

National Geodetic Survey

# Latest Developments in NGS

**CDOT  
Region 4  
May 31, 2012**



National Oceanic and Atmospheric Administration

## Agenda

- Improvements in the NSRS
- MultiYear CORS Solution ->NAD83 (2011)
- Geoid12/Heights/GRAV-D
- New Data Sheets
- DS-World
- CDOT CORS/OPUS Team Efforts
- OPUS
- CBLs
- LOCUS
- RTN
- NGS Advisor Program
- New Datums (2022)

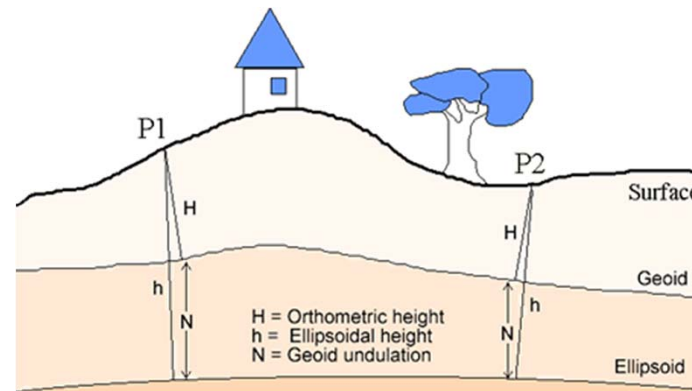
CHANGE  
Improvements



# National Geodetic Survey Mission

To define, maintain and provide access to the National Spatial Reference System (NSRS) to meet our Nation's economic, social and environmental needs.

- Latitude
- Longitude
- Height
- Scale
- Gravity
- Orientation
- Time Variations





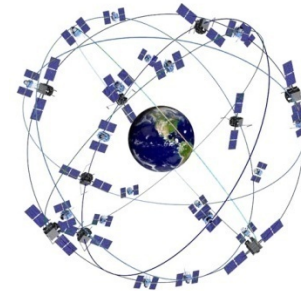
# National Spatial Reference System (NSRS)

The NSRS is a consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States.



One common datum

**Evolving from passive →  
active →  
real-time augmentations**





# NGS

## National Spatial Reference System(NSRS) Improvements

NETWORK	TIME SPAN	NETWORK ACCURACY	LOCAL ACCURACY
NAD 27	1927-1986	10 meters	(1 part in 100,000)
NAD83(86)	1986-1990	1 meter	(1 part in 100,000)
NAD83(199x)* HARN	1990-2007	0.1 meter	B-order (1 part in 1 million) A-order (1 part in 10 million)
NAD83(NSRS2007) (CORS)	2007 -	0.01 meter	0.01 meter

\* CO was completed and adjusted in 2007



# The NSRS has evolved



1 Million  
Monuments  
(Separate  
Horizontal and  
Vertical  
Systems) →

70,000  
Passive Marks  
(3-Dimensional)



Passive Marks  
(Limited Knowledge  
of Stability) →

1,800+ CORS  
(Time Dependent  
System Possible;  
4-Dimensional)



GPS CORS → GNSS CORS



# **“PASSIVE” NETWORK**

marks in the ground

1.5 million marks in the  
National Geodetic Survey database

## **NSRS**

These marks provide:

- Horizontal position, or
- Horizontal position and ellipsoid height, or
- Orthometric Heights, or
- Both Horizontal and Vertical values
- Tidal Information





# **"ACTIVE" Geodetic Network**

Continuously Operating Reference Stations

**CORS**

**NSRS**



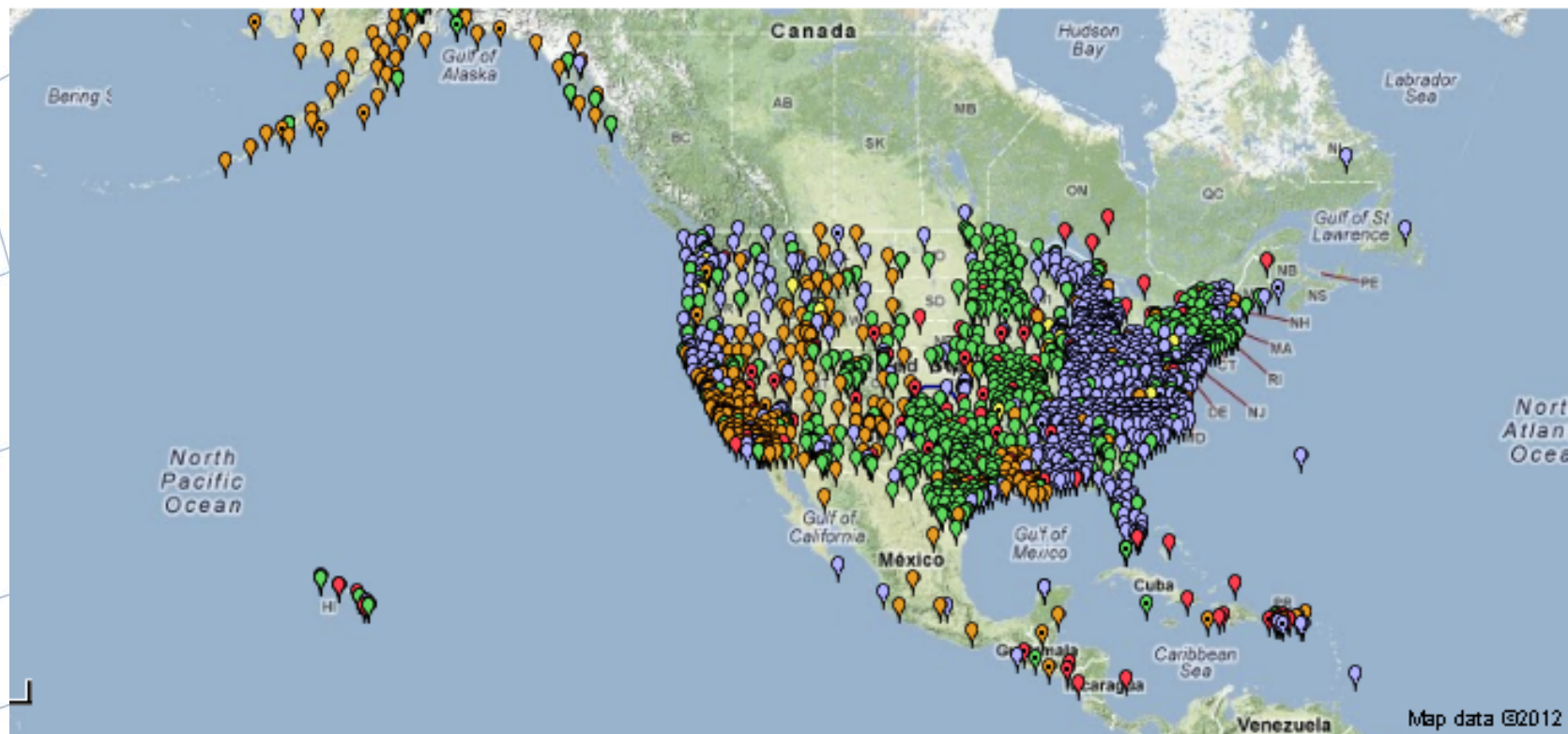
# Current/Future Activities of the NSRS

1. Multi-Year CORS solution - 2011
2. National Adjustment (geometric) of passive control - 2012
3. Hybrid Geoid Model using new ellipsoid heights -2012
4. New Data Sheets - 2012
5. National Adjustment (vertical) of GPS passive marks
  - Under consideration; This not adjusting the leveling network
6. Adoption of new datums



# CORS

Legend icons)  Non-Operational  250 km radius  
 10 sec  15 sec  30 sec  All Active  Decom



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# NAD83 (2011) and the MultiYear CORS Solution

## Previous/Current Reference Frame

NAD 83(2007-CORS96)

Epoch 2002.00

ITRF00

## New Reference Frame

NAD 83(2011)

Epoch 2010.00

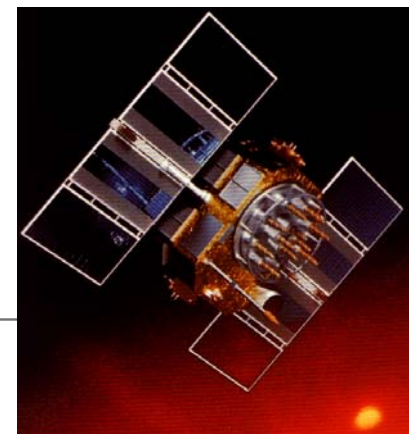
IGS08

Epoch of Observation



## A (very) brief history of NAD 83

- Original realization completed in 1986
  - Consisted (almost) entirely of classical (optical) observations
- "High Precision Geodetic Network" (HPGN) and "High Accuracy Reference Network" (HARN) realizations
  - Most done in 1990s, essentially state-by-state
  - Based on GNSS but classical stations included in adjustments
- National Re-Adjustment of 2007
  - NAD 83(CORS96) and (NSRS2007)
  - Simultaneous nationwide adjustment (GNSS only)
- *New realization: NAD 83(2011) epoch 2010.00*



# Multi-Year CORS Solution

- Longer data spans
- Absolute antenna calibrations
  - satellite transmitting and ground receiving antennas
  - most significant change
- New network design—added redundancy
  - Delaunay triangulation over global sites and CORS backbone
  - tie remaining CORS to backbone as stars
- IERS 2003 Conventions generally implemented
- Updated model for station displacements due to ocean tidal loading
- Updated models for troposphere propagation delays
- Use current frame; first attempt to obtain a full history of products in a fully consistent framework





## Why a Multi-Year CORS Solution?

- Consistent coordinates and velocities from combined solution
  - Previous a mix of station and velocity sources, few ties to global frame
  - Previous vertical velocities of zero for most CORS
- Aligned with most recent realization of global frame (IGS08)
  - **IGS08 epoch 2005.0** (previous aligned at epoch 1997.0)
  - **NAD 83 epoch 2010.0** (previous epochs of 2002.0 and 2003.0)
- Major processing algorithm, modeling, metadata improvements
  - Conformance with current international conventions (IERS)
- Absolute phase center antenna calibrations
  - Both ground (receiving) and satellite (transmitting) antennas
  - Previous (CORS96) used relative calibrations (significant change)
- **Highly accurate *and* consistent CORS coordinates *and* velocities determined using Best Available Methods**
  - ***Needed because CORS network is foundation of NSRS***



## Why a Multi-Year CORS Solution?

- Absolute phase center antenna calibrations used
- More data used in adjustment
  - Includes Velocities
  - Longer data spans
  - Reprocessed all CORS GPS data Jan 1994-Apr 2011
  - 2264 CORS & global stations
  - first attempt to obtain a full history of products in a fully consistent framework
- Consistent coordinates and velocities from combined solution
  - Previous a mix of station and velocity sources
  - Previous few ties to global frame
  - Previous vertical velocities of zero for most CORS
- Aligned with most recent realization of global frame (IGS08)
  - **IGS08 epoch 2005.0** (previous aligned at epoch 1997.0)
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## Why a Multi-Year CORS Solution?

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  - Highly accurate *and* consistent CORS coordinates *and* velocities determined using *Best Available Methods*
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- Updated models for troposphere propagation delays

***Needed because CORS network is foundation of NSRS***

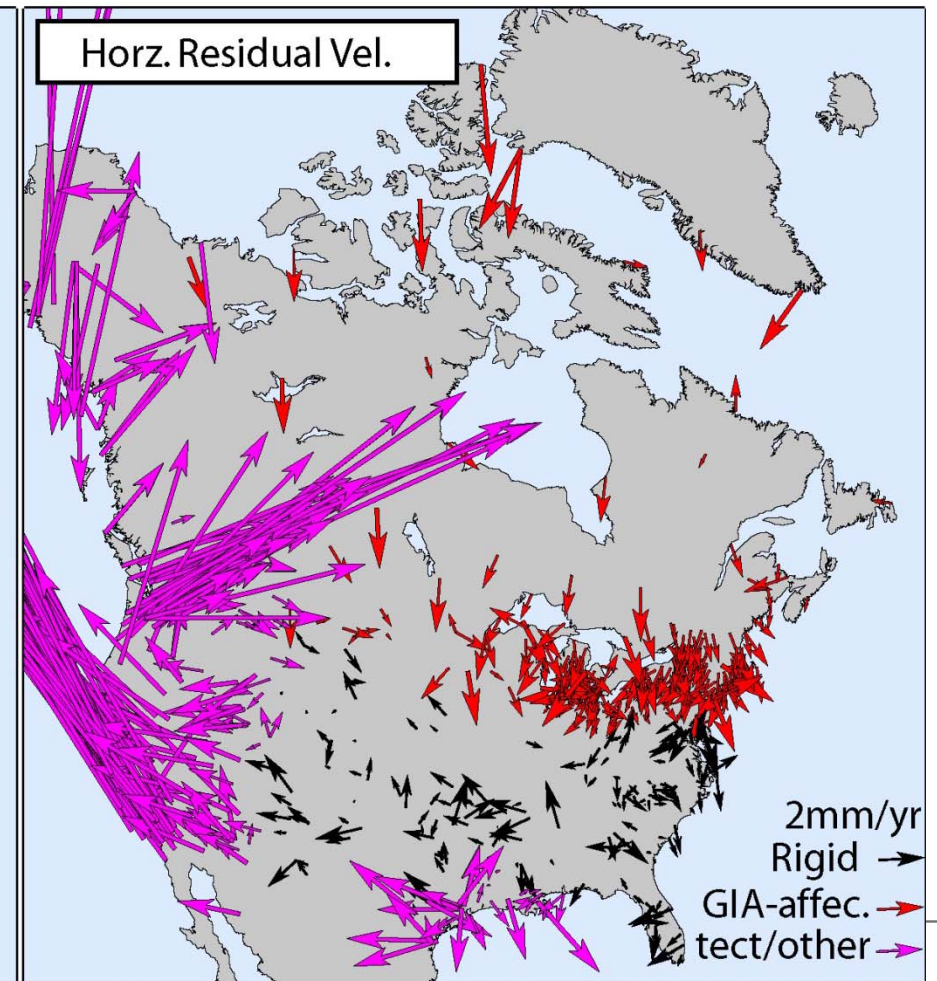
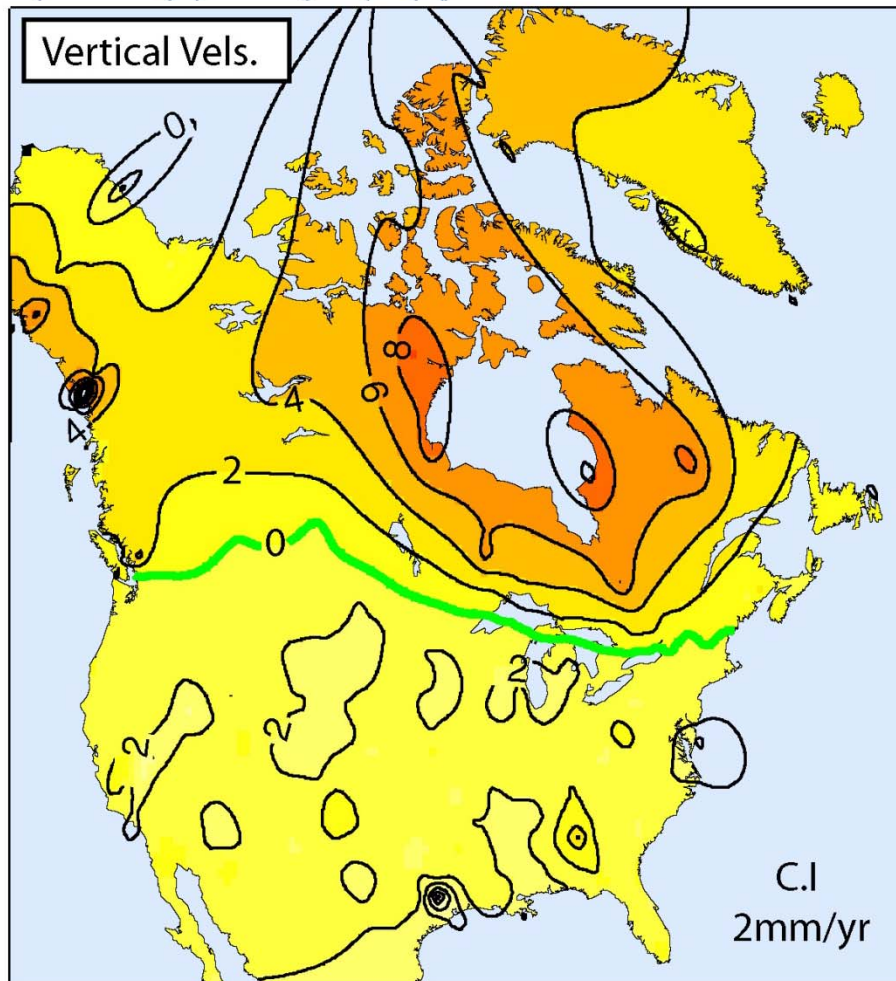




