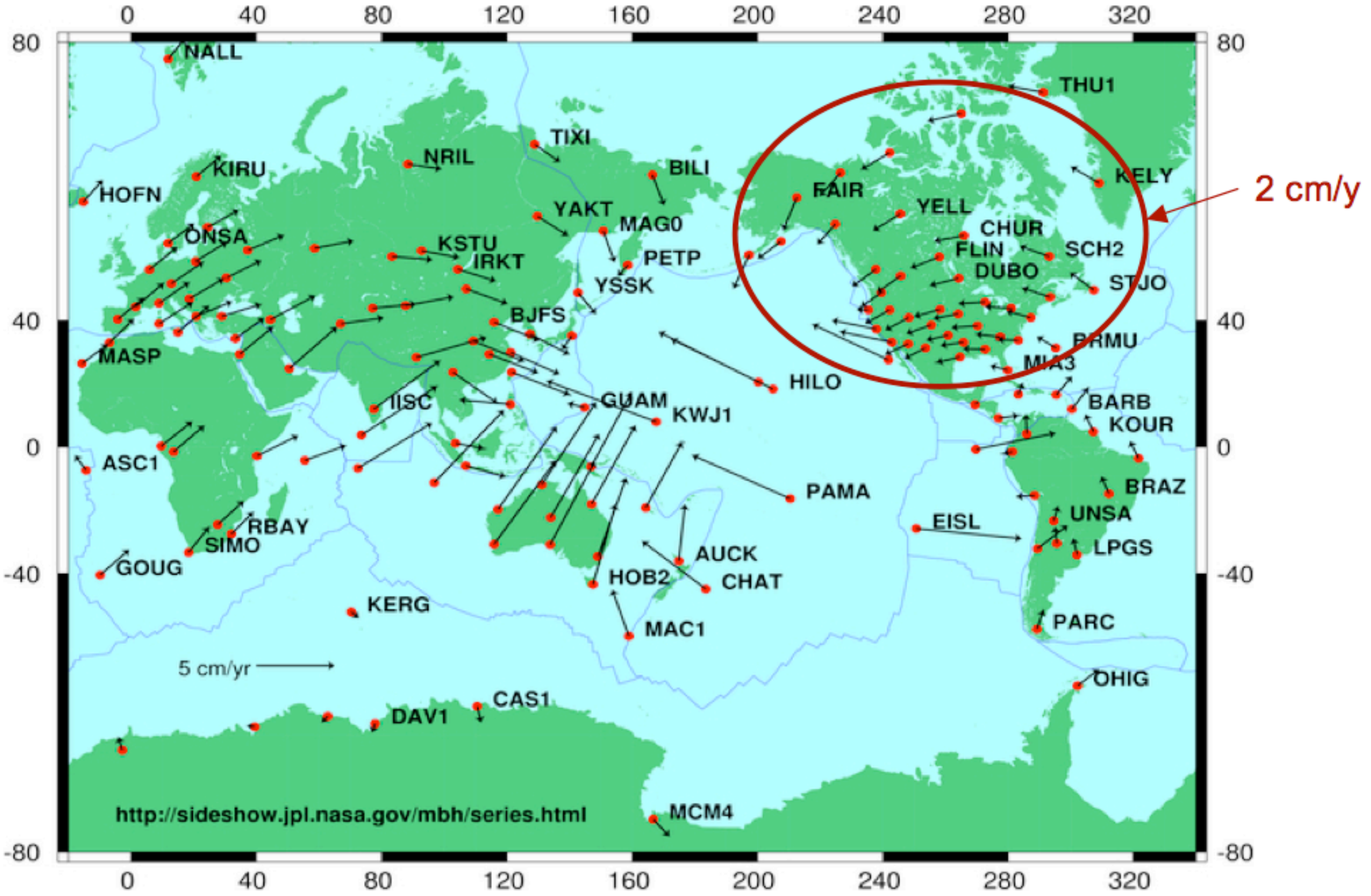
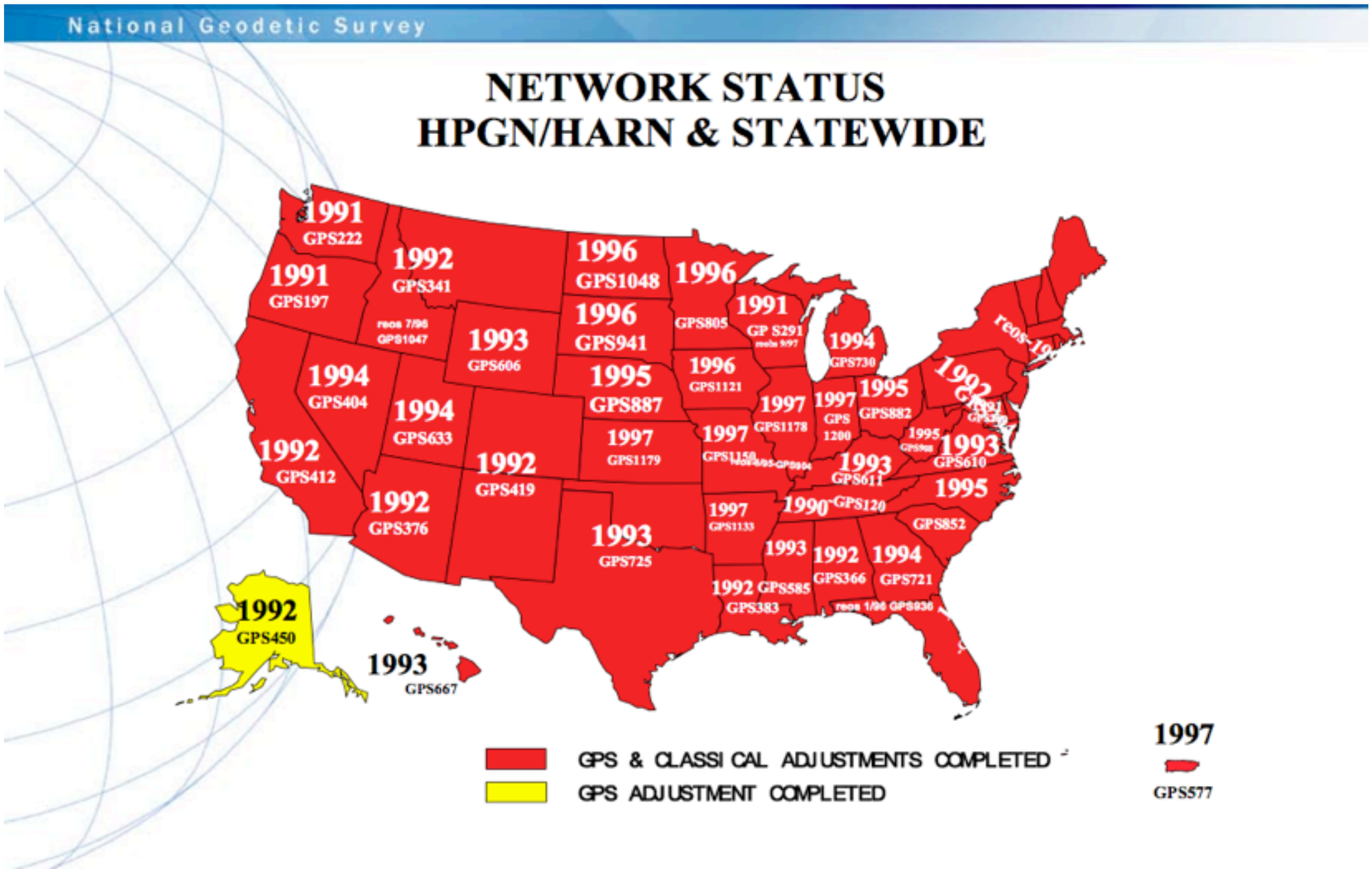


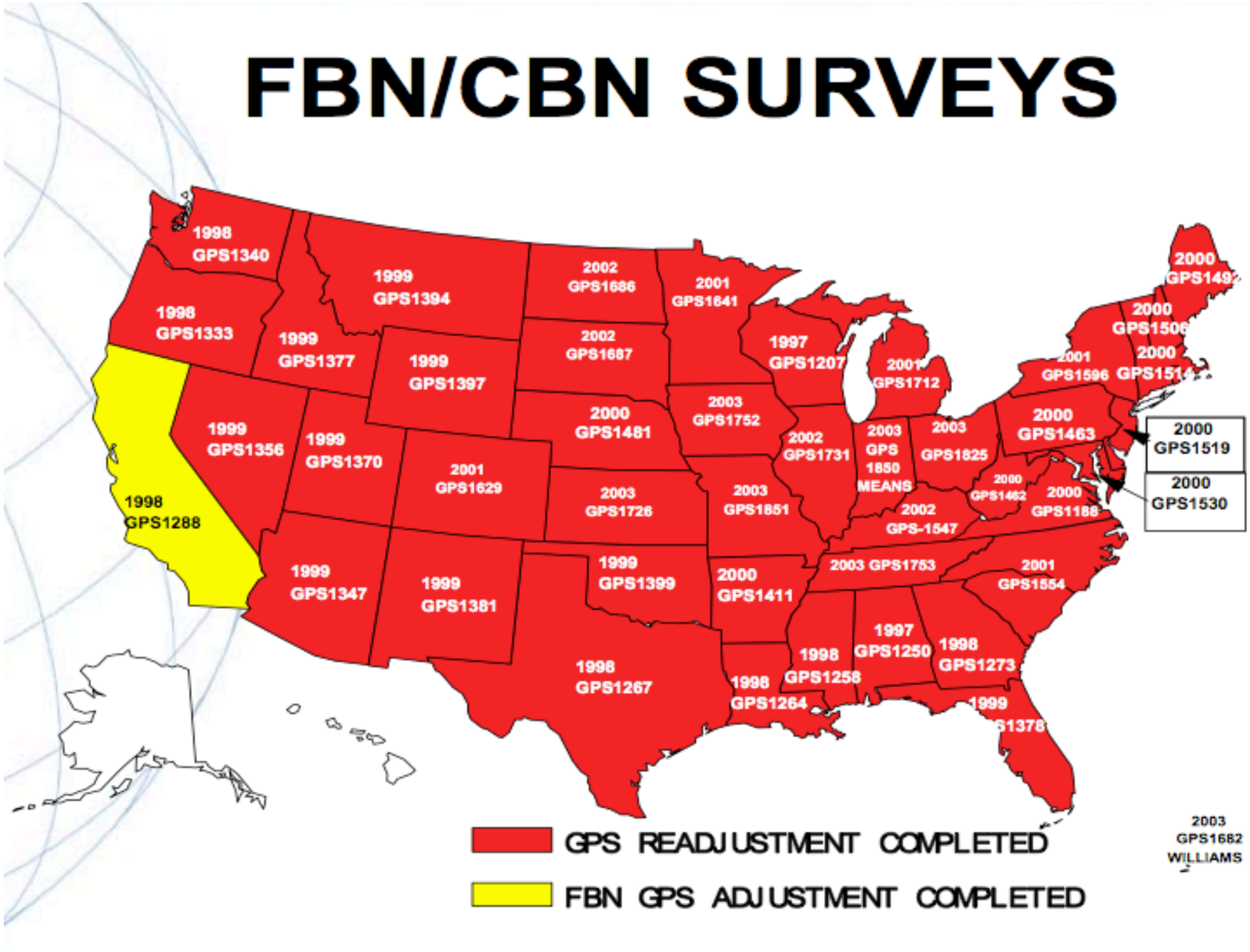
Plate Tectonic Motions



Why NAD 83 (2007)?

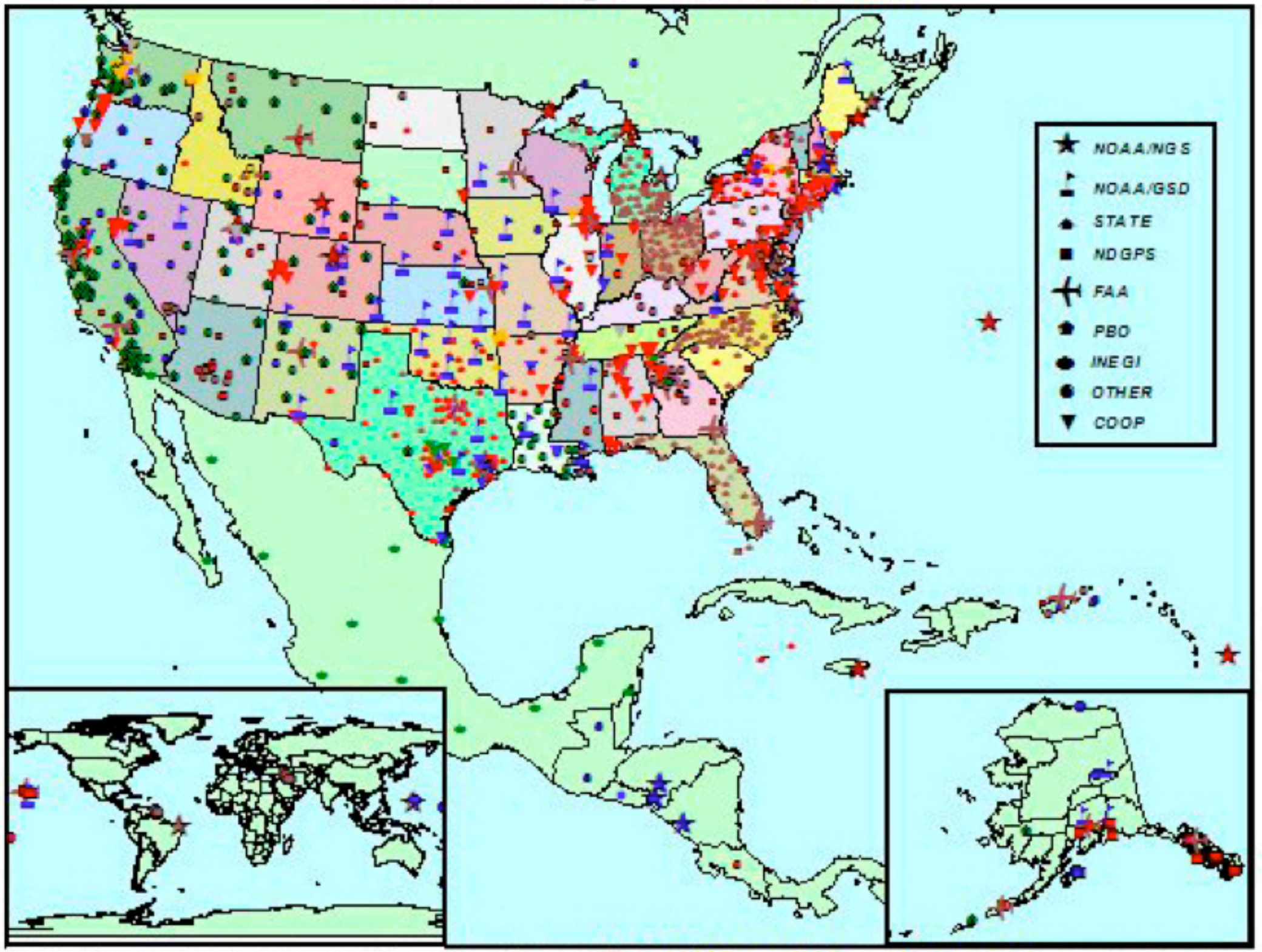
- Undertaken to remove discontinuities between the state-by-state HARN network of monuments and the CORS.





Surveys to improve ellipsoid height component.

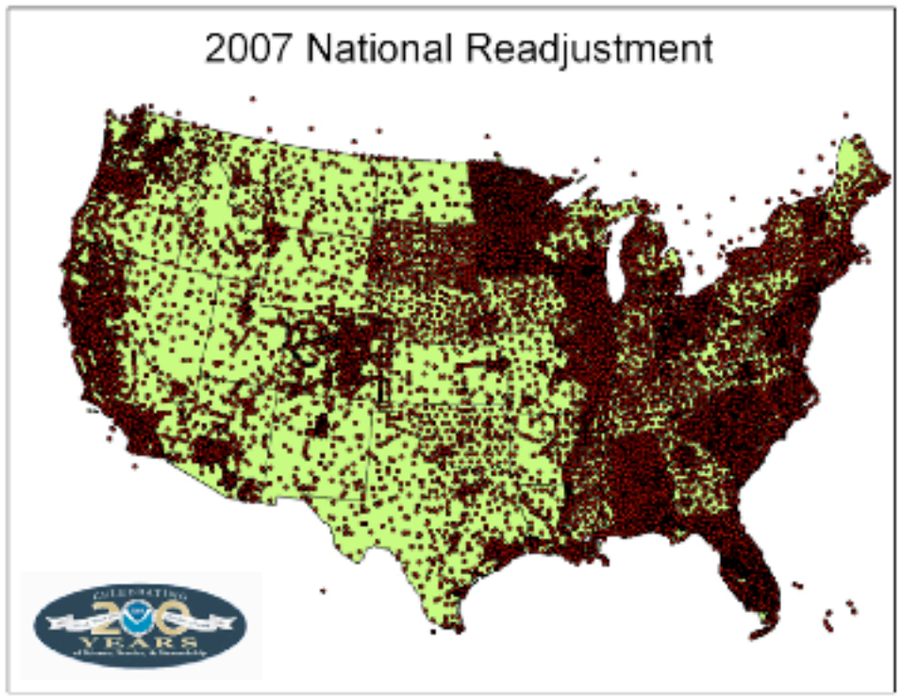
CORS Coverage



Symbol color denotes sampling rates: (1 sec) (5 sec) (10 sec) (15 sec) (30 sec) (Decommissioned)

NOAA Technical Report NOS NGS 60

NAD 83(NSRS2007) National Readjustment Final Report



Available for download from NGS web site at: http://www.ngs.noaa.gov/web/surveys/NSRS2007/

Dale G. Pursell
Mike Potterfield

Silver Spring, MD
August 2008

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

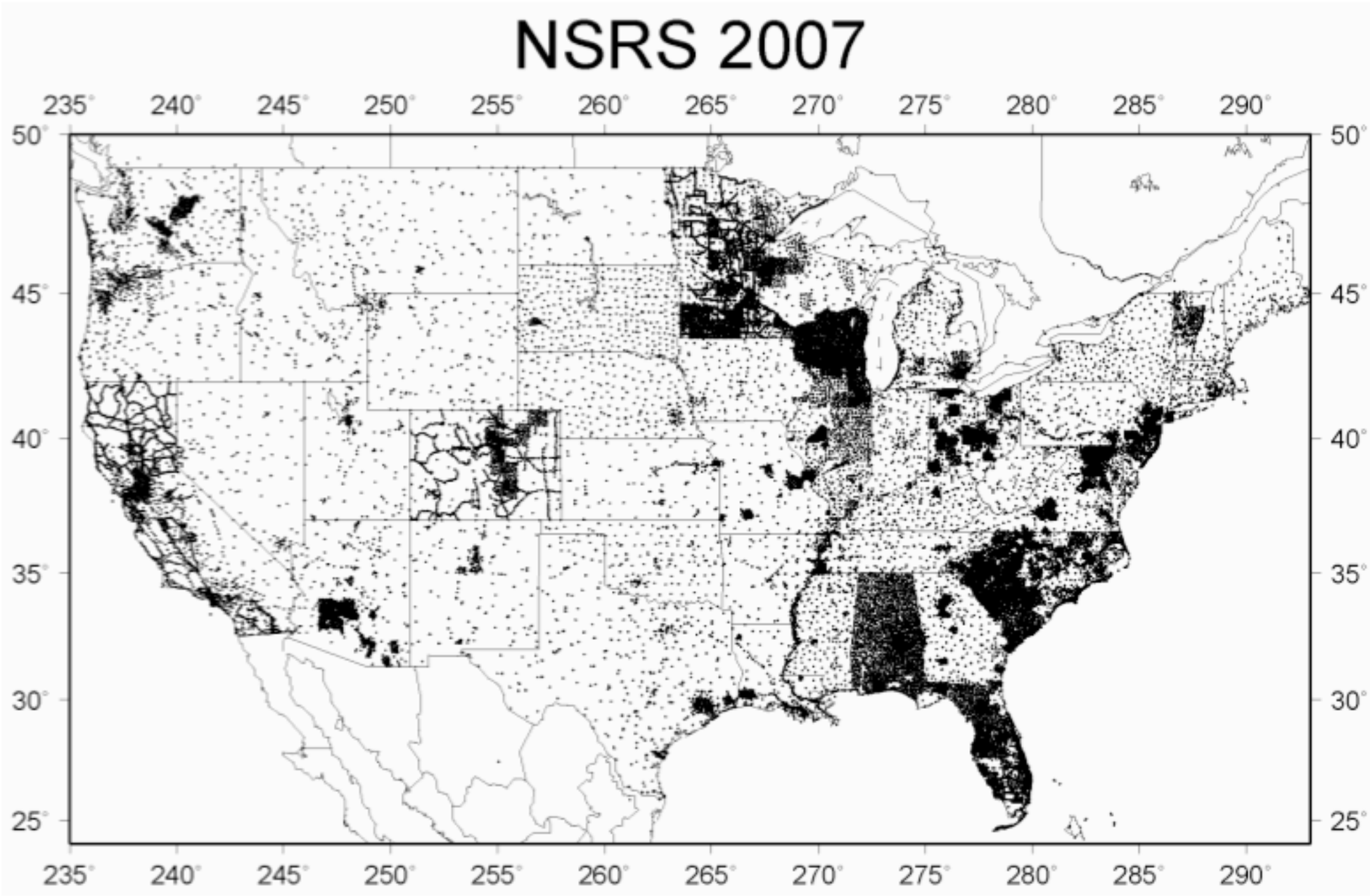
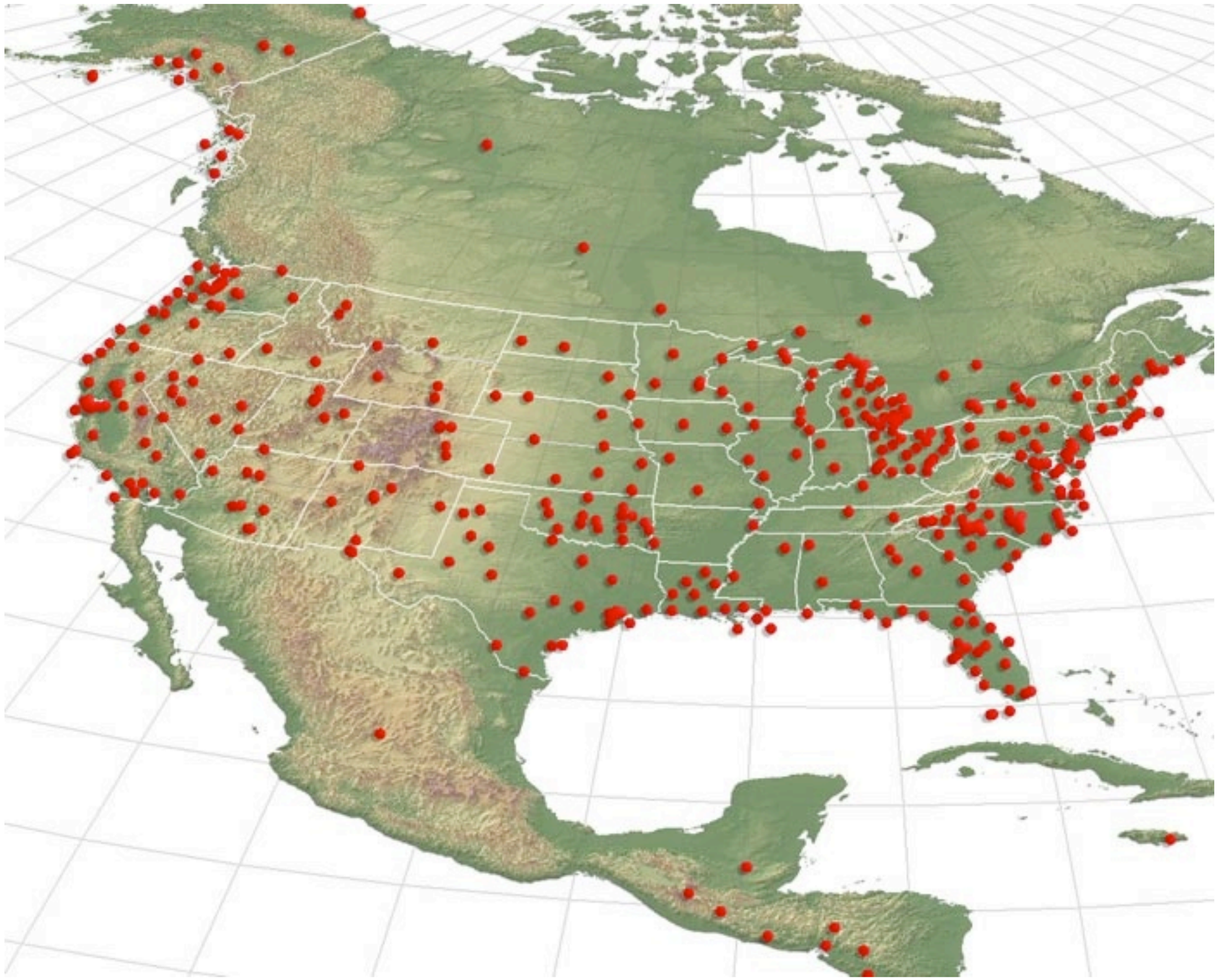


Figure 3.1. Monumented points of NSRS 2007, Conterminous U.S.

NGS CORS Map



NAD83(2007) and NAD83(CORS96)

- NAD83(2007) adjustment of ~70,000 passive geodetic control monuments
- *Approximates* NAD83(CORS96) used for CORS network
  - No correction to observations of passive monuments for vertical crustal motion when converting epoch of observations to epoch of adjustment.
- NAD83(CORS96) observations do incorporate 3D motions.

REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)		
X:	-2498423.165(m)	0.018(m)
Y:	-3802822.048(m)	0.021(m)
Z:	4454737.695(m)	0.024(m)
LAT:	44 35 7.91054	0.002(m)
E LON:	236 41 43.48129	0.014(m)
W LON:	123 18 16.51871	0.014(m)
EL HGT:	107.485(m)	0.034(m)
ORTHO HGT:	130.010(m)	0.043(m)

ITRF00 (EPOCH:2005.1596)		
	-2498423.872(m)	0.018(m)
	-3802820.836(m)	0.021(m)
	4454737.792(m)	0.024(m)
	44 35 7.92698	0.002(m)
	236 41 43.42434	0.014(m)
	123 18 16.57566	0.014(m)
	107.108(m)	0.034(m)

[Geoid03 NAVD88]

Difference in coordinates due to reference frame difference is 1.4 meters. This point is in Corvallis, Oregon. Note smaller difference in ellipsoid heights.

NAD 83 Fixed Control

Control for the NAD 83(NSRS2007) adjustment was provided by the CORS. For all states except AZ, CA, OR, WA, NV and AK, the values used were the NAD 83 epoch 2002.0 values currently published by NGS.

In California, the NAD 83 values for the California CORS (CGPS) and the National CORS were obtained through Scripps' Sector utility and are available through the California Spatial Reference Center's(CSRC) website at: http://csrc.ucsd.edu in the 2007.0 epoch.