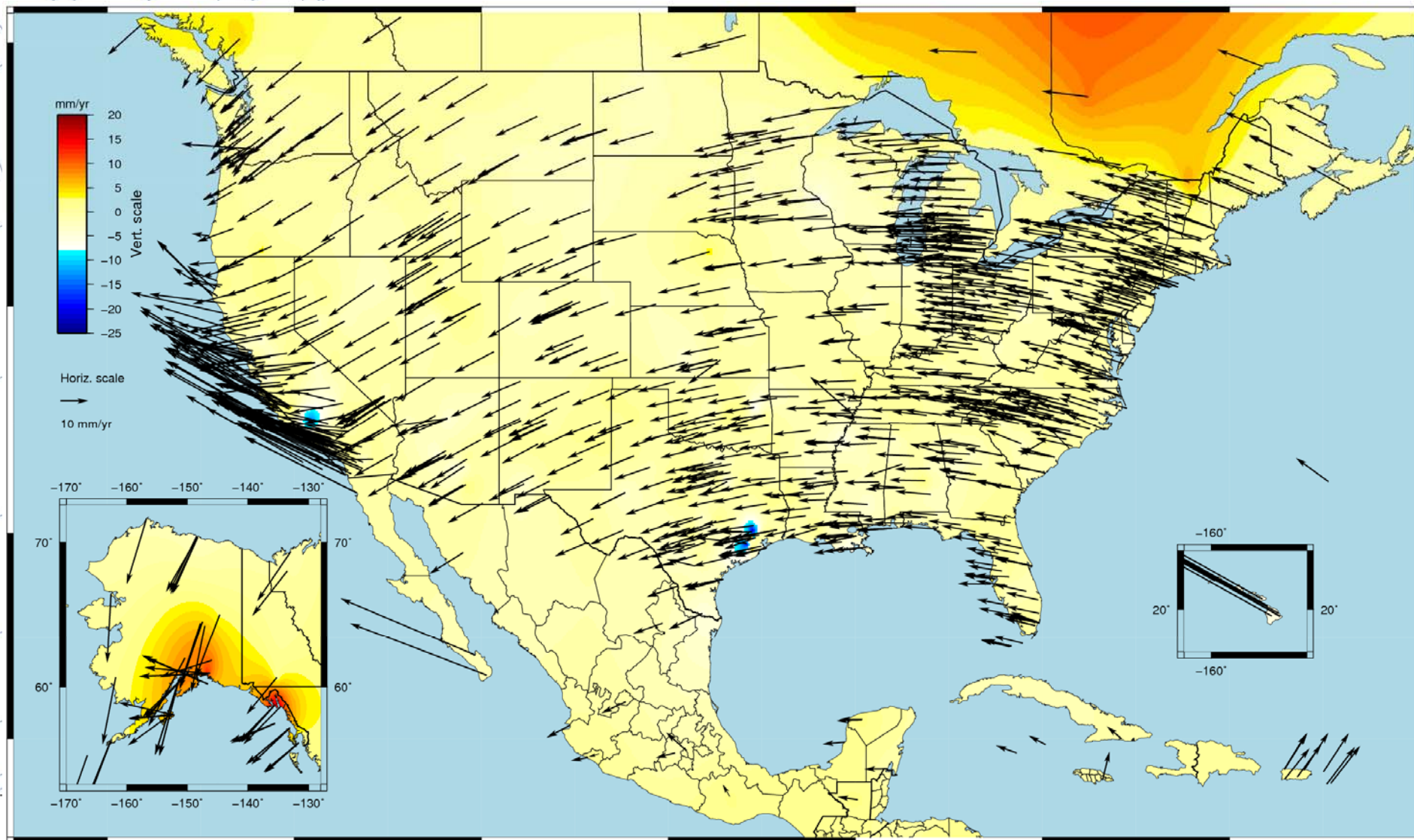
# Positions and Velocities Change!

CORS Multiyear soln.

Plate fixed



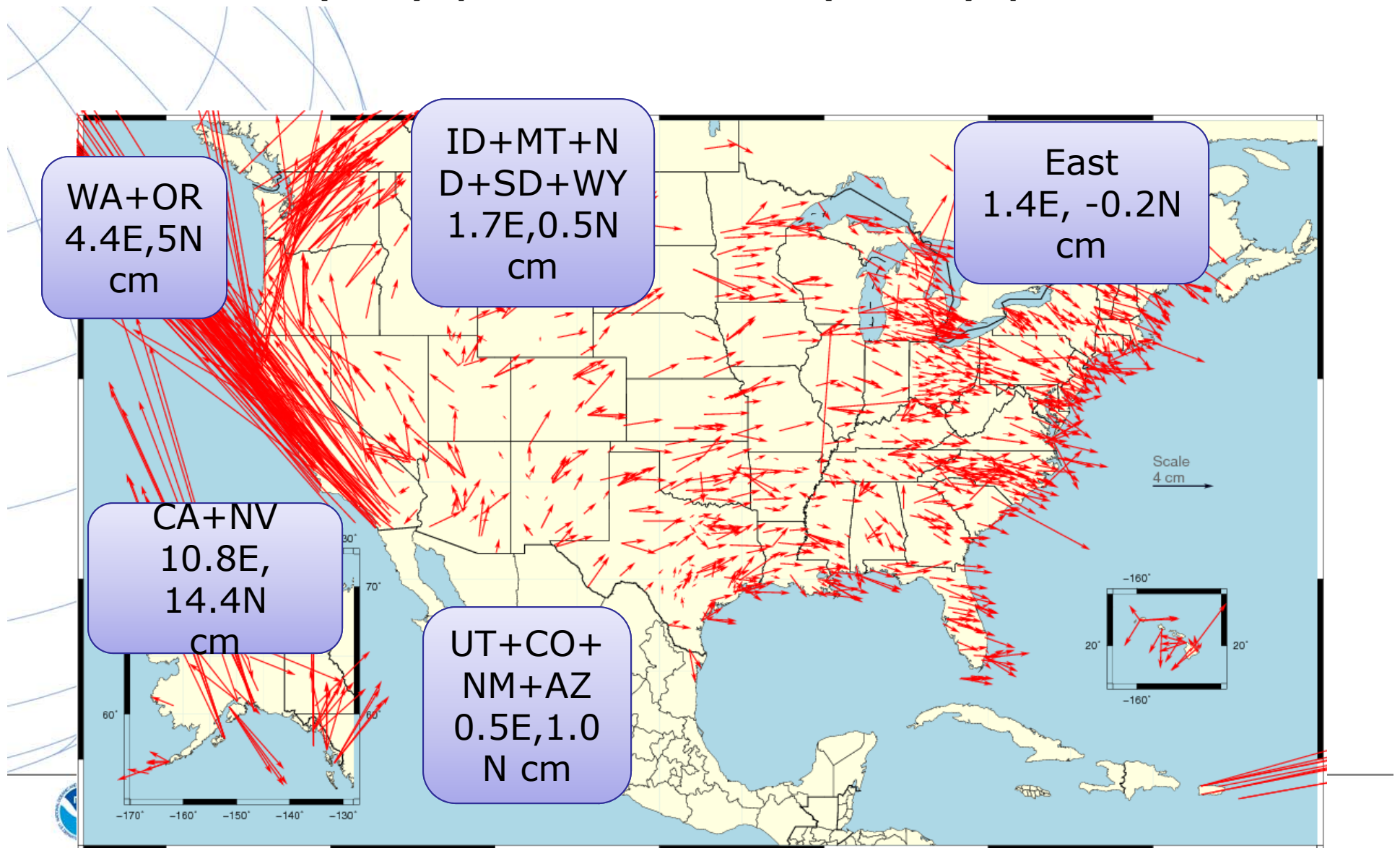
# CORS IGS08 Velocity Field





# Changes in *Horizontal* NAD 83 Positions Different Epochs

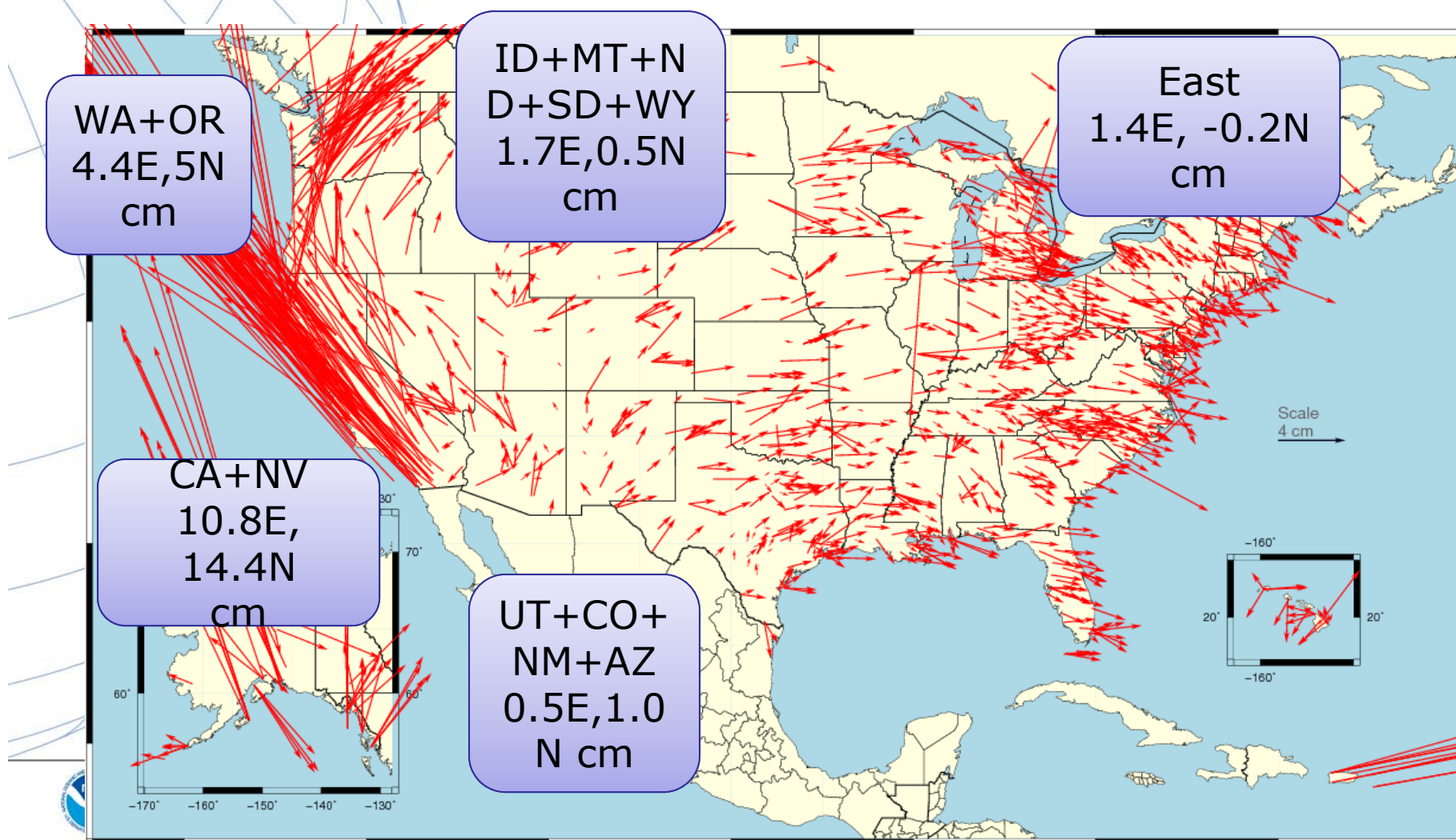
NAD 83(**2011**) epoch **2010.0** – NAD 83(**CORS96**) epoch **2002.0**



# Changes in *Horizontal* NAD 83 Positions **Different Epochs**

**NAD 83(2011) epoch 2010.0 – NAD 83(CORS96) epoch 2002.0**

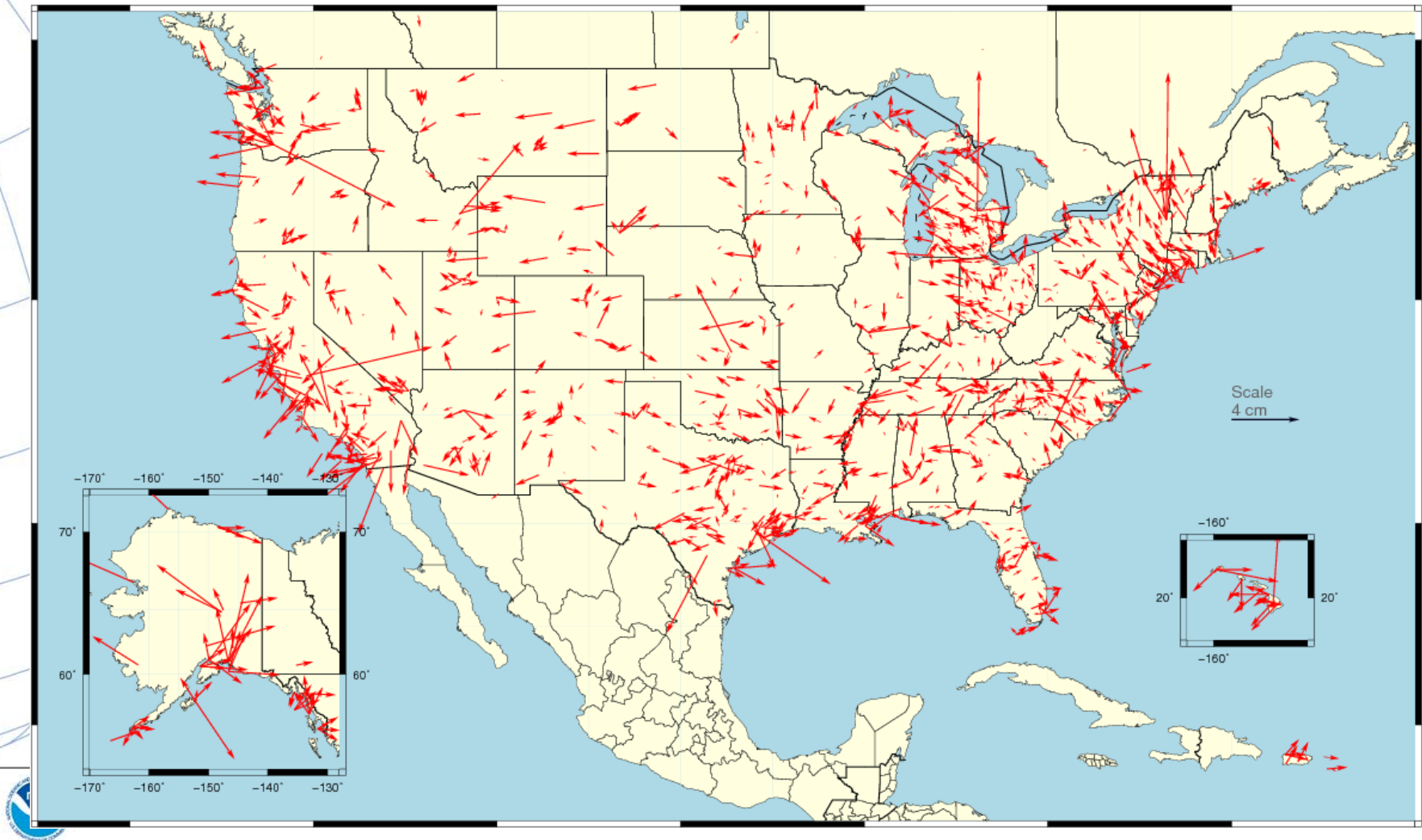
- Avg. shifts:  $\Delta E = 0.05 \pm 5.25$  (ME -0.12) cm  $\Delta N = 2.12 \pm 6.08$  (ME 0.00) cm
  - combination of position and velocity differences
  - due mostly to updated velocities (including up to 8 more years of data)