For AZ, OR, WA, NV and AK, HTDP was used to convert the currently published NAD 83 positions of the CORS to epoch 2007.0

For all stations on the stable North American plate, no epoch date will be shown – as is currently the practice. For the other states, an epoch date of 2007.0 will be shown. In those states, except CA, HTDP can be used with the currently published CORS to determine the proper value to use. In CA, the values as currently published on the CSRC website should be used to maintain consistency with NAD83 (NSRS2007).

Note: For future projects located in AZ, OR, WA, NV, CA and AK, HTDP will still be required to correct for any velocities associated with the published control.

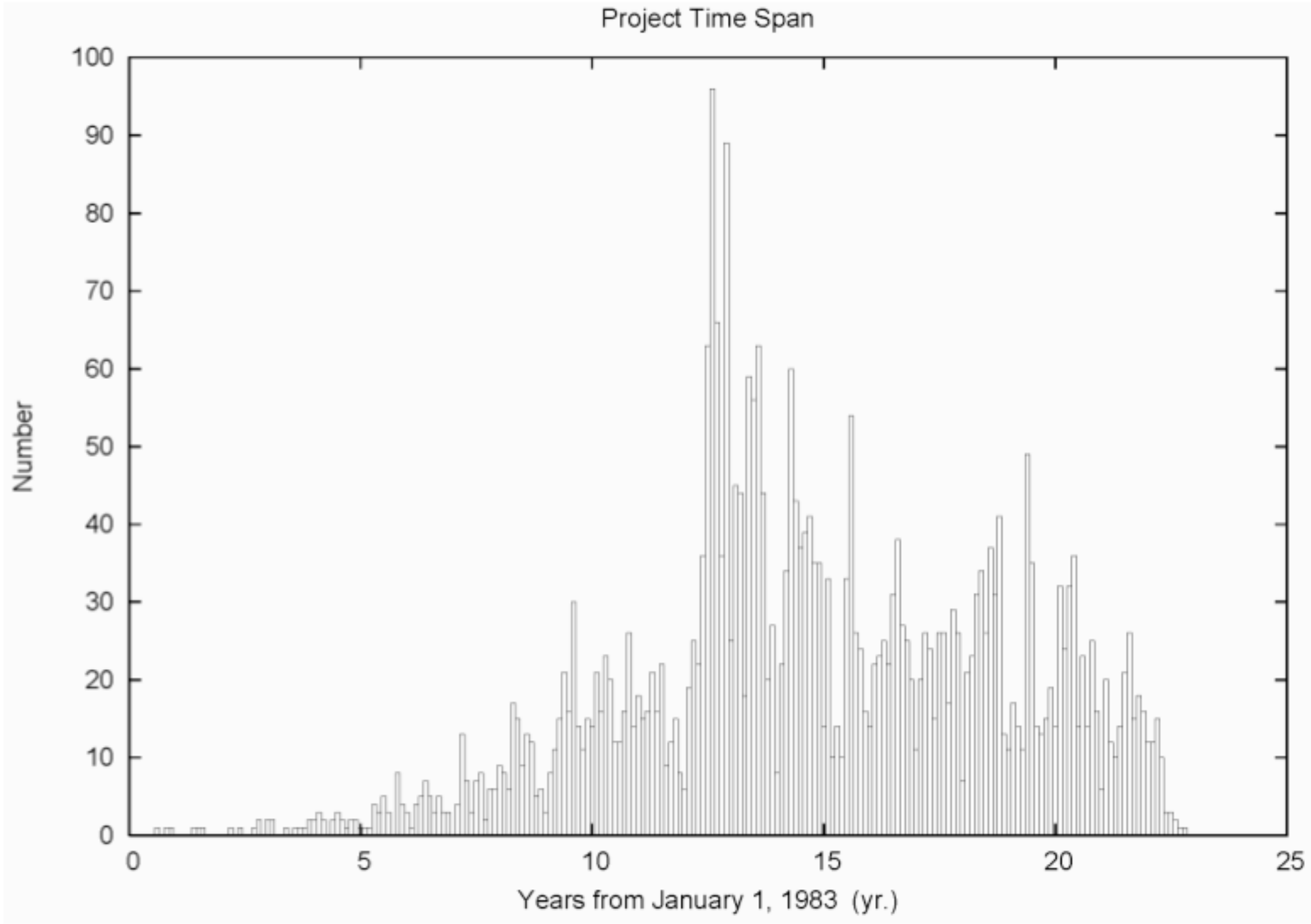


Figure 4.1. Temporal distribution of GPS projects in NSRS 2007.

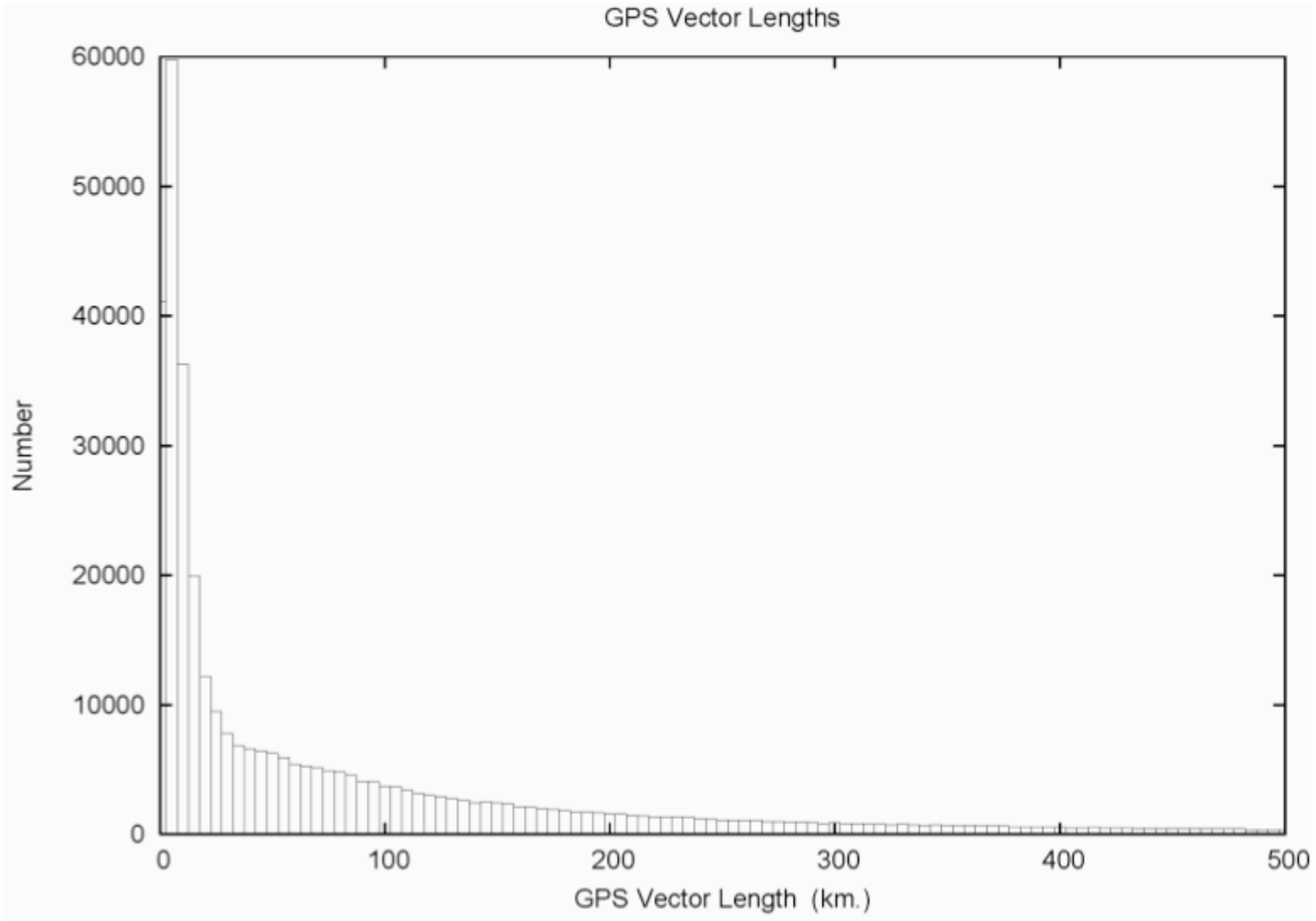


Figure 5.1. Distribution of GPS vector lengths, 0 to 500 km. 5 km bin size.

Cumulative Percentages of Baseline Lengths used in adjustment

Table 5.1 – Percentiles of GPS vector lengths

Percentile	Length (km)
50%	31
68%	89
90%	297
95%	434
99%	770
99.9%	2259

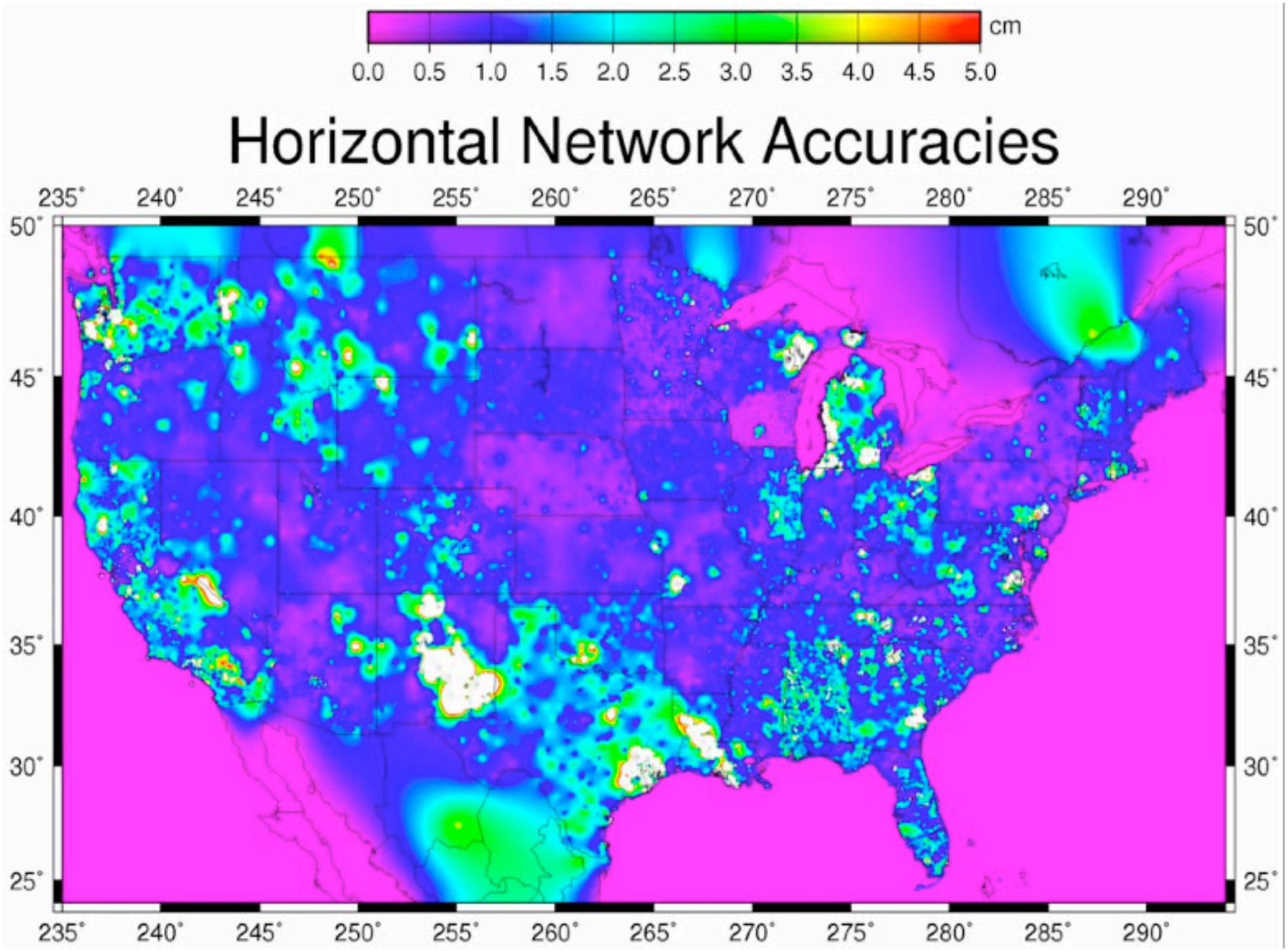


Figure 21.1. Gridded horizontal network accuracies. White exceeds 5 cm.