# Changes in *Horizontal* NAD 83 Positions Same Epoch

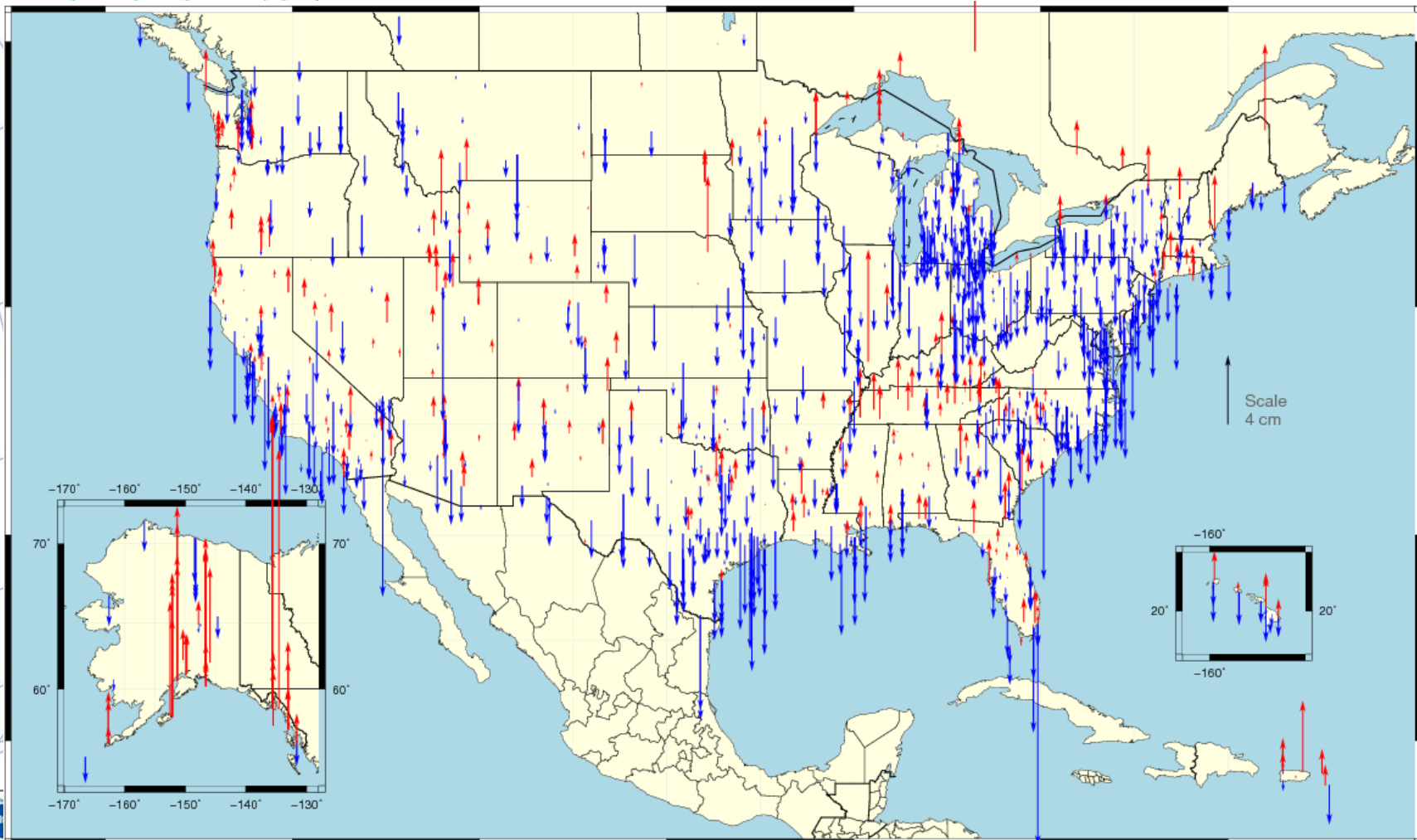
NAD 83(2011) epoch 2002.00 – NAD 83(CORS96) epoch 2002.00



# Changes in *Vertical* NAD 83 Positions

## Different Epochs

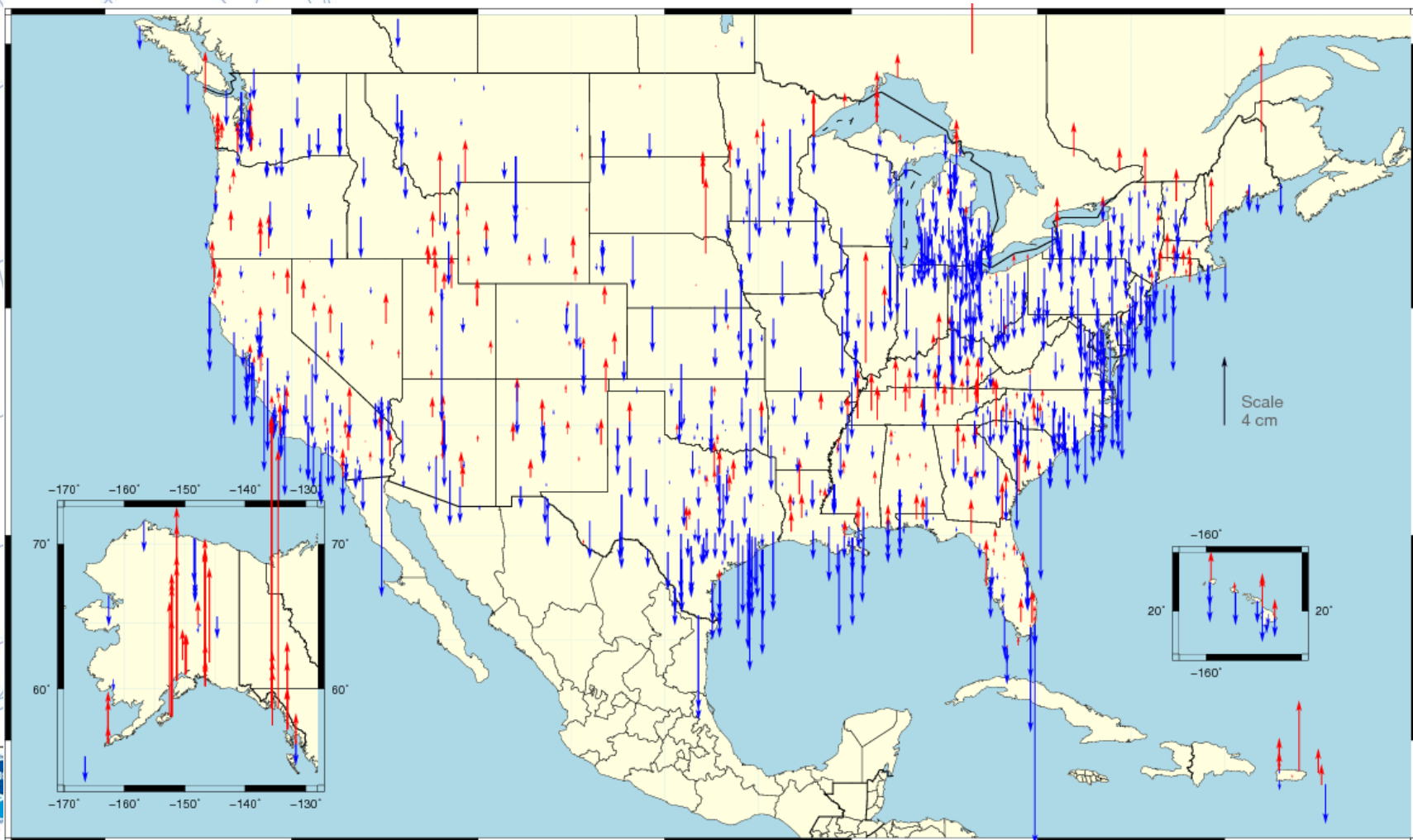
NAD 83(2011) epoch 2010.0 – NAD 83(CORS96) epoch 2002.0



# Changes in *Vertical* NAD 83 Positions **Different Epochs**

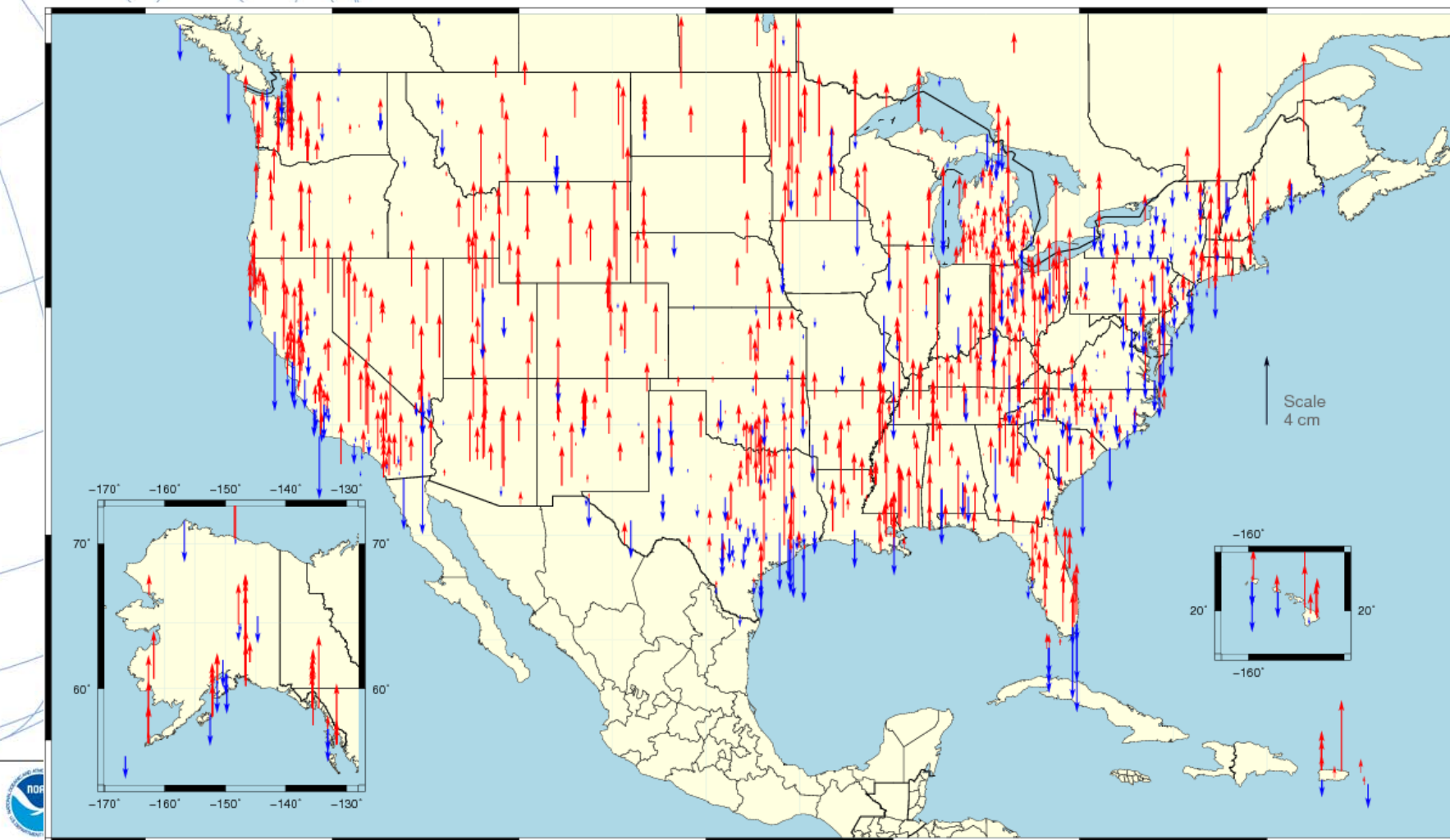
**NAD 83(2011) epoch 2010.0 – NAD 83(CORS96) epoch 2002.0**

- Avg. shifts:  $\Delta U = -0.66 \pm 2.24$  (ME  $-0.80$ ) cm
  - combination of position and velocity differences from additional data, tectonics
  - assuming vertical velocity  $\approx 0.00$  in NAD 83(CORS96)



# Changes in *Vertical* NAD 83 Positions

- **NAD 83(2011) epoch 2002.0 – NAD 83(CORS96) epoch 2002.0**
  - avg. shift:  $\Delta U = 0.80 \pm 1.89$  (ME -0.70) cm
  - random part mostly caused by switch to absolute antenna calibrations
  - shifts also caused by assuming  $V_u = 0$  in NAD 83(CORS96)