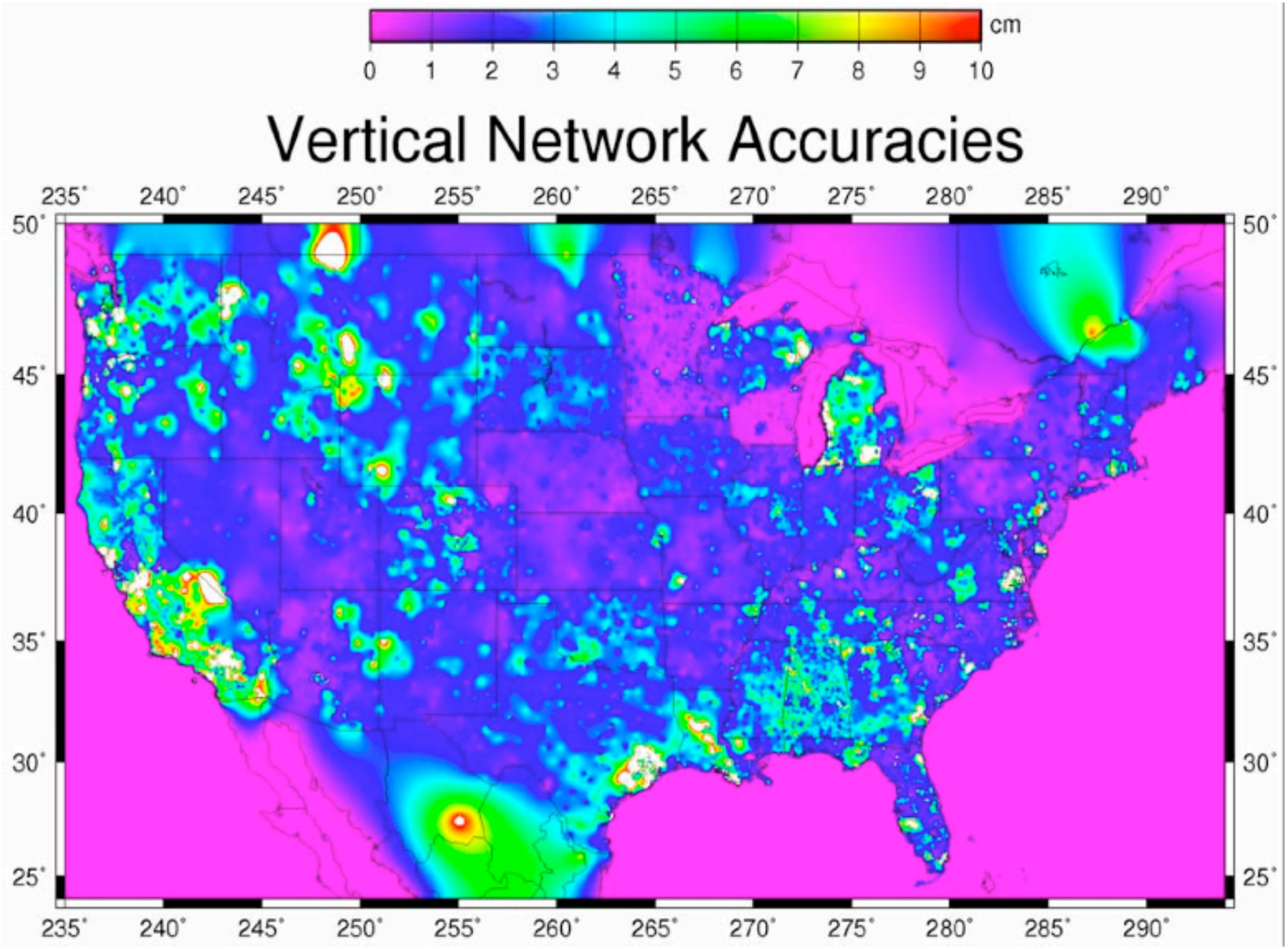


Figure 21.2. Gridded vertical network accuracies. White exceeds 10 cm.

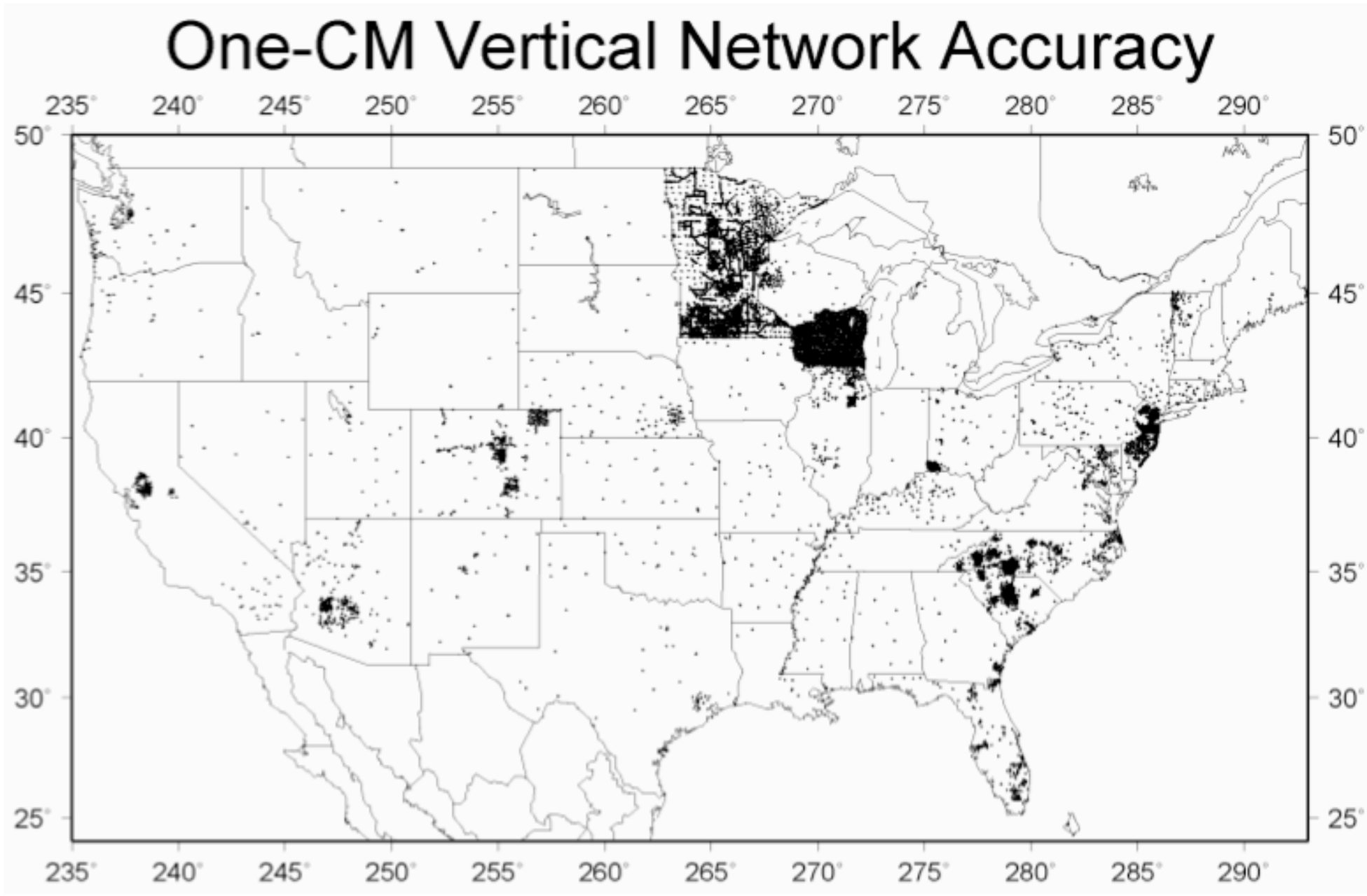


Figure 23.1. Points with one cm vertical network accuracy, conterminous U.S.

An Analysis of the NAD 83(NSRS2007) National Readjustment

Dennis Milbert, Ph.D.
Rockville, Md.

ABSTRACT

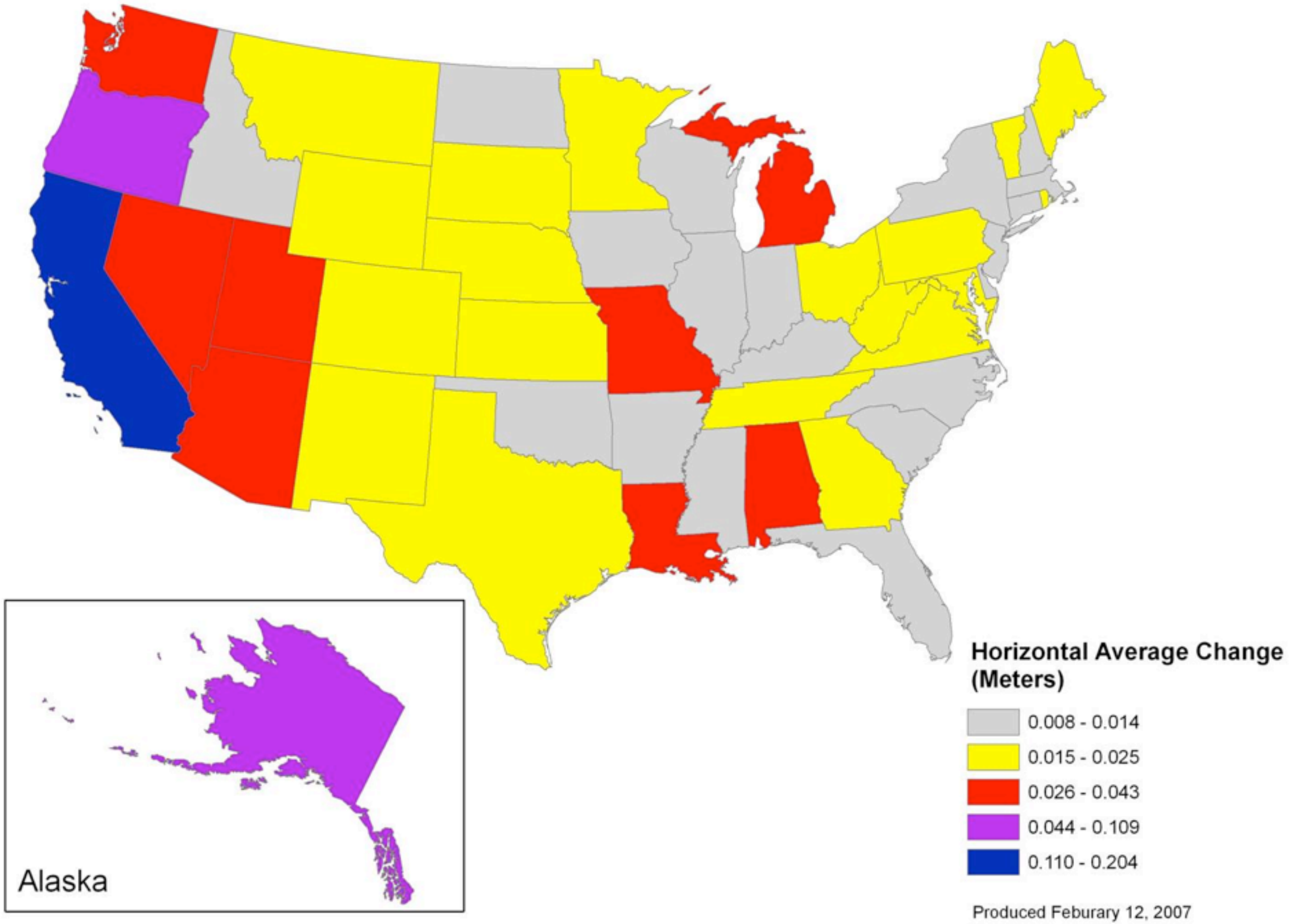
On February 6, 2007, the final fixed adjustment of the NAD 83(NSRS2007) National Readjustment was completed. GPS carrier phase data, reduced to correlated inter-station vectors observed from 1983 to November 2005, were processed in a simultaneous least-squares adjustment. A CORS coordinate set, epoch 2002.0, established the NAD 83 system; although crustal motion effects were applied to coordinates and vectors in California, Arizona, Nevada, Oregon, and Washington to realize an epoch of 2007.0. FGDC network accuracies (95% *a posteriori* statistics) show medians of 1.03 cm horizontal and 1.84 cm vertical. Analysis of the residuals shows insufficient outer rejection and the potential need to reweight four categories of projects. These problems lead to long tails in statistical distributions and inflation of the *a posteriori* statistics. Comparisons show that less than 1% of the residuals change horizontally by 1 cm or more between the free and fixed adjustments.

Table 27.2 Final Statistics of Minimally Constrained Adjustment

No. of observations = 851,073
No. of auxiliary parameters = 0
No. of unknowns = 203,079
No. of rigid constraints (+/-10 micron) = 3
No. of weighted constraints (+/-10 micron) = 0
Degrees of freedom = 647,997 approximate
Variance sum ($\mathbf{V}^T\mathbf{PV}$) = 1,056,077.7
Variance of unit weight = 1.629757
Standard deviation of unit weight = 1.276619

Table 28.1 Final Statistics of Constrained Adjustment

No. of observations = 851,073
No. of total constrained parameters = 2,055
No. of rigid constrained parameters (+/-10 micron) = 2,029
No. of weighted constrained parameters (+/-10 cm) = 26
No. of unknown parameters = 203,079
Degrees of Freedom = 650,049
Variance sum ($\mathbf{V}^T\mathbf{PV}$) = 1,229,874.4
Variance of unit weight = 1.8919718
Standard deviation of unit weight = 1.375490


Alaska
Horizontal Average Change (Meters)
0.008 - 0.014
0.015 - 0.025
0.026 - 0.043
0.044 - 0.109
0.110 - 0.204
Produced Feburary 12, 2007

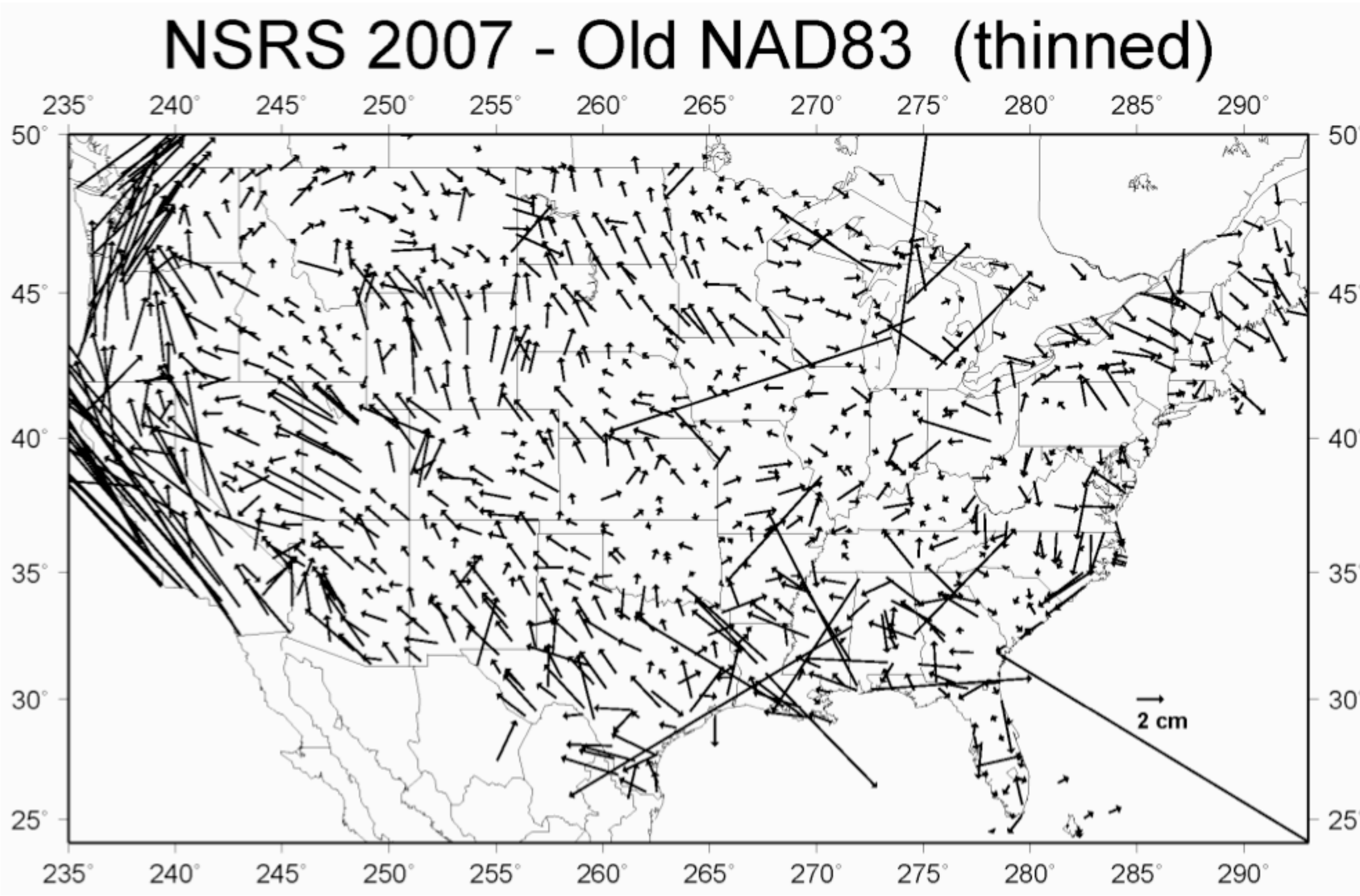


Figure 6.1. Horizontal position shifts of thinned point set, Conterminous U.S.

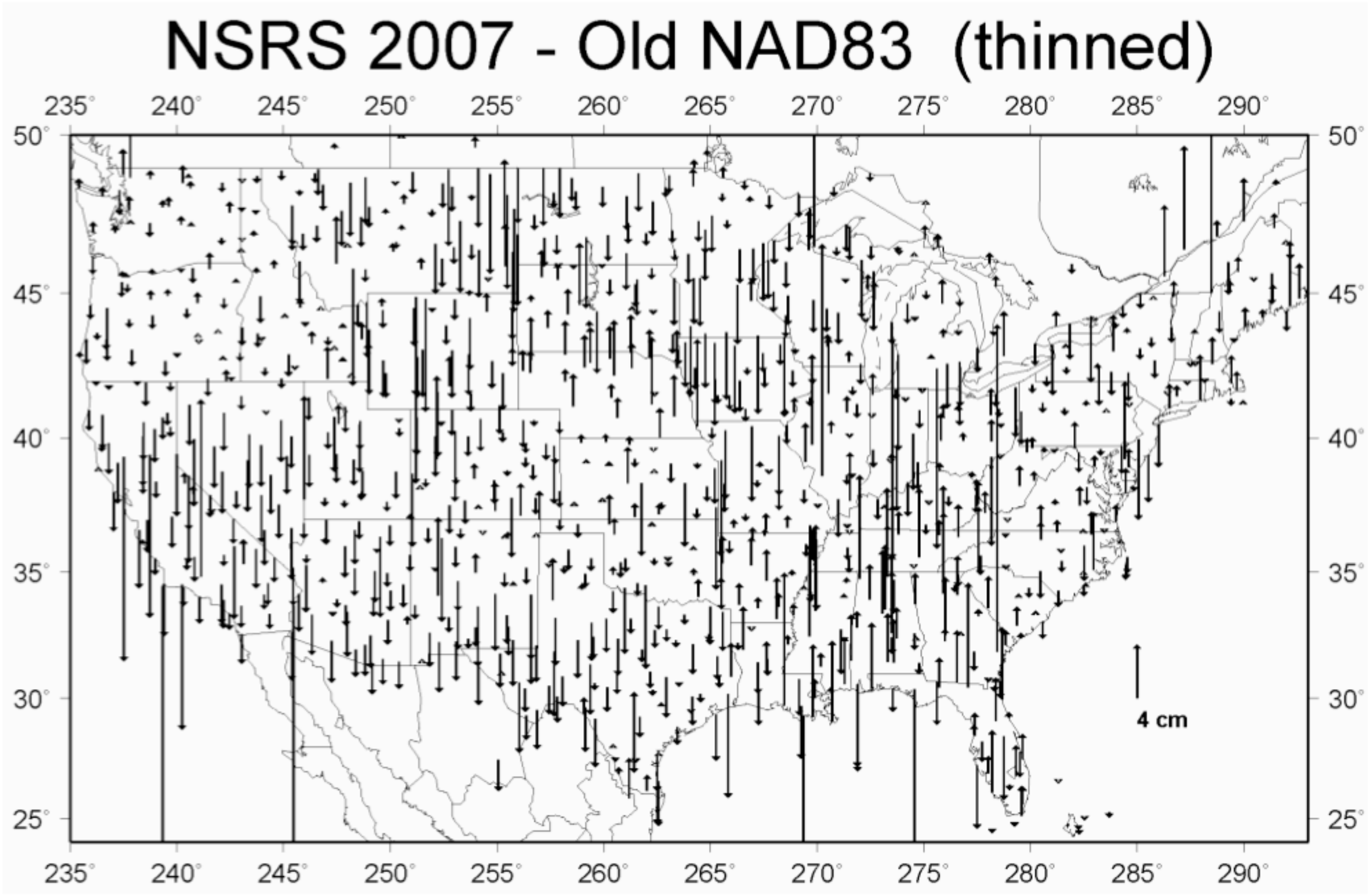


Figure 6.2. Vertical position shifts of thinned point set, Conterminous U.S.

Table 13.1 – Percentiles of Height Residual Statistics, Free Adjustment

Percentile	Residual (cm)	Std. Dev. (cm)	Standardized (unitless)
50%	0.53	1.16	0.454
68%	0.90	1.70	0.709
90%	2.01	3.69	1.311
95%	2.73	5.36	1.657
99%	4.15	12.28	2.595
99.9%	5.46	51.88	4.749

Table 14.2 – Percentiles of Height Residual Statistics, Fixed Adjustment

Percentile	Residual (cm)	Std. Dev. (cm)	Standardized (unitless)
50%	0.54	1.25	0.432
68%	0.93	1.84	0.676
90%	2.06	3.98	1.259
95%	2.80	5.78	1.600
99%	4.25	13.22	2.511
99.9%	6.32	54.41	4.814
Extrema	-46.74 to 41.26	1460.04	-49.363 to 22.580

Problems with NAD83(2007)

- Dr. Dennis Milbert, former Chief Geodesist of NGS

An Analysis of the NAD 83(NSRS2007) National Readjustment

Dennis Milbert, Ph.D.
Rockville, Md.

ABSTRACT

On February 6, 2007, the final fixed adjustment of the NAD 83(NSRS2007) National Readjustment was completed. GPS carrier phase data, reduced to correlated inter-station vectors observed from 1983 to November 2005, were processed in a simultaneous least-squares adjustment. A CORS coordinate set, epoch 2002.0, established the NAD 83 system; although crustal motion effects were applied to coordinates and vectors in California, Arizona, Nevada, Oregon, and Washington to realize an epoch of 2007.0. FGDC network accuracies (95% *a posteriori* statistics) show medians of 1.03 cm horizontal and 1.84 cm vertical. Analysis of the residuals shows insufficient outer rejection and the potential need to reweight four categories of projects. These problems lead to long tails in statistical distributions and inflation of the *a posteriori* statistics. Comparisons show that less than 1% of the residuals change horizontally by 1 cm or more between the free and fixed adjustments.

NAD83 (2011) Objectives

1. Perform a simultaneous least-squares adjustment of GNSS vectors held in the NGSIDB to derive accurate and consistent NAD 83 coordinates (latitude, longitude, and ellipsoid height) for passive marks positioned using these vectors.

2. Optimally align the new passive control coordinates with the latest realization of the Continuously Operating Reference Station (CORS) network by constraining the adjustment to the current NAD 83 CORS coordinates.

3. Seamlessly integrate the results of this Project into the NGSIDB and all affected NGS products and services.

Why MYCS?

FAQ 1: Why Reprocess?

1) Mixed coordinates from an earlier solution (1994-2002) that used only 3-8 ITRF reference frame sites to align to the global frame

2) Mixed horizontal velocities: modeled from HTDP vs. computed

3) Mixed vertical velocities, which for many of the NAD 83(COR96,MARP00,PACP00) epoch 2002.00 stations are assigned a value of 0 mm/yr

4) NGS's current global frame is ITRF00 epoch 1997.00; projecting positions 13 years to the present is unrealistic

5) NGS's current plate-fixed frame is NAD 83(CORS96,MARP00,PACP00) epoch 2002.00; projecting positions 8 years to the present is also questionable

6) Implementing significant changes to existing processing algorithms and models including compliance with IERS conventions (i.e. software changes)

7) Switching from using relative antenna calibration to absolute antenna calibrations

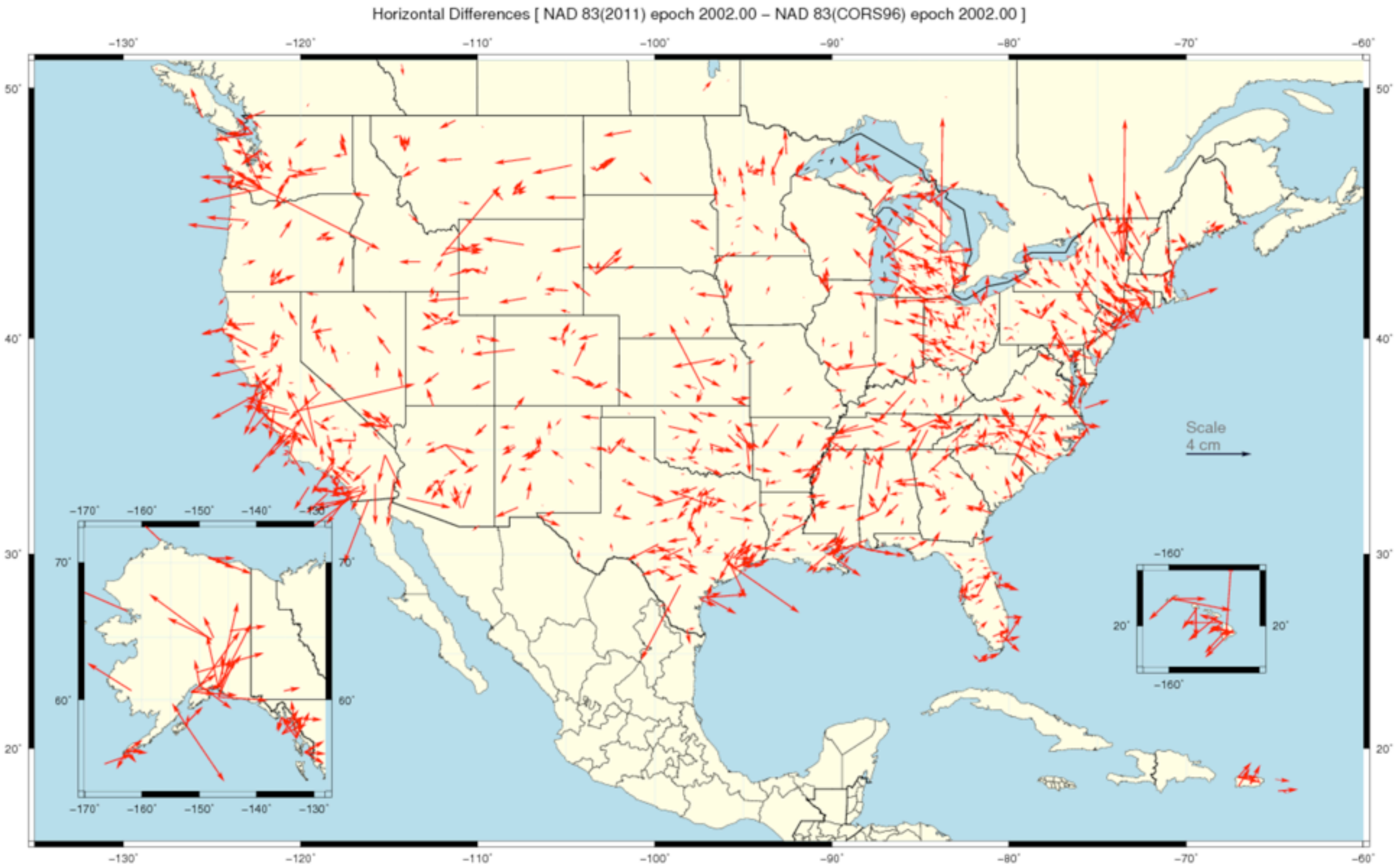
8) The current state-of-the-art full (~230 stations) global reference frame: IGS08 epoch 2005.00

Given these major inconsistencies and changes, NGS elected to reprocess all its CORS data to provide a single consistent set of coordinates for all sites computed using the best available methods.