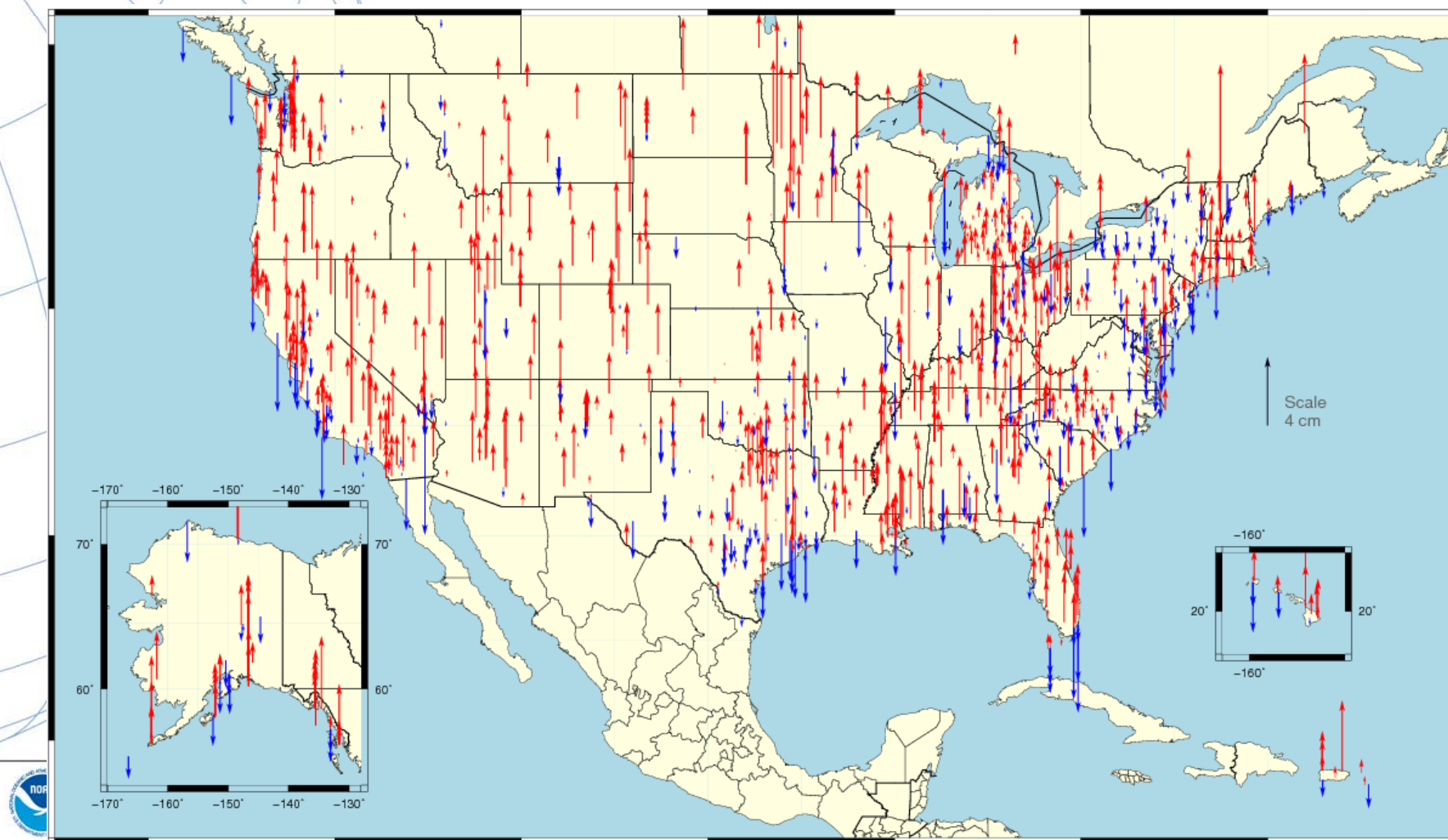




# Changes in *Vertical* NAD 83 Positions

## Same Epochs

NAD 83(**2011**) epoch **2002.0** – NAD 83(**CORS96**) epoch **2002.0**



# CORS Reference Frame Changes Due to MYCS – available now

Antenna Reference Point (ARP) : RED BUTTE CORS ARP

PID = AF9633

## ITRF00 POSITION (EPOCH 1997.0)

Computed in Aug. 2007 using 1244 days of data.

X = -1797278.745 m	latitude = 40 46 51.82884 N
Y = -4491525.887 m	longitude = 111 48 31.53360 W
Z = 4145132.622 m	ellipsoid height = 1667.743 m

> IGS08 epoch 2005.0

IGS08 = International GNSS Service 2008  
(GPS-only realization of ITRF2008)

## ITRF00 VELOCITY

Adapted in Aug. 2007 using 1244 days of data.

VX = -0.0133 m/yr	northward = -0.0087 m/yr
VY = -0.0008 m/yr	eastward = -0.0121 m/yr
VZ = -0.0066 m/yr	upward = 0.0000 m/yr

## NAD\_83 (CORS96) POSITION (EPOCH 2002.0)

Transformed from ITRF00 (epoch 1997.0) position in Aug. 2007.

X = -1797278.172 m	latitude = 40 46 51.80741 N
Y = -4491527.168 m	longitude = 111 48 31.49063 W
Z = 4145132.591 m	ellipsoid height = 1668.462 m

> NAD83 (2011) epoch 2010.0

NAD83 (2011) = North American Datum 1983  
(2011 Realization)

## NAD\_83 (CORS96) VELOCITY

Transformed from ITRF00 velocity in Aug. 2007.

VX = 0.0041 m/yr	northward = 0.0020 m/yr
VY = 0.0002 m/yr	eastward = 0.0037 m/yr
VZ = 0.0012 m/yr	upward = -0.0005 m/yr



# CORS Coordinates – New Reference Frames

Antenna Reference Point (ARP): RED BUTTE CORS ARP

PID = AF9633

IGS08 = International GNSS Service 2008  
(GPS-only realization of ITRF2008)

## IGS08 POSITION (EPOCH 2005.0)

Computed in Aug 2011 using data through gpswk 1631.

X = -1797278.855 m	latitude = 40 46 51.82726 N
Y = -4491525.894 m	longitude = 111 48 31.53784 W
Z = 4145132.598 m	ellipsoid height = 1667.763 m

## IGS08 VELOCITY

Computed in Aug 2011 using data through gpswk 1631.

VX = -0.0157 m/yr	northward = -0.0080 m/yr
VY = 0.0009 m/yr	eastward = -0.0149 m/yr
VZ = -0.0063 m/yr	upward = -0.0003 m/yr

NAD83 (2011) = North American  
Datum 1983

## NAD\_83 (2011) POSITION (EPOCH 2010.0)

Transformed from IGS08 (epoch 2005.0) position in Aug 2011. (2011. Realization)

X = -1797278.160 m	latitude = 40 46 51.80799 N
Y = -4491527.169 m	longitude = 111 48 31.49014 W
Z = 4145132.612 m	ellipsoid height = 1668.472 m

## NAD\_83 (2011) VELOCITY

Transformed from IGS08 velocity in Aug 2011.

VX = 0.0016 m/yr	northward = 0.0014 m/yr
VY = 0.0017 m/yr	eastward = 0.0009 m/yr
VZ = -0.0000 m/yr	upward = -0.0016 m/yr

L1 Phase Center of the current GPS antenna: RED BUTTE CORS L1 PC C

The Trimble L1/L2 Dorne Margolin element wit antenna

(Antenna Code = TRM29659.00 SCIS) was installed on 13Apr1997.

The L2 phase center is 0.032 m above the L1 phase center.

PID = DI0171



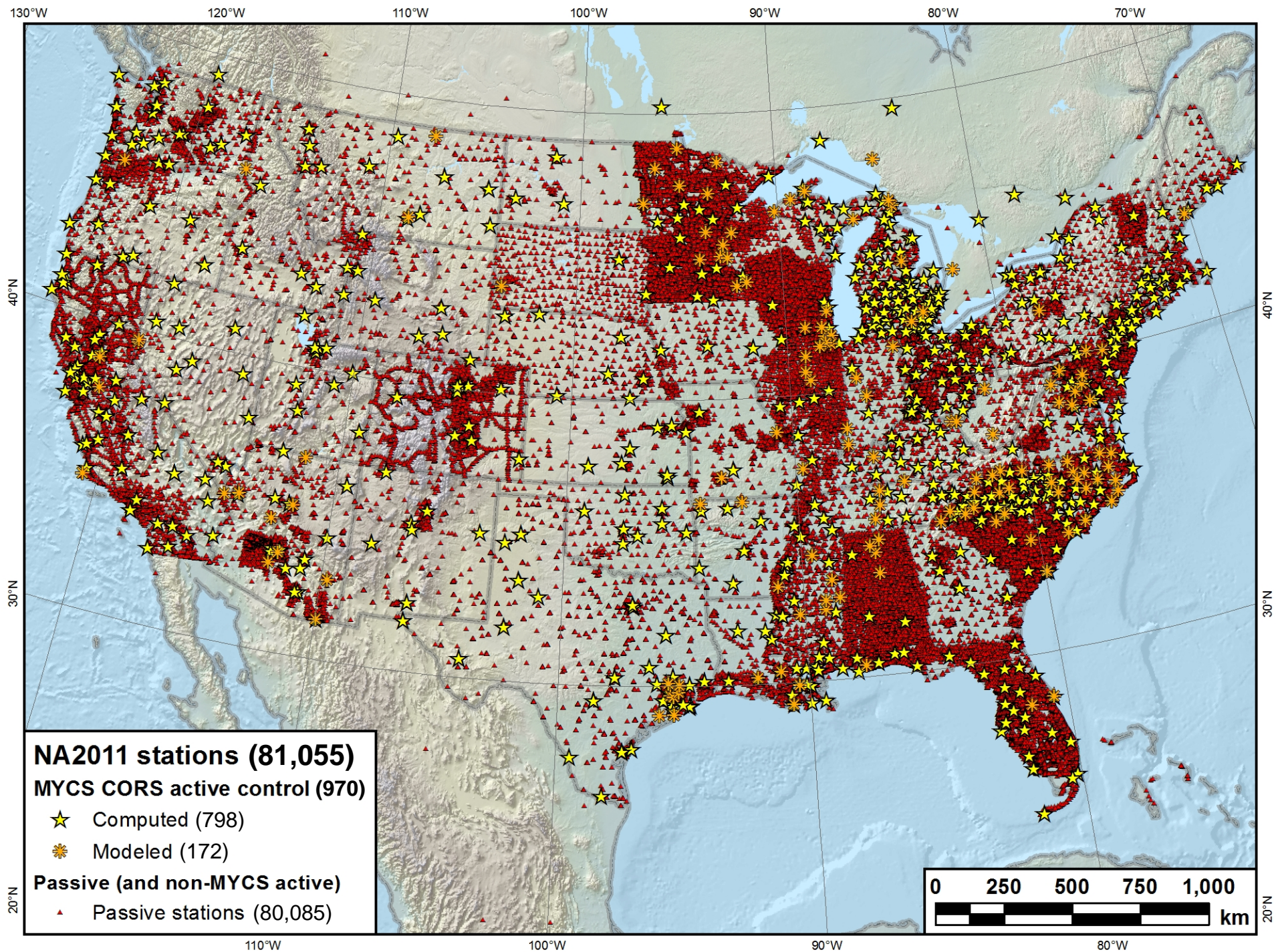


# NAD 83(2011) epoch 2010.00

- **Multi-Year CORS Solution (MYCS)**
  - NAD 83 computed by *transformation* from IGS08
- **National Adjustment of 2011 (NA2011)**
  - New adjustment of GNSS passive control
  - GNSS vectors tied (and constrained) to CORS
  - NAD 83(2011) epoch 2010.00
  - Approximately 80,000 stations and more than 400,000 GNSS vectors
- **Realization** SAME for CORS *and* passive marks
- **This is *NOT* a new datum! (still NAD 83)**









# NAD 83(2011) epoch 2010.00

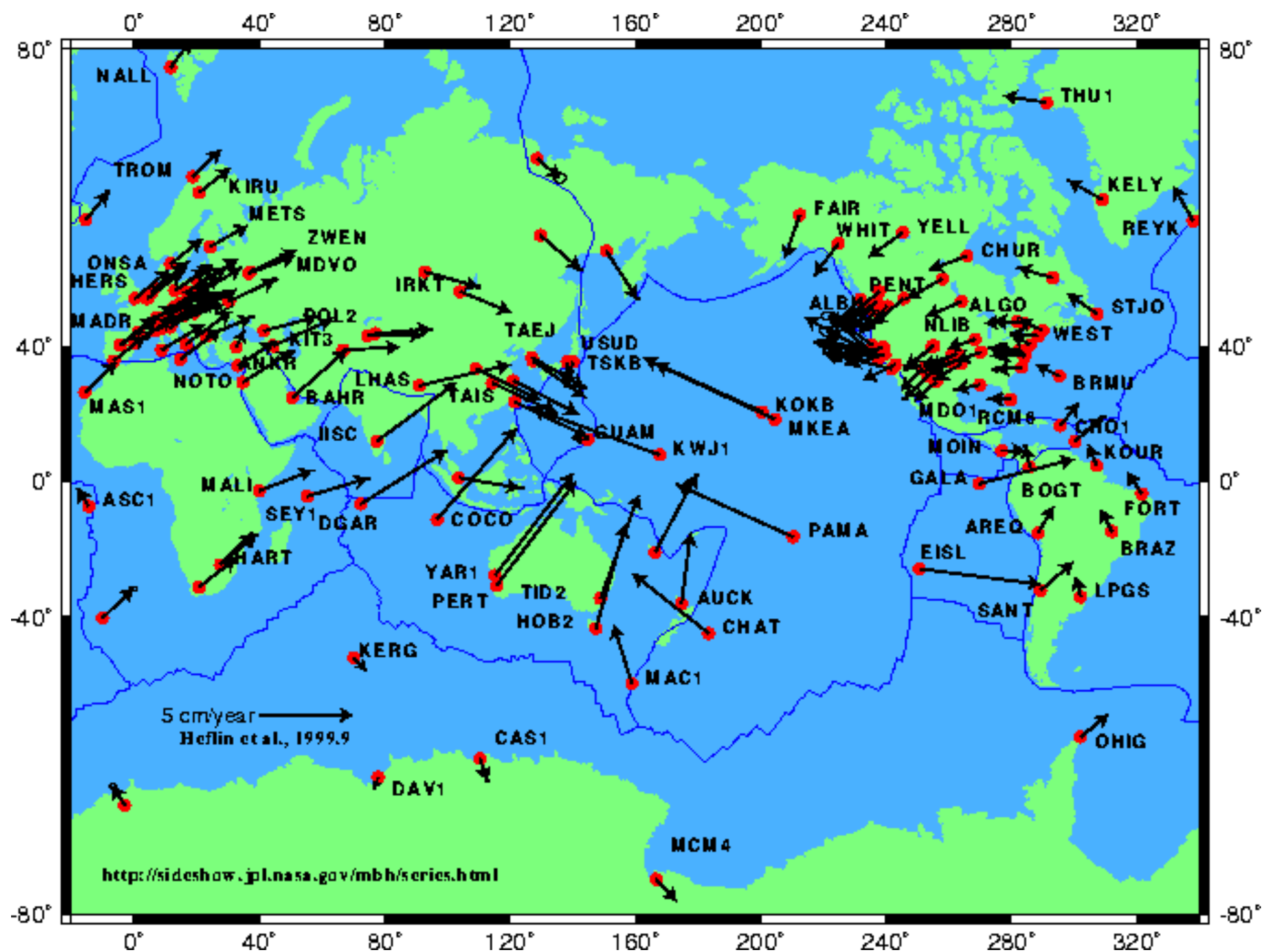
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- **National Adjustment of 2011 (NA2011)**
  - New adjustment of GNSS passive control
  - GNSS vectors tied (and constrained) to CORS NAD 83(2011) epoch 2010.00
  - Approximately 80,000 stations and more than 400,000 GNSS vectors



## Why a New National Adjustment?

- Optimally align passive control with new CORS
- Add >1000 projects submitted since 2007 project
  - Also observations for Hawaii, other Pacific islands
- Network and local accuracies on all stations
  - Including future submitted projects
- More consistent results in tectonically active areas
  - More current data, better tectonic modeling
- Better computations and analysis techniques
  - E.g., improved outlier detection
  - Incorporation of lessons learned from previous national adjustment





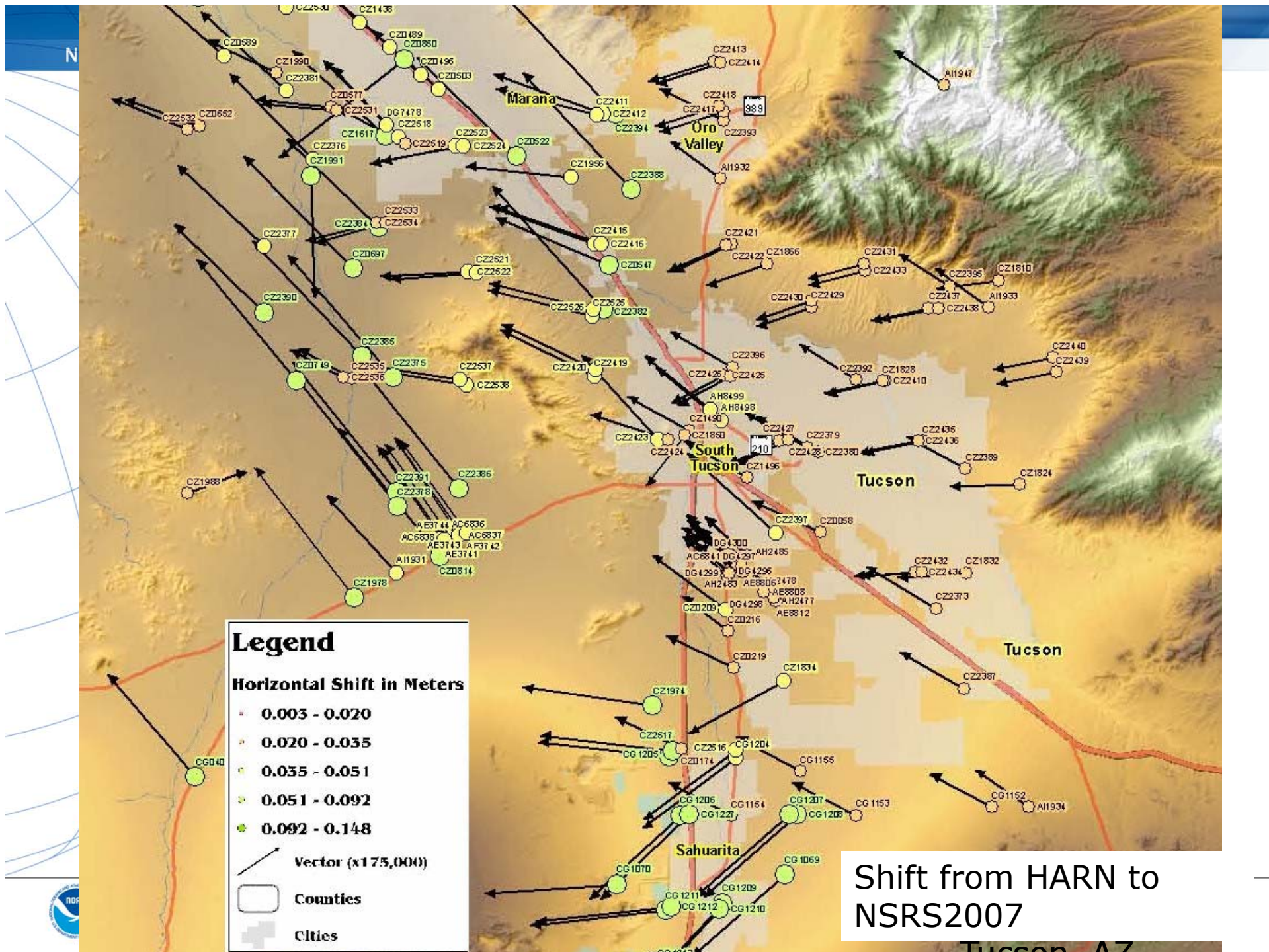


# How to get to the New Geometric Datum

“NGS will provide simple transformation tools between historic and current datums and reference frames used by NGS, in four dimensions, wherever practical and possible.”

There is no NGS-sanctioned transformation from NAD 83(HARN) to NAD 83(NSRS2007). Therefore, if your data are on a realization prior to NAD 83(NSRS2007) you will either have to get them on NSRS2007 (or 2011) or ignore the position shift and transform them to the new datum. NGS's OPUS may be the answer for you.

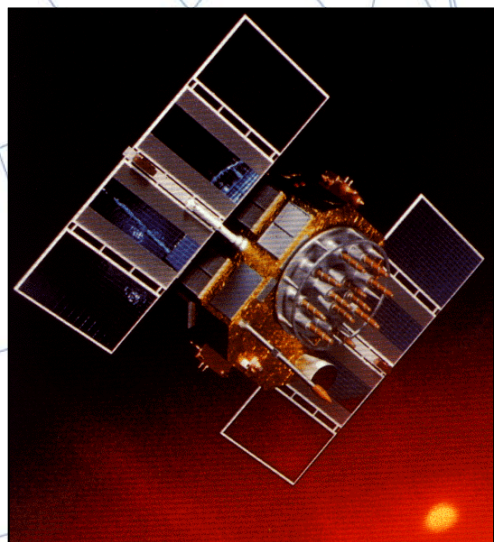






# National Adjustment of 2011

## *Project Update*



**National Geodetic Survey**  
**Observations and Analysis Division**  
April 25, 2012 • Silver Spring, MD

**Michael L. Dennis,**  
**RLS, PE**  
**NA2011 Project**



## Transformation & Tectonic Complications

- NAD 83(2011) transformation tools?
  - NAD 83(2011)  $\leftrightarrow$  (NSRS2007/CORS96)  $\leftrightarrow$  (HARN)
  - Under study by NGS
- When is North America not North America?
  - Not all stations on the North American tectonic plate
  - Pacific plate: Hawaii and American Samoa
  - Mariana plate: Guam and CNMI
  - Caribbean plate: Referenced to North American plate
  - Can relate frames (and epoch dates) with HTDP



# Current/Future Activities of the NSRS

1. Multi-Year CORS solution - 2011
2. National Adjustment (geometric) of passive control - 2012
3. Hybrid Geoid Model using new ellipsoid heights -2012
  - Use NAD 83(2011) epoch 2010.00 ellipsoid heights on NAVD 88 benchmarks
  - Might also use OPUS-Database results on NAVD 88 BMs
4. New Data Sheets - 2012
5. National Adjustment (vertical) of GPS passive marks
  - Under consideration; This not adjusting the leveling network
  - Constrain vertically to NAVD 88 benchmarks
  - GNSS-derived orthometric heights
    - NAD 83(2011) ellipsoid heights with GEOID12
6. Adoption of new datums -
  - Geometric, could happen any time
  - Vertical, requires completion of GRAV-D



# Current/Future Milestones of the NSRS

1. Multi-Year CORS solution –
  - Completed (for all intents and purposes)
2. National Adjustment (geometric) of passive control
  - 2012
3. Hybrid Geoid Model using new ellipsoid heights
  - 2012
4. National Adjustment (vertical) of GPS passive marks
  - Under consideration
  - This not adjusting the leveling network
5. Adoption of new datums
  - Geometric, could happen any time
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# How to Plan for the Future

- Use most recent realization of NAD 83
- Move away from passive marks to GNSS
- Move off of NGVD 29 to NAVD 88
  - Understand the accuracy of VERTCON in your area
- Collect OPUS-DB on NAVD 88 bench
- Require/provide complete metadata for all survey/mapping contracts
  - How did they get the positions/heights?
  - Survey Manual/Spatial Data Accuracy and Georeferencing Standards



## How to Plan for the Future

- Move to a contemporary realization of NAD 83
  - No NAD 83(HARN) <-> NAD 83(NSRS2007) tool
- Obtain precise ellipsoid heights on NAVD 88 bench marks (OPUS, contact NGS Geodetic Advisor(s))
  - Improves hybrid geoid models and provides “hard points” in new vertical datum
- Move off of NGVD 29 to NAVD 88
  - Understand the accuracy of VERTCON in your area
- Move away from passive marks to GNSS
  - Especially move off of classical passive control
- Require/provide complete metadata for all survey/mapping contracts
  - How did they get the positions/heights?
  - Survey Manual/Spatial Data Accuracy and Georeferencing Standards



## A Question to Consider:

*What is good enough  
with respect to the NSRS,  
i.e. have we reached a level of precision  
and accuracy where further realizations  
(adjustments) are unnecessary?*





## Near-future plans & possibilities

- **New hybrid geoid model (GEOID12)**
  - Use NAD 83(2011) epoch 2010.00 ellipsoid heights on NAVD 88 benchmarks
  - Might also use OPUS-Database results on NAVD 88 BMs
- ***May*** perform national vertical adjustment
  - Constrain vertically to NAVD 88 benchmarks
    - Perform as simultaneous nationwide adjustment
  - GNSS-derived orthometric heights
    - NAD 83(2011) ellipsoid heights with GEOID12
    - ***NOT*** a readjustment of NAVD 88 leveling



# Heights Bottom Line

**Using GNSS is cheaper, easier than leveling**

**To use GNSS we need a good geoid model**

GNSS – Global Navigation Satellite System



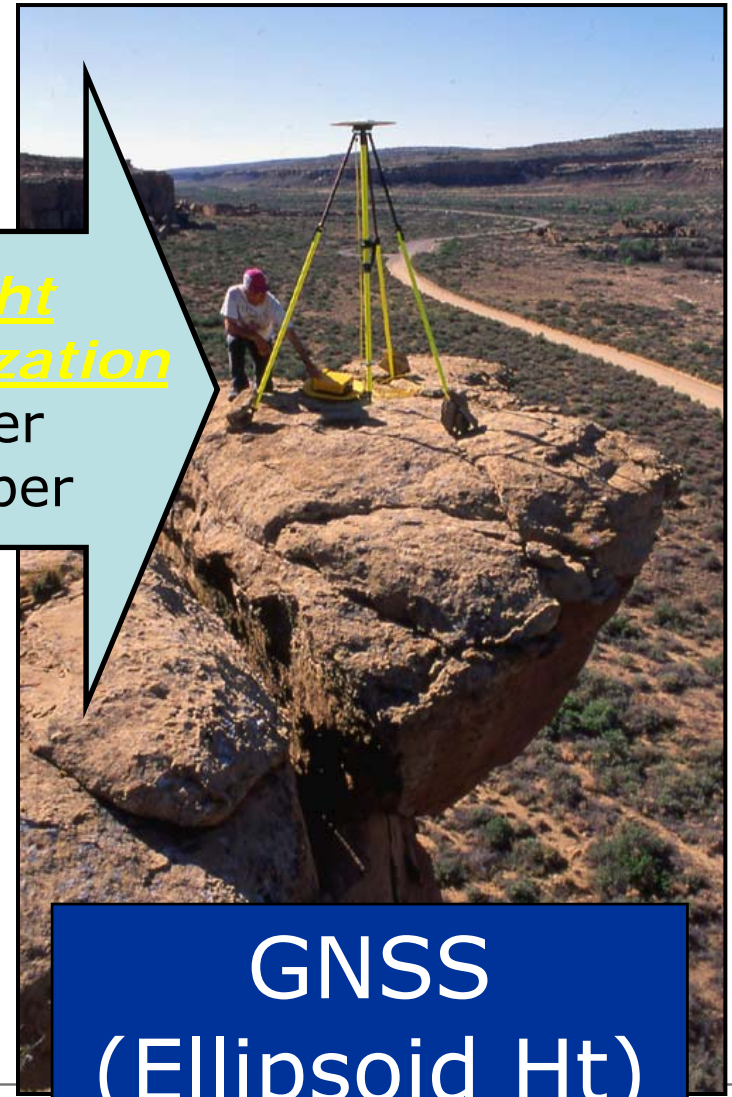
# Height Modernization



Differential  
Leveling  
(Orthometric Ht)

Height  
Modernization

-faster  
-cheaper



GNSS  
(Ellipsoid Ht)



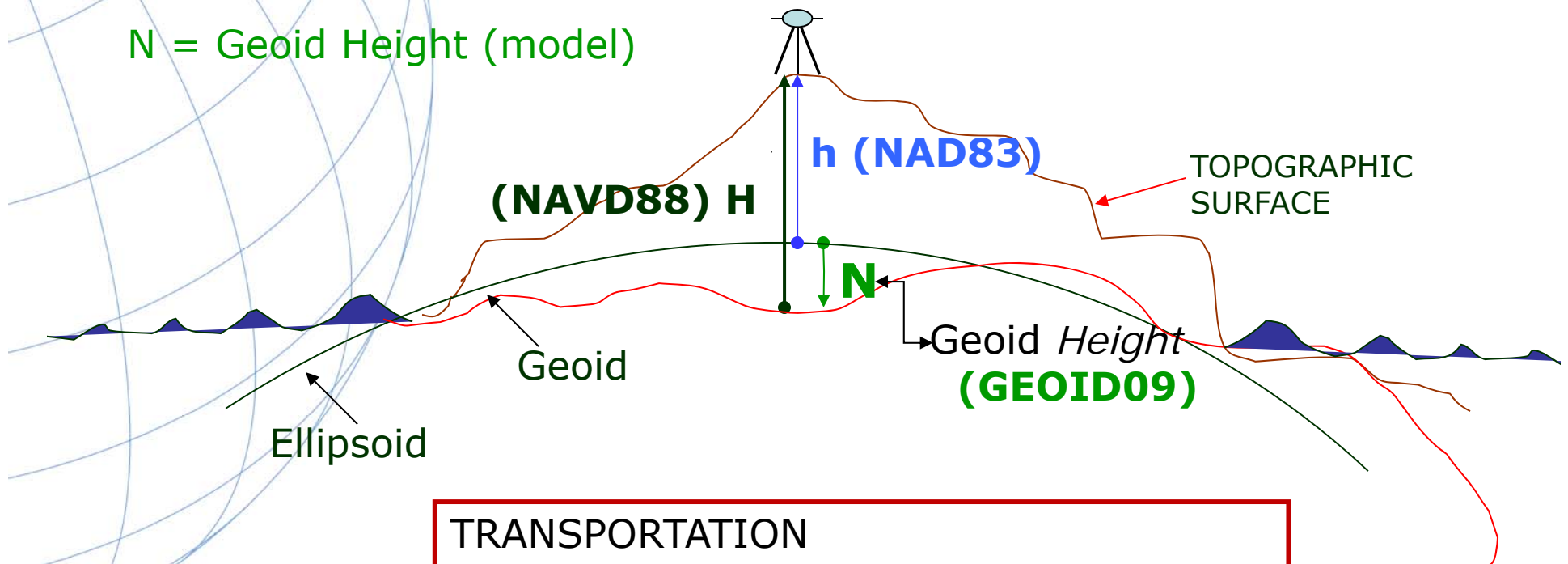
# Ellipsoid, Geoid, and Orthometric Heights

H = Orthometric Height (leveling)

h = Ellipsoidal Height (GPS)