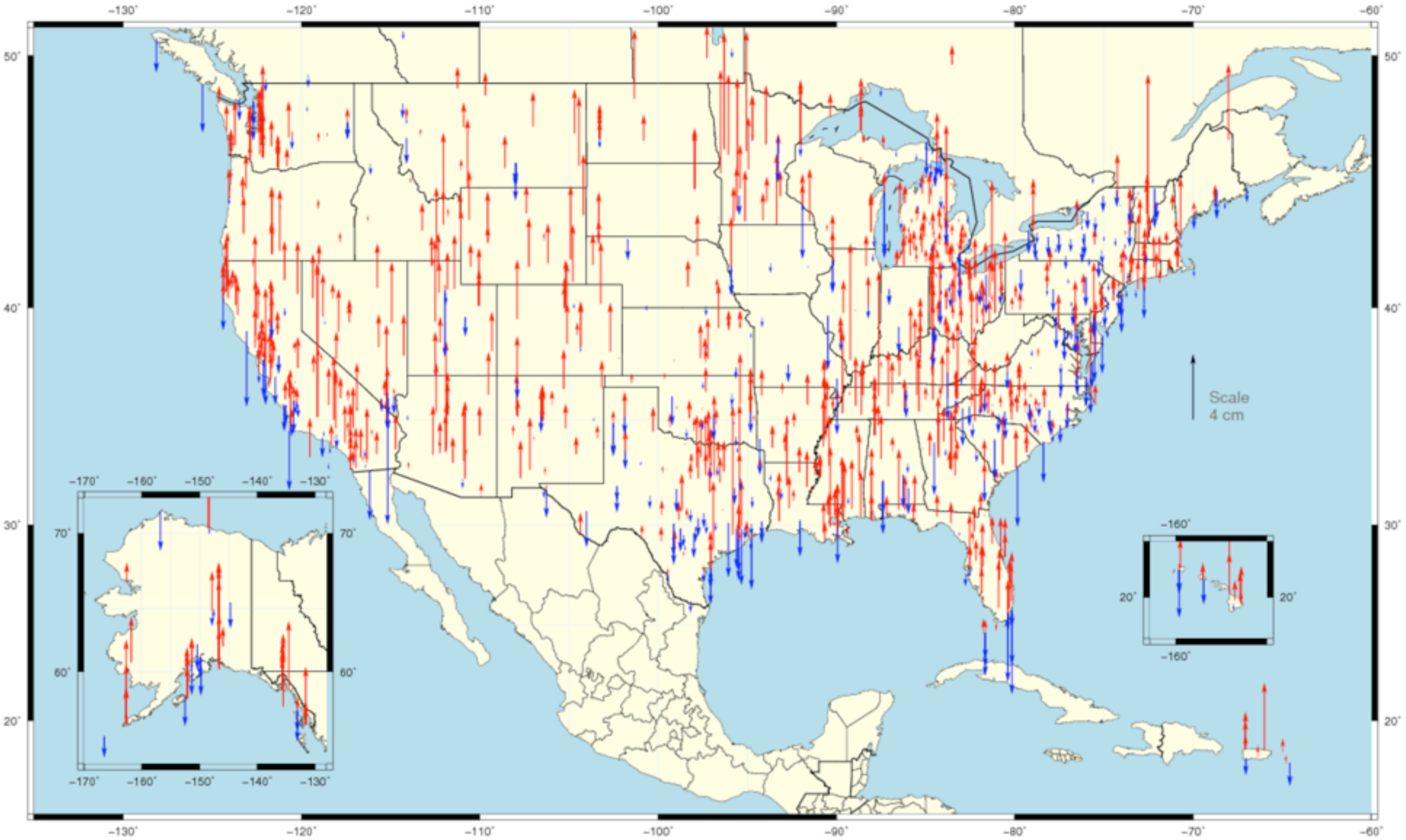
MYCS and NAD83 (2011)

2. NGS has performed a reanalysis of Continuously Operating Reference Station (CORS) data, in conjunction with an international effort coordinated by the International GNSS Service (IGS). This reanalysis, known as the Multi-Year CORS Solution (MYCS), has yielded new geometric coordinates and velocities on CORS using data from 1994 through the present. For NGS products and services to be mutually aligned, it is necessary to perform an adjustment (constrained to the new MYCS coordinates) of as many of the GNSS vectors held in the NGS Integrated Data Base (NGSIDB) as possible. These vectors represent GNSS observations between passive stations, and between passive stations and CORS (i.e., active stations). The vectors that are tied to CORS will make it possible to determine new coordinates on passive control consistent with the MYCS. More information on the MYCS is available on the NGS

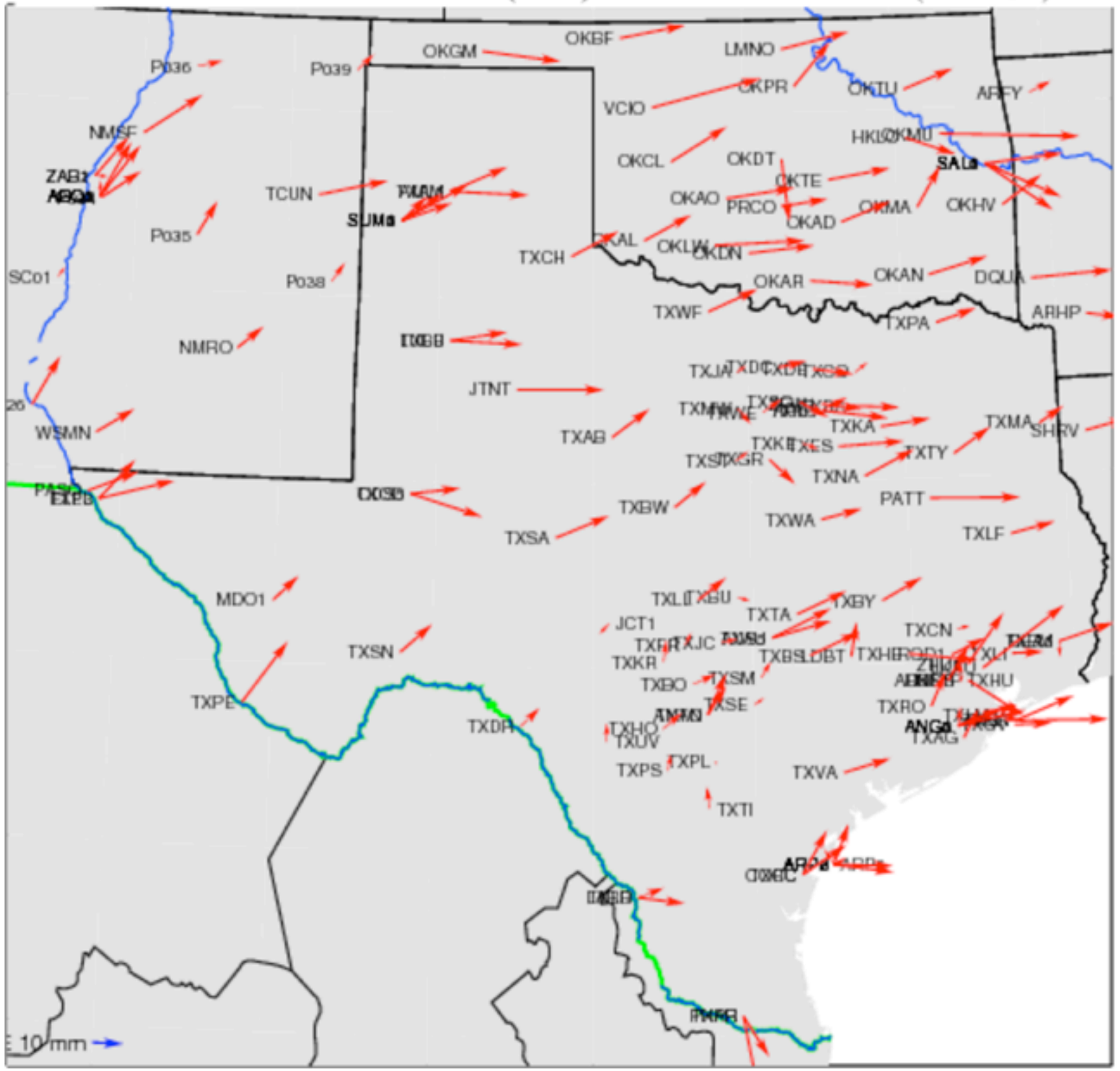
NAD83 (2011) and NAD83(CORS96)



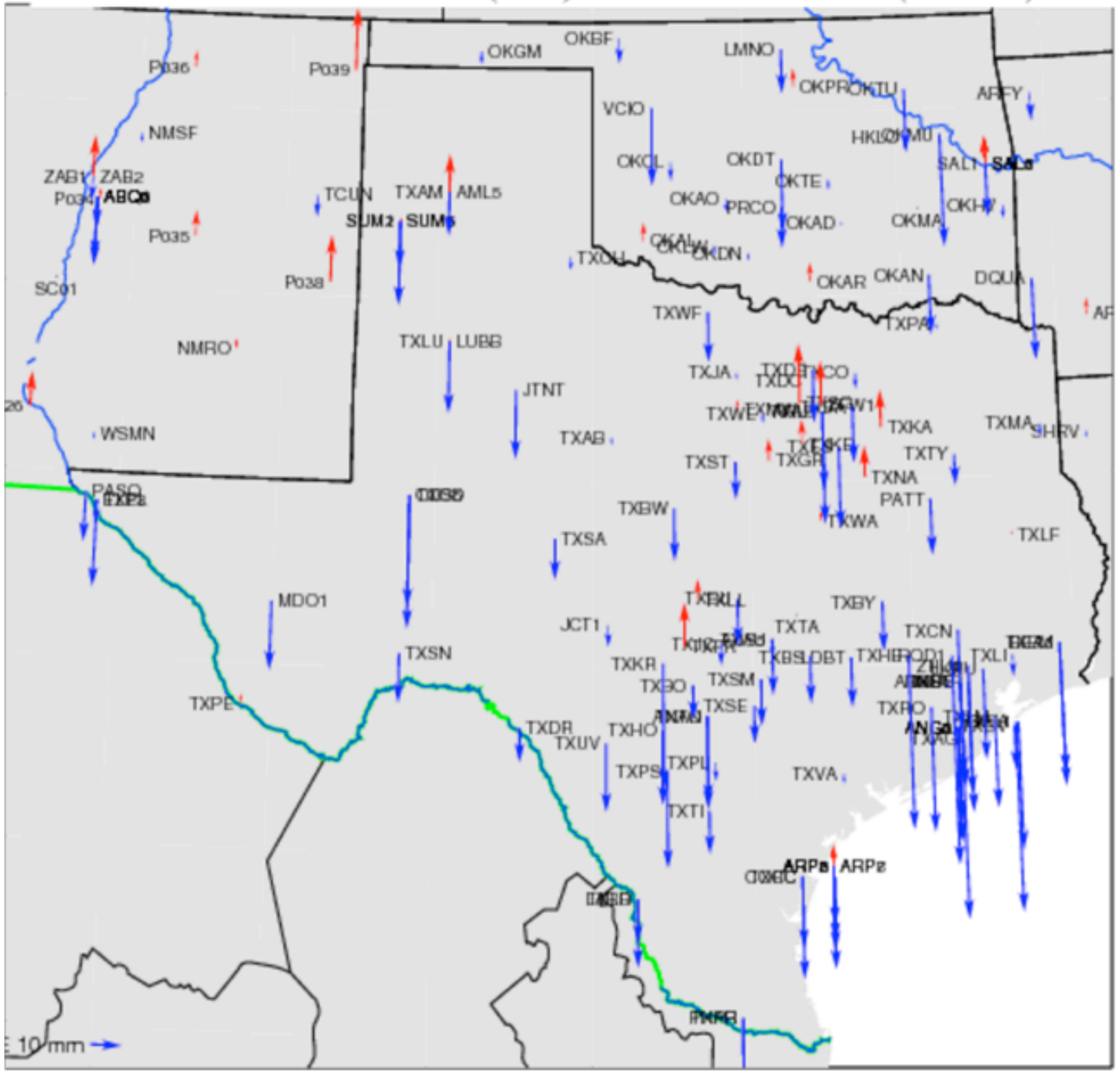
Vertical Differences [NAD 83(2011) epoch 2002.00 – NAD 83(CORS96) epoch 2002.00]



TX Horizontal POSITIONS NAD 83(2011) 2010.00 minus NAD 83(CORS96) 2002.0



TX Vertical POSITIONS NAD 83(2011) 2010.00 minus NAD 83(CORS96) 2002.