N = Geoid Height (model)

$$H = h - N$$

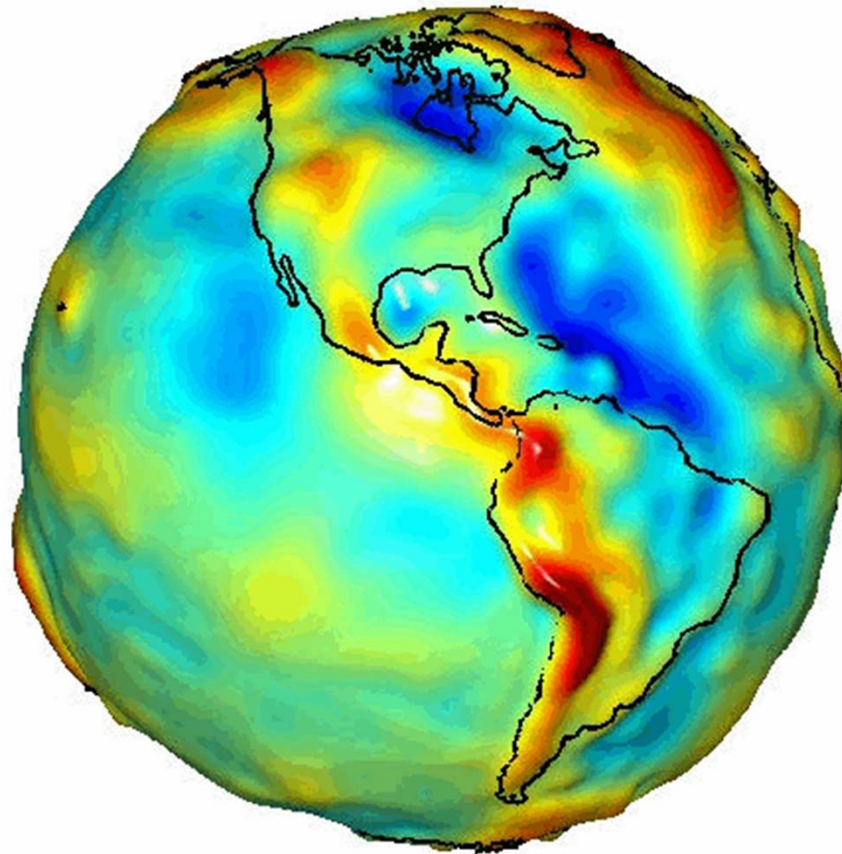


TRANSPORTATION

1660.6 = 1643.354 - (-17.23\*) METERS

1660.6 = 1643.4 + 17.2

# Exaggerated view of the Earth's Gravity Measure.



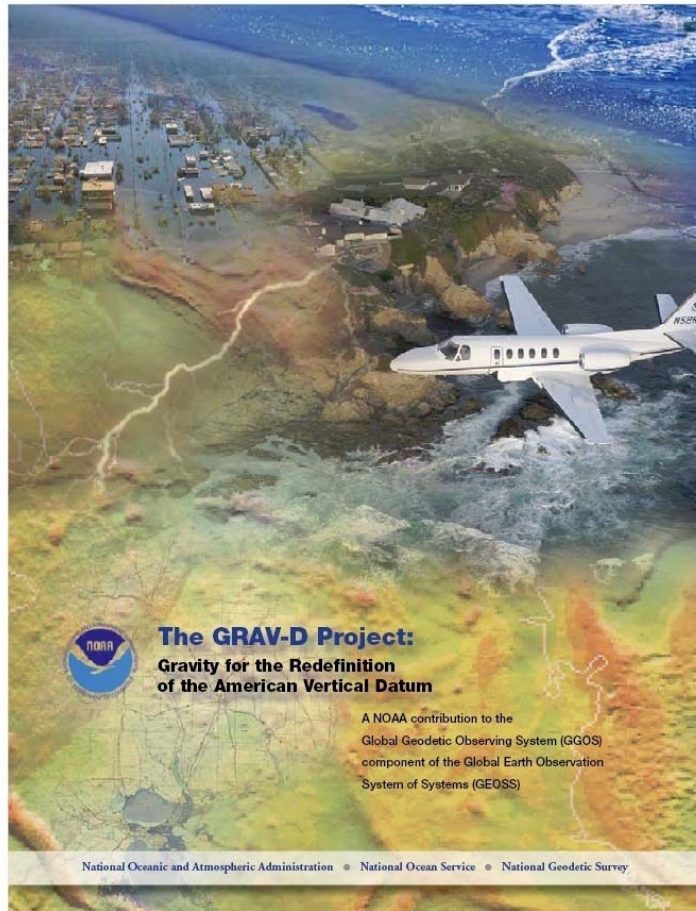
## Problems in NAVD 88

- A North American realization through spirit leveling networks
- Pre-satellite era product (625,000 km of leveling added to the NGVD29)
- Height information through passive bench marks whose positions change constantly in our changing world (e.g., PGR, subsidence, earthquakes, ...)
- The geoid differences between NAVD 88 and GRACE are in meter range: compare to  $\pm 2$ -3 cm error in typical GPS ellipsoidal heights





# GRAV-D

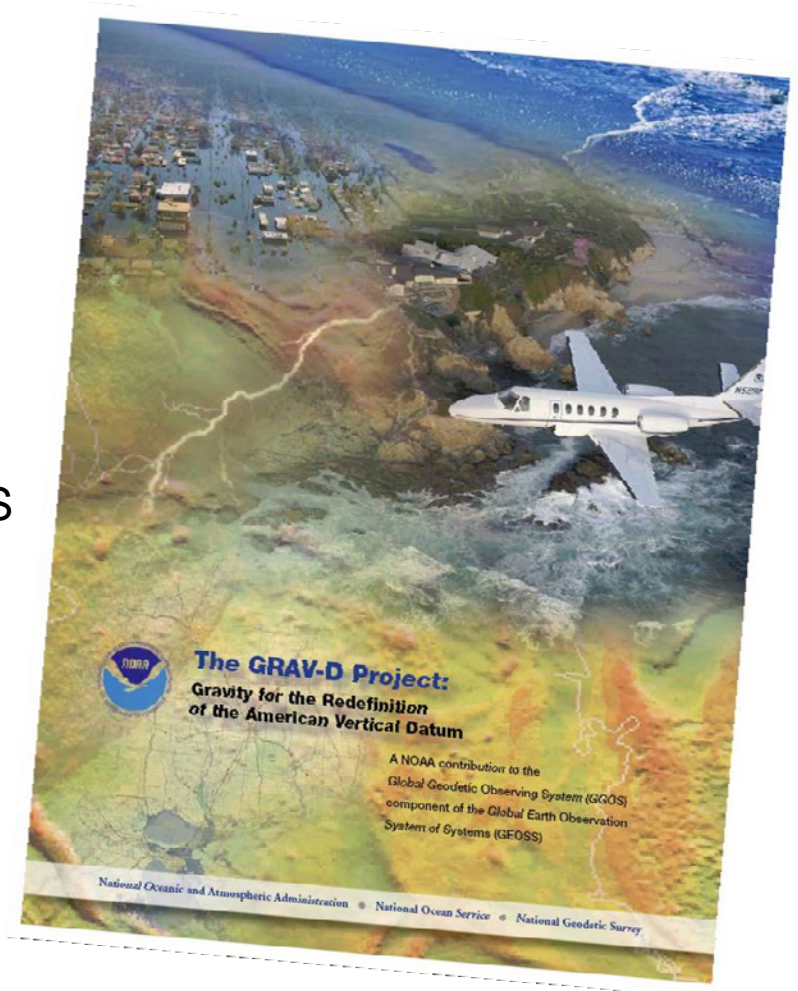


- GRAV-D **means fast, accurate, consistent orthometric heights** everywhere in the USA
- GPS already gives fast accurate *ellipsoid* heights
- If the geoid were **modeled** (and **monitored**) to highest accuracy...
- Voila... Fast, accurate orthometric heights, anywhere, anytime
- No need to use leveling to “bring in the datum”

# The Future of Height Mod: **GRAV-D**

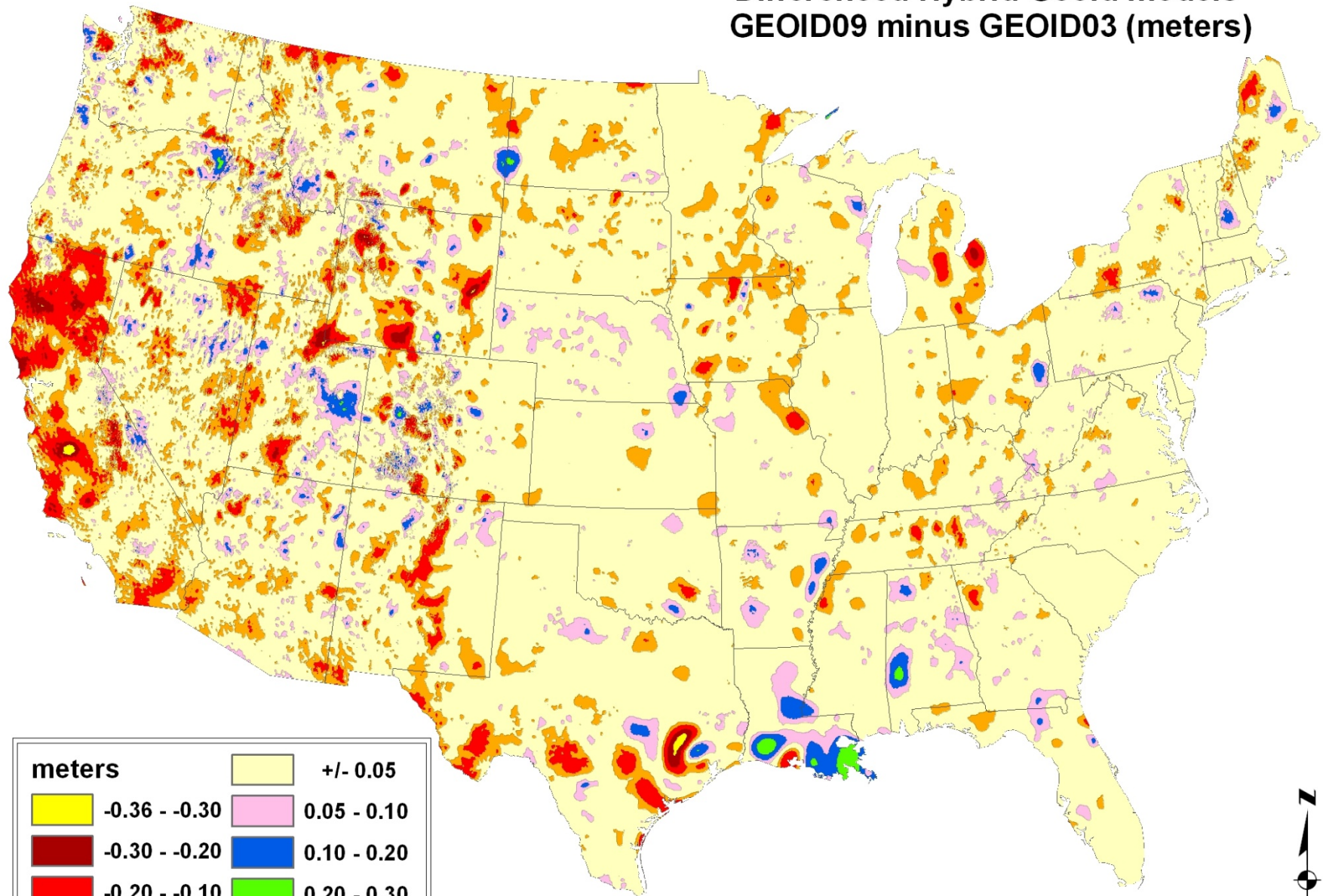
## **G**ravity for the **R**edefinition of the **A**merican **V**ertical **D**atum

- GRAV-D
  - Airborne gravity survey (10 years)
  - Gravity monitoring into the future
  - Coastal areas surveyed first
  - All USA states and territories
  - [www.ngs.noaa.gov/GRAV-D](http://www.ngs.noaa.gov/GRAV-D)
- 2018-2022 Targets:
  - Orthometric heights (“elevations” on maps) good to 2 cm anywhere, anytime from GNSS technology
  - Height changes easily monitored using new vertical datum
- Gravity for the Nation’ benefits
  - **Imagery for the Nation**
  - **Lidar for the Nation**
  - **Elevation for the Nation**

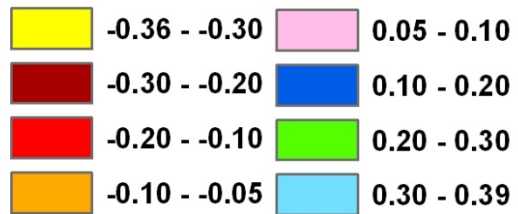




# Differenced Hybrid Geoid models GEOID09 minus GEOID03 (meters)



meters



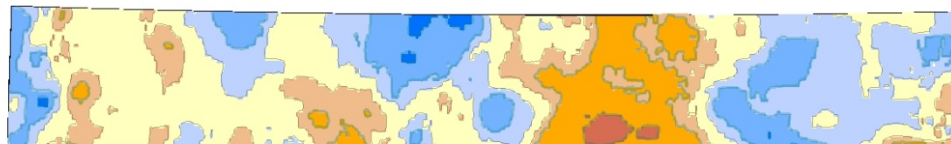
**-1.18 ft to +1.28 ft**

750 1,000  
Kilometers





**Geoid Height Differences (m)**  
**GEOID03 - GEOID09**



## **GPS-derived orthometric heights Warning #1**

$$H \approx h - N$$

**NAVD 88 height  $\approx$  NAD 83 ellipsoid height - GEOID03**

**NAVD 88 height  $\approx$  NAD 83 ellipsoid height - GEOID09**

**Provide, to client(s), datum & realization, ellipsoid heights, geoid model used, methodology (e.g. OPUS or adjusted survey), along with orthometric heights.**

**-0.10 - -0.05**

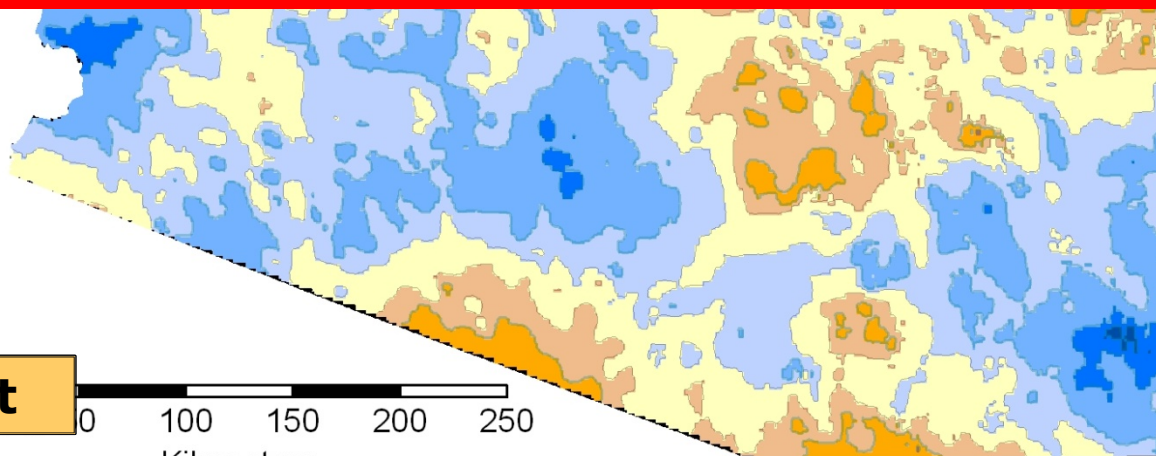
**-0.15 - -0.10**

**-0.17 - -0.15**

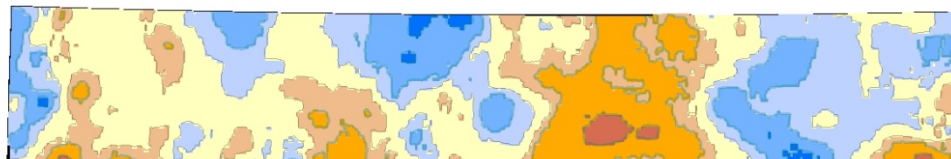


**-0.49 ft to +0.72 ft**

0 100 150 200 250  
Kilometers



**Geoid Height Differences (m)  
GEOID03 - GEOID09**



**GPS-derived orthometric heights Warning #2**

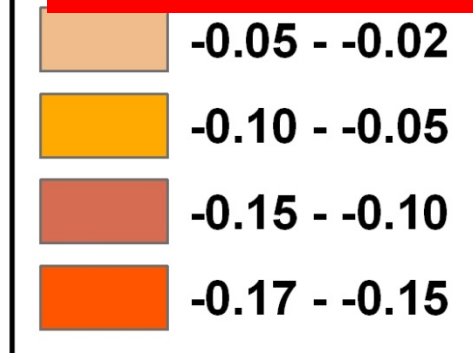
$$H \approx h - N$$

**The Hybrid GEOID model is defined with respect to a particular realization of NAD 83.**

**GEOID09 should only be used with NAD 83(NSRS 2007)**

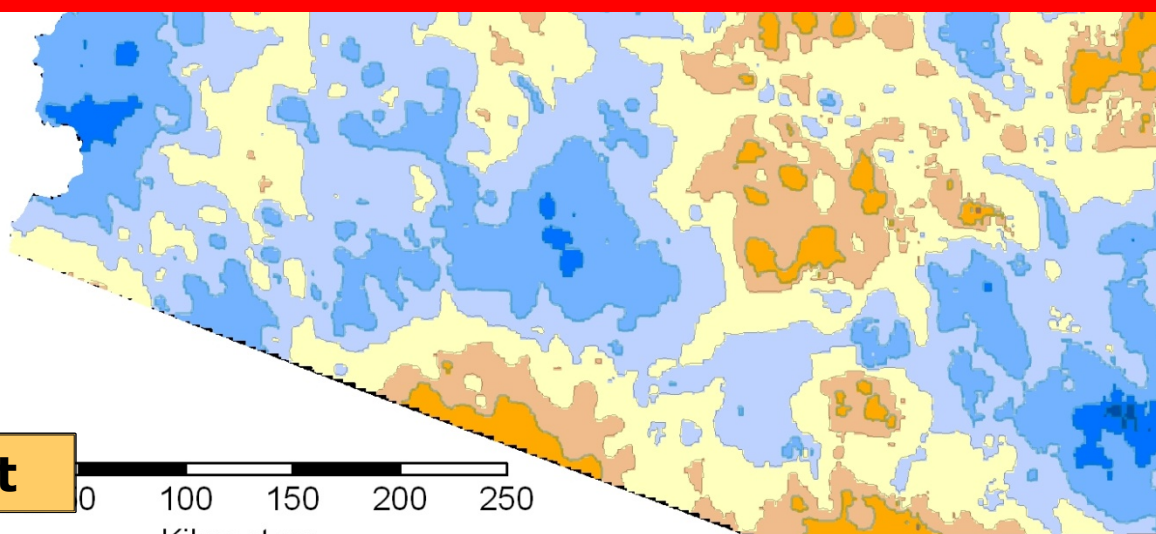
**GEOID03 should only be used with NAD 83(1992 aka HARN)**

**NAD 83(HARN) – NAD 83(NSRS2007) in Arizona:  
Heights -> min = -20.1 cm, max = 11.5 cm, avg = -2.4 cm**



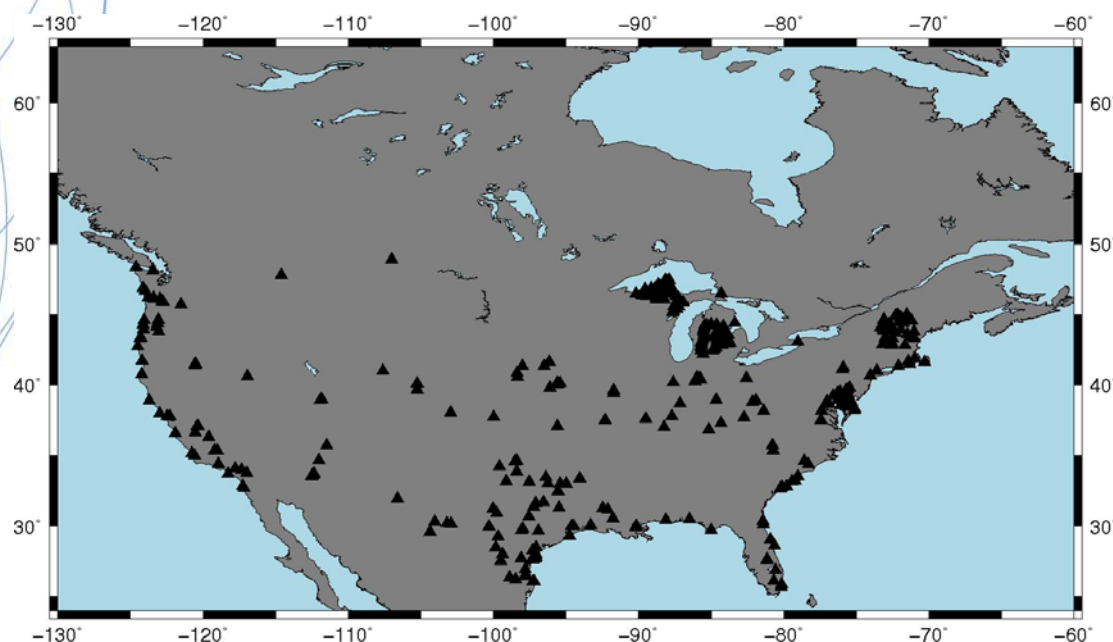
**-0.49 ft to +0.72 ft**

0 100 150 200 250  
Kilometers



# Leveled Bench Marks Occupied by GPS and stored in OPUS-DB

OPUS-DB shows great promise for filling gaps





## **Work to be Done (Ht Modernization) *Big Picture***

- Assessment of Vertical Issues in CO
- Gap Analysis of Where we need better vertical measurements, whether orthometric or ellipsoidal
- Collect Data in those Key areas, using OPUS-DB, and determine what other means (leveling)
- In the meantime, collect what you can using OPUS-DB
- Write a report capturing all of this



# ***Announcing...***

## **A New NGS Datasheet Format**

- **Update to new Datasheet version (8.00)**
  - Changed location, length, and text for many fields
  - Added new fields, deleted fields, augmented existing fields
  - To be Implemented in 2012
  - Will add announcement and prototype to NGS web site soon
- **Summary of content changes**
  - Added country (e.g., USA) where control station located
  - Hyperlinked vertical datum designation to datum web page
  - Ortho height epoch date, if applicable (e.g., subsidence areas)
  - Note for geoid model used on Ht Mod stations if not current geoid
  - Network and (median) local accuracies
    - Horizontal and ellipsoid height accuracy at 95% confidence (per FGDC)
    - Includes link to detailed accuracy info, list of all local accuracies
  - Superseded Ht Mod ortho heights indicate geoid model used



```

DATABASE = NGSIDB , PROGRAM = datasheet95, VERSION = 7.87.4
1      National Geodetic Survey,   Retrieval Date = AUGUST 19, 2011
AC6803 *****
AC6803 HT_MOD      -   This is a Height Modernization Survey Station.
AC6803 PACS        -   This is a Primary Airport Control Station.
AC6803 DESIGNATION -   AZC A
AC6803 PID         -   AC6803
AC6803 STATE/COUNTY-   AZ/MOHAVE
AC6803 USGS QUAD   -   LOST SPRING MTN EAST (1988)
AC6803
AC6803                                     *CURRENT SURVEY CONTROL
AC6803
AC6803* NAD 83(2007)- 36 57 59.55377(N)    113 00 32.22917(W)    ADJUSTED
AC6803* NAVD 88      -      1485.56    (meters)    4873.9    (feet)    GPS OBS
AC6803
AC6803 EPOCH DATE   -      2007.00
AC6803 X            -   -1,994,789.496 (meters)                      COMP
AC6803 Y            -   -4,697,388.731 (meters)                      COMP
AC6803 Z            -   3,815,306.819 (meters)                      COMP
AC6803 LAPLACE CORR-      3.37    (seconds)                      DEFLEC09
AC6803 ELLIP HEIGHT-      1462.787 (meters)                      (02/10/07) ADJUSTED
AC6803 GEOID HEIGHT-      -22.80    (meters)                      GEOID09
AC6803
AC6803 ----- Accuracy Estimates (at 95% Confidence Level in cm) -----
AC6803 Type      PID      Designation                      North    East    Ellip
AC6803 -----
AC6803 NETWORK AC6803 AZC A                      0.74    0.61    1.37
AC6803 -----
AC6803
AC6803.This mark is at Colorado City Municipal Airport (AZC)
AC6803
AC6803.The horizontal coordinates were established by GPS observations
AC6803.and adjusted by the National Geodetic Survey in February 2007.
AC6803
AC6803.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
AC6803 See National Readjustment for more information

```



DATABASE = NGSIDB , PROGRAM = datasheet95, VERSION = 8.00

1 National Geodetic Survey, Retrieval Date = JANUARY 1, 2012

AC6803 \*\*\*\*\*

AC6803 HT\_MOD - This is a Height Modernization Survey Station.

AC6803 PACS - This is a Primary Airport Control Station.

AC6803 DESIGNATION - AZC A

AC6803 PID - AC6803

AC6803 STATE/COUNTY- AZ/MOHAVE

AC6803 COUNTRY - USA

AC6803 USGS QUAD - LOST SPRING MTN EAST (1988)

AC6803

AC6803 \*CURRENT SURVEY CONTROL

AC6803

AC6803\* NAD 83(2007) POSITION- 36 57 59.55377(N) 113 00 32.22917(W) ADJUSTED

AC6803\* NAD 83(2007) ELLIP HT- 1462.787 (meters) (02/10/07) ADJUSTED

AC6803\* NAD 83(2007) EPOCH - 2007.00

AC6803\* NAVD 88 ORTHO HEIGHT - 1485.56 (meters) 4873.9 (feet) GPS OBS

AC6803\* NAVD 88 EPOCH - 2006.81 (for example only, n/a for AC6803)

AC6803

AC6803 NOTE: NAVD 88 ortho height was determined from prior model GEOID03.

AC6803 GEOID03 HEIGHT - -22.75 (meters)

AC6803 GEOID09 HEIGHT - -22.80 (meters)

AC6803 NAD 83(2007) X - -1,994,789.496 (meters) COMP

AC6803 NAD 83(2007) Y - -4,697,388.731 (meters) COMP

AC6803 NAD 83(2007) Z - 3,815,306.819 (meters) COMP

AC6803 LAPLACE CORR - 3.37 (seconds) DEFLEC09

AC6803

AC6803 FGDC Geospatial Positioning Accuracy Standards (95% confidence, cm)

AC6803 Type Horiz Ellip Dist(km)

AC6803 -----

AC6803 NETWORK ACCURACY 0.86 1.37

AC6803 MEDIAN LOCAL ACCURACY AND DIST ( 11 points) 0.67 1.22 1.64

AC6803 -----

AC6803 NOTE: Individual local accuracy values and other accuracy information

AC6803 are available [here](#).

AC6803



DATABASE = ,PROGRAM = datasheet, VERSION = 8.00

1 National Geodetic Survey, Retrieval Date = January 1, 2012

AC6803 \*\*\*\*\*

AC6803 ACCURACIES - Complete network and local accuracy information.

AC6803 HT\_MOD - This is a Height Modernization Survey Station.

AC6803 PACS - This is a Primary Airport Control Station.

AC6803 NAME - AZC A

AC6803 PID - AC6803

AC6803

AC6803 FGDC Geospatial Positioning Accuracy Standards (95% confidence, cm)

AC6803 Type/PID Horiz Ellip Dist(km) Std N Std E Std h Correltn NE

AC6803 -----

AC6803 NETWORK 0.86 1.37 0.38 0.31 0.70 -0.29917912

AC6803 -----

AC6803 MEDIAN LOCAL ACCURACY AND DIST ( 11 points)

AC6803 AE3181 0.36 0.69 0.07 0.17 0.11 0.35 -0.05276934

AC6803 AC6804 0.22 0.20 0.98 0.10 0.08 0.10 -0.02295189

AC6803 AE3183 0.57 0.90 1.27 0.26 0.19 0.46 -0.24478497

AC6803 AE3184 0.67 1.22 1.35 0.32 0.20 0.62 -0.05253846

AC6803 AE3182 0.66 0.90 1.60 0.30 0.21 0.46 -0.48667427

AC6803 AC6805 0.29 0.24 1.64 0.13 0.10 0.12 -0.07383703

AC6803 HO0112 1.21 2.29 42.91 0.53 0.45 1.17 0.07206508

AC6803 HO0076 0.94 1.71 45.99 0.42 0.34 0.87 -0.05592834

AC6803 AC6806 0.83 1.47 136.10 0.37 0.30 0.75 -0.14246214

AC6803 AC6816 0.82 1.51 139.26 0.33 0.34 0.77 -0.00353532

AC6803 FQ0454 0.86 1.35 230.42 0.38 0.31 0.69 -0.30702358

AC6803

AC6803 MEDIAN 0.67 1.22 1.64

AC6803 -----

AC6803 NOTE: Documentation for the accuracy information is available [here](#).

AC6803

\*\*\* retrieval complete.

Elapsed Time = 00:00:00

AC6803.part of the NAVD 88 network.

AC6803

AC6803.The X, Y, and Z were computed from the position and the ellipsoidal ht.

AC6803

AC6803.The Laplace correction was computed from DEFLEC09 derived deflections.

AC6803

AC6803.The ellipsoidal height was determined by GPS observations

AC6803.and is referenced to NAD 83.

AC6803

AC6803.The geoid height was determined by GEOID09.

AC6803

AC6803;

	North	East	Units	Scale Factor	Converg.
--	-------	------	-------	--------------	----------

AC6803;SPC AZ W	- 662,036.150	279,346.877	MT	0.99998696	+0 26 44.3
-----------------	---------------	-------------	----	------------	------------

AC6803;SPC AZ W	- 2,172,034.61	916,492.38	iFT	0.99998696	+0 26 44.3
-----------------	----------------	------------	-----	------------	------------

AC6803;UTM 12	- 4,093,046.689	321,162.779	MT	0.99999401	-1 12 30.2
---------------	-----------------	-------------	----	------------	------------

AC6803

AC6803! - Elev Factor x Scale Factor = Combined Factor

AC6803!SPC AZ W - 0.99977049 x 0.99998696 = 0.99975746

AC6803!UTM 12 - 0.99977049 x 0.99999401 = 0.99976451

AC6803

PID	Reference Object	Distance	Geod. Az ddmmss.s
AE3181	AZC CL END RWY 20	68.963 METERS	15655

AC6803

AC6803 SUPERSEDED SURVEY CONTROL

AC6803

AC6803 ELLIP H (01/12/01) 1462.805 (m) GP( ) 4 1

AC6803 NAD 83(1992)- 36 57 59.55345(N) 113 00 32.22767(W) AD( ) B

AC6803 ELLIP H (03/14/97) 1462.873 (m) GP( ) 3 1

AC6803 NAVD 88 (03/14/97) 1485.51 (m) 4873.7 (f) GPS OBS

AC6803

AC6803.Superseded values are not recommended for survey control.

AC6803.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.

AC6803.[See file dsdata.txt](#) to determine how the superseded data were derived.