International Terrestrial Reference Frame

Best geocentric system available

- Stable to about a cm
- Maintained by IERS under auspices of IAG
- Primarily for scientific community & national datums

Dynamic system

- Coordinates changing due to plate tectonics
  - Valid only for a specific date (epoch)
  - Velocities provided to update to other epochs

Frequent new realizations

- Due to more data & improved techniques

ITRF88
ITRF89
ITRF90
ITRF91
ITRF92
ITRF93
ITRF94
ITRF96
ITRF97
ITRF2000
ITRF2005

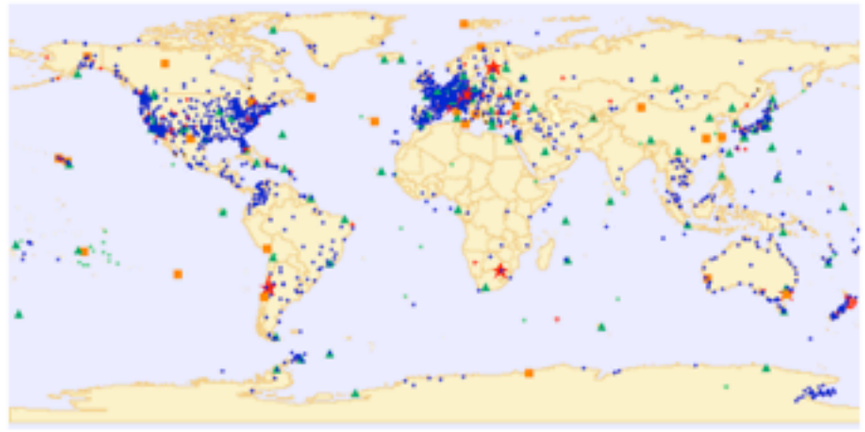
International Terrestrial Reference Frame
I T R F

Search by DOMES number : OK SEARCH ?

Welcome to the ITRF web site

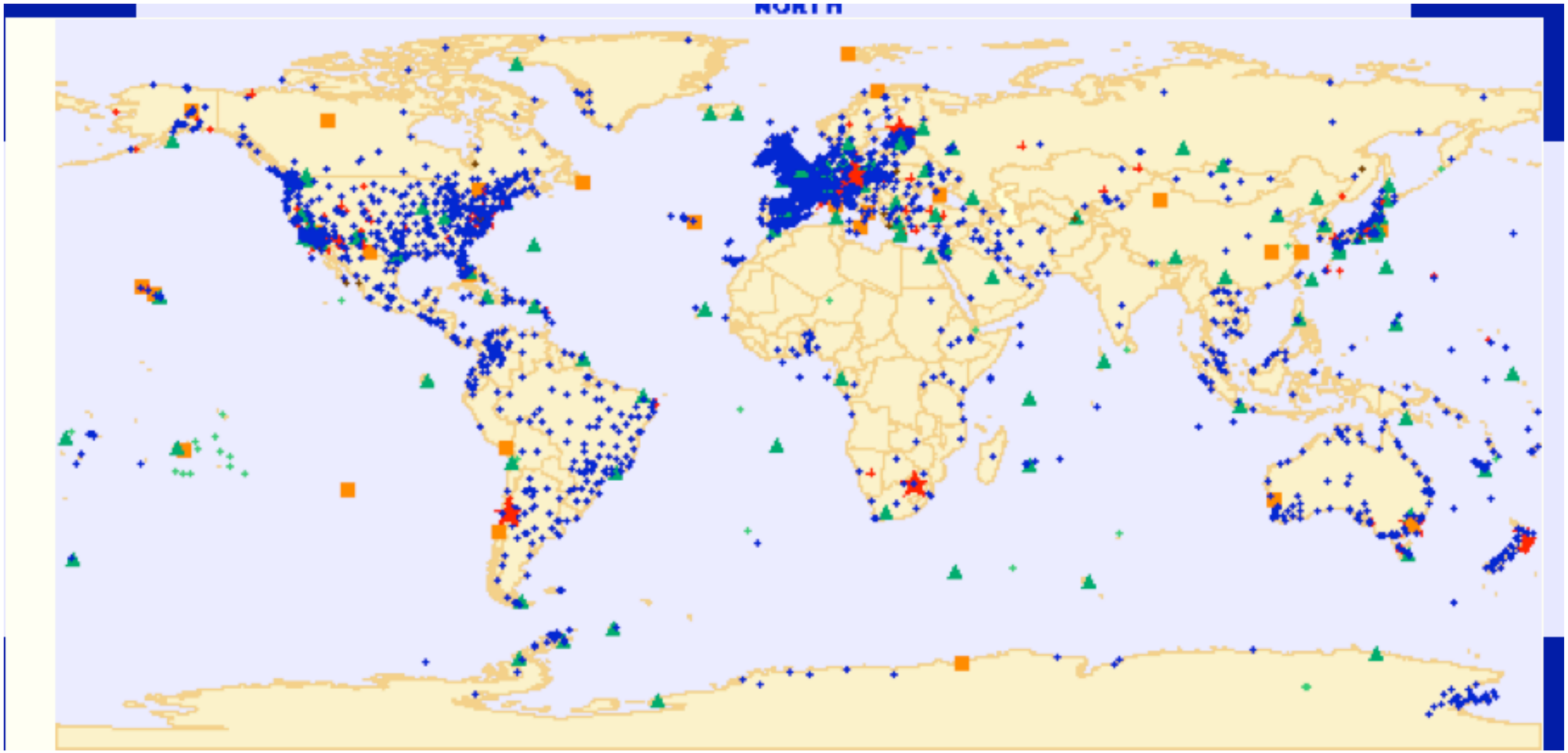
The objective of this web site is to distribute the International Terrestrial Reference Frame (ITRF) products. ITRF94, ITRF96, ITRF97, ITRF2000, ITRF2005 and ITRF2008 solutions are available for download. It also contains the description and list of all the IERS stations.

A map server is available here to familiarize users about ITRF and help them to work with the products. The request for ITRF coordinates has also been simplified by the introduction of new web site tools.



map server

ITRF sites



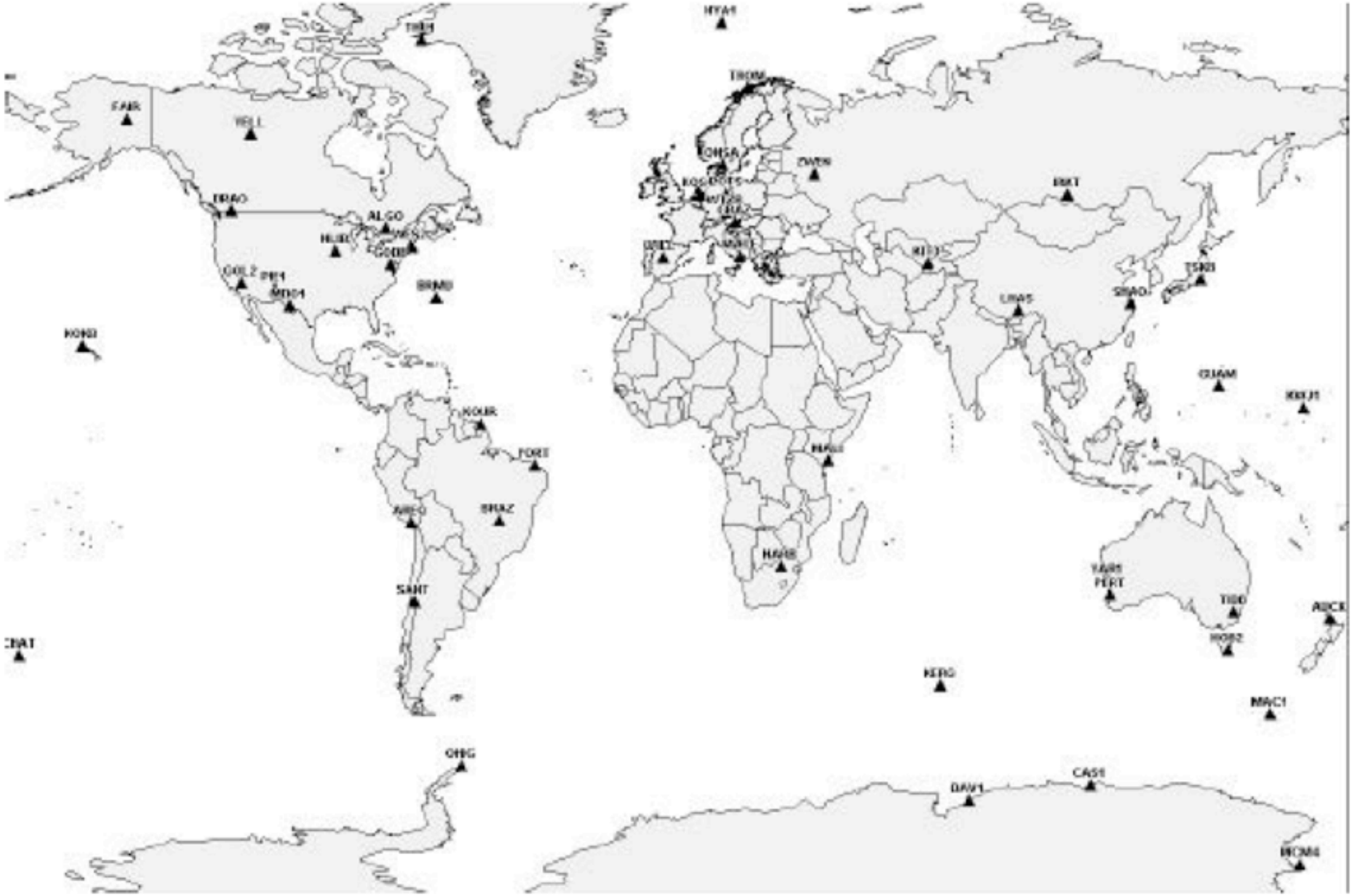


Figure 2. Worldwide Distribution of IGS Fiducial Stations ? IGS Station

International Terrestrial Reference Frame

The International Terrestrial Reference System (ITRS) is a world spatial reference system co-rotating with the Earth in its diurnal motion in space. The IERS, in charge of providing global references to the astronomical, geodetic and geophysical communities, supervises the realization of the ITRS. Realizations of the ITRS are produced by the IERS ITRS Product Center (ITRS-PC) under the name International Terrestrial Reference Frames (ITRF). ITRF coordinates were obtained by combination of individual TRF solutions computed by IERS analysis centers using the observations of Space Geodesy techniques : GPS , VLBI , SLR, LLR and DORIS. They all use networks of stations located on sites covering the whole Earth.

ITRF2008

Introduction

ITRF2008 is the new realization of the International Terrestrial Reference System. Following the procedure already used for the ITRF2005 formation, the ITRF2008 uses as input data time series of station positions and Earth Orientation Parameters (EOPs) provided by the Technique Centers of the four space geodetic techniques (GPS, VLBI, SLR, DORIS). Based on completely reprocessed solutions of the four techniques, the ITRF2008 is expected to be an improved solution compared to ITF2005.

The International Terrestrial Reference System

Definitions

IERS is the current structure in charge to define, realize and promote the International Terrestrial Reference System (ITRS) as defined by the IUGG resolution No 2 adopted in Vienna, 1991 (Geodesist's Handbook, 1992), providing the definition of a CTRS which is the basis of the ITRS. The resolution recommends the following definitions of the CTRS:

1. CTRS to be defined from a geocentric non-rotating system by a spatial rotation leading to a quasi-Cartesian system,
2. the geocentric non-rotating system to be identical to the Geocentric Reference System (GRS) as defined in the IAU resolutions,
3. the coordinate-time of the CTRS as well as the GRS to be the Geocentric Coordinate Time (TCG),
4. the origin of the system to be geocenter of the Earth's masses including oceans and atmosphere, and
5. the system to have no global residual rotation with respect to horizontal motions at the Earth's surface.

The ITRS definition fulfills the following conditions:

- it is geocentric, the center of mass being defined for the whole Earth, including oceans and atmosphere.
- the unit of length is the meter (SI). This scale is consistent with the TCG time coordinate for a geocentric local frame, in agreement with IAU and IUGG (1991) resolutions. This is obtained by appropriate relativistic modelling.
- its orientation was initially given by the Bureau International de l'Heure (BIH) orientation at 1984.0.
- the time evolution of the orientation is ensured by using a no-net-rotation condition with regards to horizontal tectonic motions over the whole Earth.

Transformation Parameters ITRF00 to previous

TRANSFORMATION PARAMETERS AND THEIR RATES FROM ITRF2000 TO PREVIOUS FRAMES
(See Note Below)

SOLUTION	T1	T2	T3	D	R1	R2	R3	EPOCH	Ref.
UNITS---------->	cm	cm	cm	ppb	.001"	.001"	.001"		IERS Tech. Note #
	.	.	.	.	.	.	.		
RATES	T1	T2	T3	D	R1	R2	R3		
UNITS---------->	cm/y	cm/y	cm/y	ppb/y	.001"/y	.001"/y	.001"/y		
ITRF97	0.67	0.61	-1.85	1.55	0.00	0.00	0.00	1997.0	27
rates	0.00	-0.06	-0.14	0.01	0.00	0.00	0.02		
ITRF96	0.67	0.61	-1.85	1.55	0.00	0.00	0.00	1997.0	24
rates	0.00	-0.06	-0.14	0.01	0.00	0.00	0.02		
ITRF94	0.67	0.61	-1.85	1.55	0.00	0.00	0.00	1997.0	20
rates	0.00	-0.06	-0.14	0.01	0.00	0.00	0.02		
ITRF93	1.27	0.65	-2.09	1.95	-0.39	0.80	-1.14	1988.0	18
rates	-0.29	-0.02	-0.06	0.01	-0.11	-0.19	0.07		
ITRF92	1.47	1.35	-1.39	0.75	0.00	0.00	-0.18	1988.0	15
rates	0.00	-0.06	-0.14	0.01	0.00	0.00	0.02		
ITRF91	2.67	2.75	-1.99	2.15	0.00	0.00	-0.18	1988.0	12
rates	0.00	-0.06	-0.14	0.01	0.00	0.00	0.02		
ITRF90	2.47	2.35	-3.59	2.45	0.00	0.00	-0.18	1988.0	9
rates	0.00	-0.06	-0.14	0.01	0.00	0.00	0.02		
ITRF89	2.97	4.75	-7.39	5.85	0.00	0.00	-0.18	1988.0	6
rates	0.00	-0.06	-0.14	0.01	0.00	0.00	0.02		
ITRF88	2.47	1.15	-9.79	8.95	0.10	0.00	-0.18	1988.0	IERS An. Rep. for 1988
rates	0.00	-0.06	-0.14	0.01	0.00	0.00	0.02		

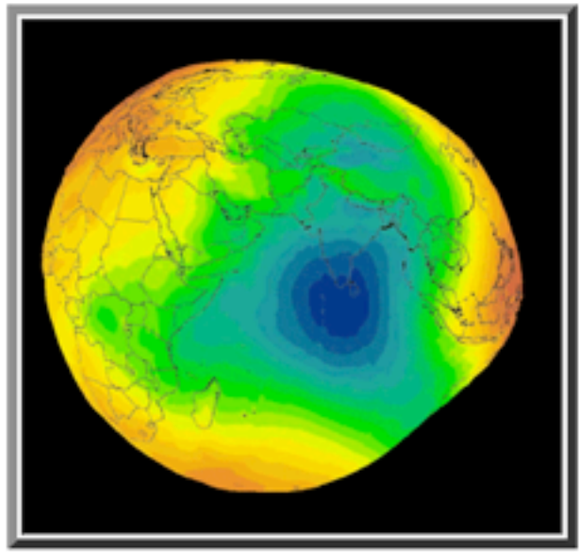
Transformation Parameters wrt ITRF2008

Transformation parameters from ITRF2008 to past ITRFs.

SOLUTION	Tx	Ty	Tz	D	Rx	Ry	Rz	EPOCH
UNITS---------->	mm	mm	mm	ppb	.001"	.001"	.001"	
	.	.	.	.	.	.	.	
RATES	Tx	Ty	Tz	D	Rx	Ry	Rz	
UNITS---------->	mm/y	mm/y	mm/y	ppb/y	.001"/y	.001"/y	.001"/y	
ITRF2005	-2.0	-0.9	-4.7	0.94	0.00	0.00	0.00	2000.0
rates	0.3	0.0	0.0	0.00	0.00	0.00	0.00	
ITRF2000	-1.9	-1.7	-10.5	1.34	0.00	0.00	0.00	2000.0
rates	0.1	0.1	-1.8	0.08	0.00	0.00	0.00	
ITRF97	4.8	2.6	-33.2	2.92	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF96	4.8	2.6	-33.2	2.92	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF94	4.8	2.6	-33.2	2.92	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF93	-24.0	2.4	-38.6	3.41	-1.71	-1.48	-0.30	2000.0
rates	-2.8	-0.1	-2.4	0.09	-0.11	-0.19	0.07	
ITRF92	12.8	4.6	-41.2	2.21	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF91	24.8	18.6	-47.2	3.61	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF90	22.8	14.6	-63.2	3.91	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF89	27.8	38.6	-101.2	7.31	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF88	22.8	2.6	-125.2	10.41	0.10	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	

http://earth-info.nga.mil/GandG/wgs84/

Office of Geomatics: World Geodetic System 1984 (WGS 84)



Our Mission .....Develop, maintain, and enhance the World Geodetic System 1984, the reference frame upon which all geospatial-intelligence is based

Our Customers .....Unlimited

Original WGS84

Native reference frame of GPS

Datum

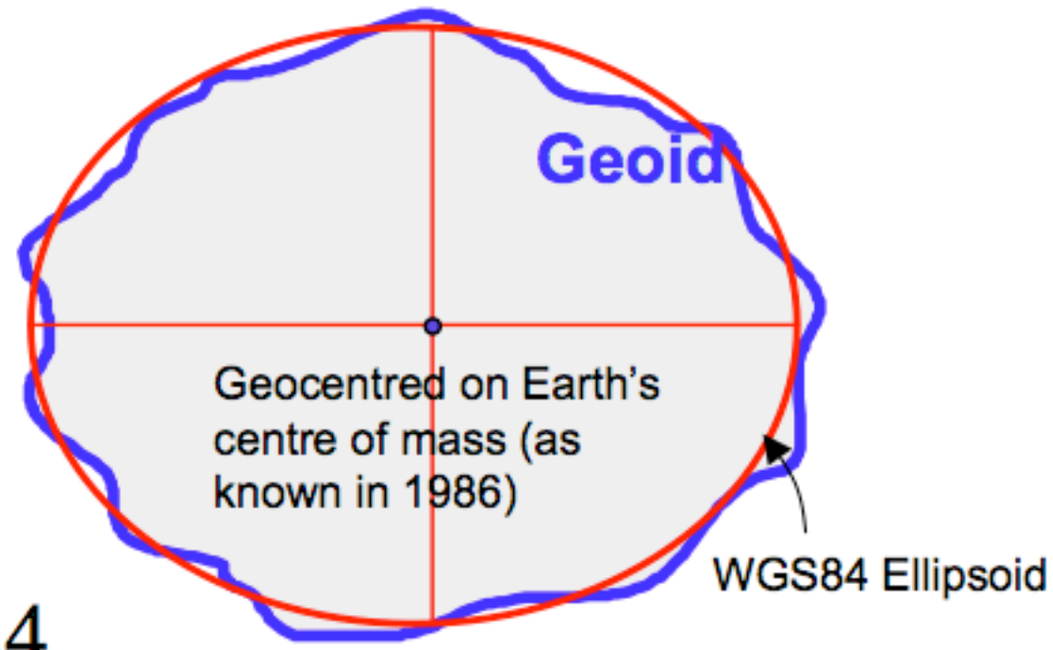
- WGS84 ellipsoid (=GRS80)

Based on Doppler & BTS84

- Aligned to international BTS84
- Near-geocentric +/- 1 m (best could do at the time)

No physical ground network or coordinates

- Satellites (brdcst orbits) are only accessible "control"
- Enables point positioning only: 1-10 m accuracy



Taken from M. Craymer's talk at: http://www.naref.org/transf/nad83_hydroscan2006.pdf

WGS84 "G" Series

Original WGS84 Realigned to ITRF (shifted/reoriented)

- Greater accuracy & stability
- Compatible with internationally adopted ITRF

Version	Based on	Introduced
WGS84(G730)	ITRF91	1994
WGS84(G873)	ITRF94	1996
WGS84(G1150)	ITRF2000	2002

Introduced a coordinate shift

- In Canada: 1.5 m horiz. 0.2-1.0 m vert.
- Not noticeable in WGS84 (+/- 1 m) but is in NAD83

What about WGS84?

ITRS and WGS84
Last update : 2007-10-11

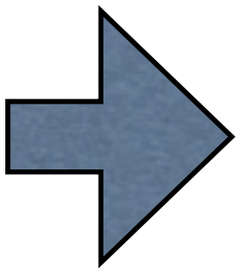
In general the ITRS (and its realizations ITRFyy) are identical to WGS84
at one meter level.

Meanwhile there are two types of WGS84 realization:

- old realization based on U.S. Navy Navigation Satellite System,
  commonly known as DOPPLER Transit, and provided station coordinates
  with accuracies of about one meter. With respect to this realization
  we published, some years ago, transformation parameters between
  ITRF90 and this Doppler realized system:

Parameters from ITRF90 to WGS84-Doppler realized system

	T1	T2	T3	D	R1	R2	R3
UNITS ----->	(m)	(m)	(m)	(ppm)	(")	(")	(")
	0.060	-0.517	-0.223	-0.011	0.0183	-0.0003	0.0070



- New realizations of WGS84 based on GPS data, such as WGS84(G730, G873
  and G1150). These new WGS84 realizations are coincident with ITRF at
  about 10-centimeter level. For these realizations there are no official
  transformation parameters. This means that one can consider that ITRF
  coordinates are also expressed in WGS84 at 10 cm level.

  For more information about WGS84 realizations, see
  U.S. National Imagery and Mapping Agency, "Department of
  Defense World Geodetic System 1984 -- Its Definition and
  Relationships with Local Geodetic Systems." NIMA Technical
  Report 8350.2 3rd release, St. Louis, MO, 23 June 2004.
  http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html

WGS 84 G1674

WGS84(G1150) ≈ ITRF00

WGS84(G873) ≈ ITRF96

WGS84(G730) ≈ ITRF92

ION GNSS 2012
Session A3: Geodesy, Surveying & RTK for Civil Applications

Title: Recent Updates to the WGS84 Reference Frame
Author(s): R. Wong, C. Rollins, National Geospatial Intelligence Agency
Date/Time: Thursday, September 20, 2012, 11:48 a.m.
Room: 103/104 (NCC)

The World Geodetic System of 1984 (WGS 84) was developed and is maintained by the National Geospatial Intelligence Agency (NGA) for DoD and the armed services. It is the reference system for all DoD operations and provides the common framework for all geospatial information. In particular, the Global Positioning System (GPS) uses WGS 84 as its geodetic reference system. Consequently all real-time users of GPS are, by default, using the WGS 84 spatial reference frame.

The world-wide use of WGS 84 motivates NGA to make WGS 84 conform, as much as possible, to the international standard for geodetic reference frames, i.e. the International Terrestrial Reference Frame (ITRF). ITRF has undergone numerous revisions over the last two decades, and the most recent version is ITRF08. Likewise, WGS 84 has seen several versions, sometimes called datum tags, namely G730, G873, G1150, and the newest is now G1674, implemented on February 8, 2012 by the GPS Master Control Station. The goal of these re-adjustments has been to align with the newest version of ITRF.

The need for the new adjustment: Since the implementation of G1150 in January of 2002, ITRF has undergone two revisions (ITRF00 to ITRF05, and ITR05 to ITRF08), and additionally, during 2009 and 2010, NGA (with USAF participation) performed some life-cycle replacements of GPS monitor station equipment, especially the antennas. The replacement of the antenna alone (from Ashtech brand to customized antennas from ITT) implies a coordinate change because the new antennas have different antenna phase centers compared to the old. At several monitor stations, NGA took the opportunity to couple antenna replacement with site maintenance, such as replacing rickety towers, or moving an antenna to a site less susceptible to electromagnetic interference.

General method to align WGS 84 to ITRF: In theory, WGS 84 and ITRF are defined by the same principles, such as that the origin of XYZ coordinates is to be the center of mass of the Earth, and the Z-axis of XYZ coordinate is to be aligned in some way to a mean rotation axis of the Earth (this list is not exhaustive). But in practice, the ITRF frame is realized by the XYZ coordinates of its fiducial points, and the WGS 84 frame is likewise realized by XYZ coordinates of its fiducial points, a complete separate set. The two frames are aligned if, the coordinates of the first Frame´s fiducial points are consistent with the coordinates of the 2nd Frame´s fiducial points. The goal of the G1674 re-adjustment was to give the WGS 84 fiducial points, i.e. the GPS monitor station antenna´s phase centers, coordinates consistent with the ITRF08 Frame.

A Refinement to the World Geodetic System 1984 Reference Frame

Michael J. Merrigan, *Naval Surface Warfare Center, Dahlgren Division*
Everett R. Swift, *Naval Surface Warfare Center, Dahlgren Division*
Robert F. Wong, *National Imagery and Mapping Agency*
Joedy T. Saffel, *National Imagery and Mapping Agency*

SUMMARY

To ensure the highest possible degree of accuracy and stability in the WGS 84 reference frame, a joint effort between NSWCDD and NIMA was undertaken to refine the coordinates for the operational GPS tracking stations. The station coordinates were estimated while holding the ITRF2000 coordinates of a large subset of 49 of the IGS fiducial stations fixed using a 15-day data set collected in February 2001. The 15 independent daily solutions were formally combined to obtain the final coordinates. The adopted velocities for the stations were used to move the coordinates back to the 2001.0 epoch. This station coordinate set has been designated WGS 84 (G1150), since they were first implemented at NIMA starting GPS week 1150. The standard deviations of the daily solutions about their means were 0.9, 0.5, and 1.2 cm in the east, north, and up directions, respectively. The formal uncertainties in the solutions combined over all NIMA and Air Force stations were 0.4, 0.2, and 0.4 cm in the east, north, and up directions, respectively. Based on these results, the accuracy of each station coordinate component is estimated to be on the order of one cm, one sigma.

WGS 84 does it matter?

- We (civilians) encounter WGS 84 in the form of broadcast orbit information only (??)
- DOD and NGA elements use WGS 84. We do not.
- Many software packages do not acknowledge the changes shown above in WGS 84. They usually assert WGS84 == NAD 83.

The redefinition of WGS84 resulted in coordinates differences of up to 1.5 m horizontally and 1 m vertically with respect to NAD83 in Canada. Although the national geodetic agencies in both Canada and the U.S. adopted a common transformation between NAD83 and the various ITRFs for use with the new realizations of WGS84, the bias between NAD83 and WGS84 was never acknowledged by the agency maintaining WGS84. Consequently, the vast majority of GPS receiver manufactures continue to treat NAD83 as being identical with the new realizations of WGS84 which results in position errors of over a meter. Moreover, ITRF-based systems are global systems in which all the continents are in continuous motion due to the Earth's tectonic forces while NAD83 is fixed to the North American tectonic plate and move with it. Consequently, NAD83 moves at about 2.5 cm/y relative to the ITRF/WGS84 systems.

Reference frame depends on service/source

- *Uncorrected or WAAS corrections*
  - Receiver positions always in WGS84
  - Still in WGS84 if NGA (zsero) shift to NAD83 applied
- *CDGPS or Coast Guard corrections*
  - Receiver positions in NAD83(CSRS)
  - *Falls back to WGS84 without warning if service signal lost*
- *Post-processing with CSRS-PPP*
  - User selects either NAD83(CSRS) or ITRF/WGS84(G)
- *CSRS Database ("published" values)*
  - Either NAD83 or NAD83(CSRS)