AC6803.The X, Y, and Z were computed from the position and the ellipsoidal ht.  
AC6803

AC6803.The Laplace correction was computed from DEFLEC09 derived deflections.  
AC6803

AC6803.The ellipsoidal height was determined by GPS observations  
AC6803.and is referenced to NAD 83.  
AC6803

AC6803.The geoid height was determined by GEOID09. (remove line)

AC6803

AC6803.The following values were computed from NAD 83(2007).

AC6803

AC6803;		North	East	Units	Scale Factor	Converg.
AC6803;SPC AZ W	-	662,036.150	279,346.877	MT	0.99998696	+0 26 44.3
AC6803;SPC AZ W	-	2,172,034.61	916,492.38	iFT	0.99998696	+0 26 44.3
AC6803;UTM 12	-	4,093,046.689	321,162.779	MT	0.99999401	-1 12 30.2

AC6803

AC6803!	-	Elev Factor	x	Scale Factor	=	Combined Factor
AC6803!SPC AZ W	-	0.99977049	x	0.99998696	=	0.99975746
AC6803!UTM 12	-	0.99977049	x	0.99999401	=	0.99976451

AC6803

AC6803	PID	Reference Object	Distance	Geod. Az
AC6803				dddmss.s
AC6803	AE3181	AZC CL END RWY 20	68.963 METERS	15655

AC6803

AC6803 SUPERSEDED SURVEY CONTROL

AC6803

AC6803	ELLIP H (01/12/01)	1462.805 (m)	GP(	)	4 1
AC6803	NAD 83(1992)-	36 57 59.55345(N)	113 00 32.22767(W)	AD(	) B
AC6803	ELLIP H (03/14/97)	1462.873 (m)	GP(	)	3 1

AC6803 NAVD 88 (03/14/97) 1485.51 (m) GEOID96 model used GP(epoch if appl)

AC6803

AC6803.Superseded values are not recommended for survey control.

AC6803.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.

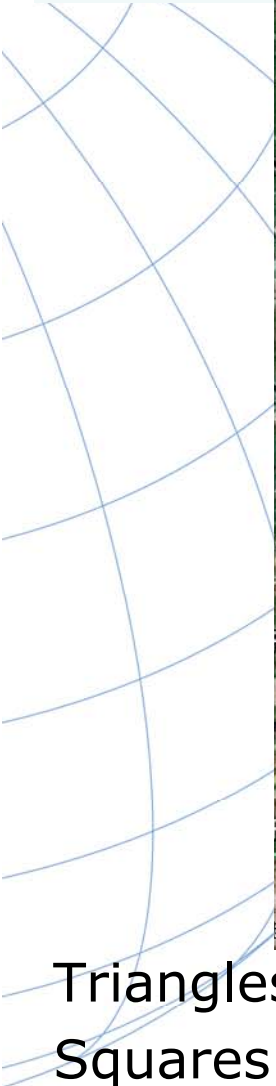
AC6803.[See file dsdata.txt](#) to determine how the superseded data were derived.

## **“DSWorld” Software Program**

- Highly rated new NGS software tool
- Developed to search the NGS database
- Easy to learn/use
- Multiple search options available
- Displays search results using Google Earth



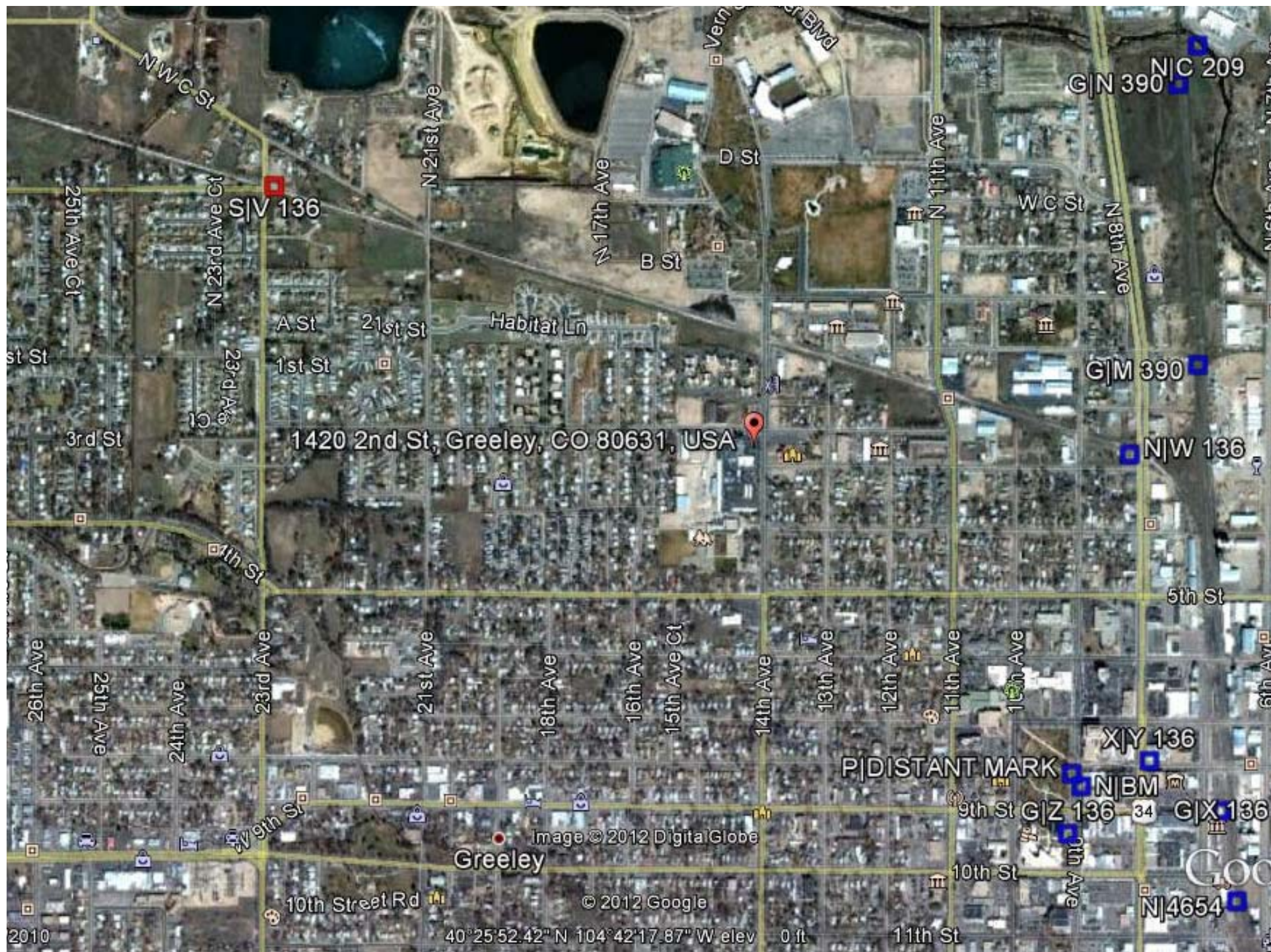
# Geodetic Control



## Squares – Vertical Control

Red – Second Order









# The NGS Data Sheet

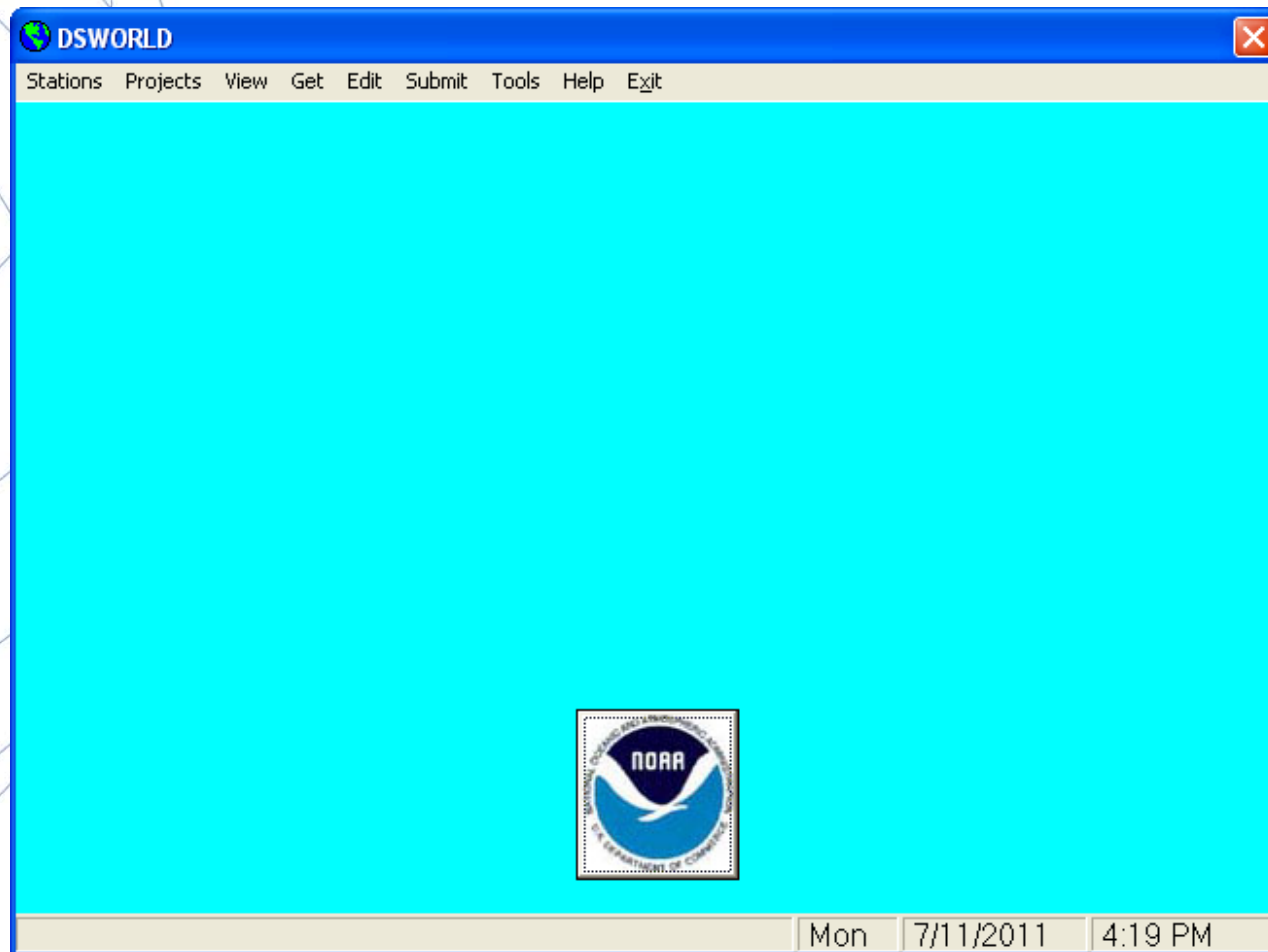
See file [dsdata.txt](#) for more information about the datasheet.

```
DATABASE = NGSIDB , PROGRAM = datasheet95, VERSION = 7.88.2
1      National Geodetic Survey,   Retrieval Date = MAY 23, 2012
LL0217 *****
LL0217 DESIGNATION - W 136
LL0217 PID - LL0217
LL0217 STATE/COUNTY- CO/WELD
LL0217 COUNTRY - US
LL0217 USGS QUAD - GREELEY (1980)
LL0217
LL0217 *CURRENT SURVEY CONTROL
LL0217
LL0217* NAD 83(1986) POSITION- 40 25 54. (N) 104 41 28. (W) SCALED
LL0217* NAVD 88 ORTHO HEIGHT - 1416.245 (meters) 4646.46 (feet) ADJUSTED
LL0217
LL0217 GEOID HEIGHT - -18.22 (meters) GEOID09
LL0217 DYNAMIC HEIGHT - 1415.035 (meters) 4642.49 (feet) COMP
LL0217 MODELED GRAVITY - 979,722.7 (mgal) NAVD 88
LL0217
LL0217 VERT ORDER - FIRST CLASS II
LL0217
LL0217.The horizontal coordinates were scaled from a topographic map and have
LL0217.an estimated accuracy of +/- 6 seconds.
LL0217.
LL0217.The orthometric height was determined by differential leveling and
LL0217.adjusted in June 1991.
LL0217
LL0217.The dynamic height is computed by dividing the NAVD 88
LL0217.geopotential number by the normal gravity value computed on the
LL0217.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
LL0217.degrees latitude (g = 980.6199 gals.).
LL0217
LL0217.The modeled gravity was interpolated from observed gravity values.
LL0217
```

## Direct Access to the NGS Datasheet



## DSWorld opening screen



# Where do you get DS-World?



**Download NGS PC Software**  
National Geodetic Survey

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

**Download Free Geodetic Software Developed by NGS**

ADJUST & UTILITIES	DSWIN	HTDP	SPCS83
CALIBRAT	DSFILES	INTERORB	TOLADD
CARIB97	DSUPDATE	INV/FWD3D	Translev
COMPGB	ENHANCEMENTS	LOOP	USNG
COMPVECS	G99SSS	LVL_DH	USGG2003
CORPSCON	GEOID99	MEXICO97	USGG2009
CR88B	GEOID03	MTEN4	UTMS
CR88ER	GEOID06	NA2VBBK	VDatum
DCAR97	GEOID09	NADCON	VERTCON
DEFLEC99	Gethv1st	PCVOBS	WinDesc
DMEX97	GPPCGP	PROMPTER	XYZWIN

If you have questions, refer to the [Software Download FAQ](#).  
If you have download problems, contact the [NGS Webmaster](#).

[User-Contributed Software](#) is also available to perform related functions.

**Descriptions of Free Geodetic Software Developed by NGS**

**ADJUST AND UTILITIES**  
Programs and utilities to perform least squares adjustment on horizontal, vertical angle, and/or GPS observations. Data checking programs are included. [\[Return to top.\]](#)

**CALIBRAT (Version 1.0)**  
This program is used to determine the scale and constant corrections for electronic distance measuring instruments by making measurements over previously determined base lines. The formulas used in the program are found in NOAA Technical Memorandum NOS NGS-10, "Use of Calibration Base Lines." [\[Return to top.\]](#)

**CARIB97 (Version 3.1)**  
Specially designed software to compute geoid heights for the Caribbean Sea. Boundaries of area



National Geodetic Survey

# CORS/OPUS



National Oceanic and Atmospheric Administration



## **CDOT CORS/OPUS Team**

- To incorporate CORS and OPUS into the CDOT Survey Manual
- Presented to SAC on Feb 15, 2012
- Proposed Addendum
- Recommendations



## CDOT CORS/OPUS Team

# DRAFT Proposed Addendum DRAFT

Surveying and mapping work, upon which all planning, studies and engineering designs are based, shall use the established CDOT project datum. Unless otherwise determined and approved by CDOT Region Survey Coordinator, the horizontal datum shall be the most recent realization of the North American Datum of 1983 (NAD83) as defined by the National Geodetic Survey (NGS). The horizontal control may utilize accepted CDOT and NGS ground based monuments (such as former HARN) and CORS (Continuously Operating Reference Stations).

Established Static Procedures (two 20 minute observations and fast static procedures) as written in Chapter 3 of the CDOT Survey Manual can be followed for baselines up to 60 kms. For baselines greater than 60 kms the following should be used unless otherwise determined and approved by the CDOT Region Coordinator:

Baseline Distance	Number of Satellites	Time (minutes)
Greater than 60 km ( 37.2 miles)	4	180
	5	135
	6 or more	95



## CDOT CORS/OPUS Team

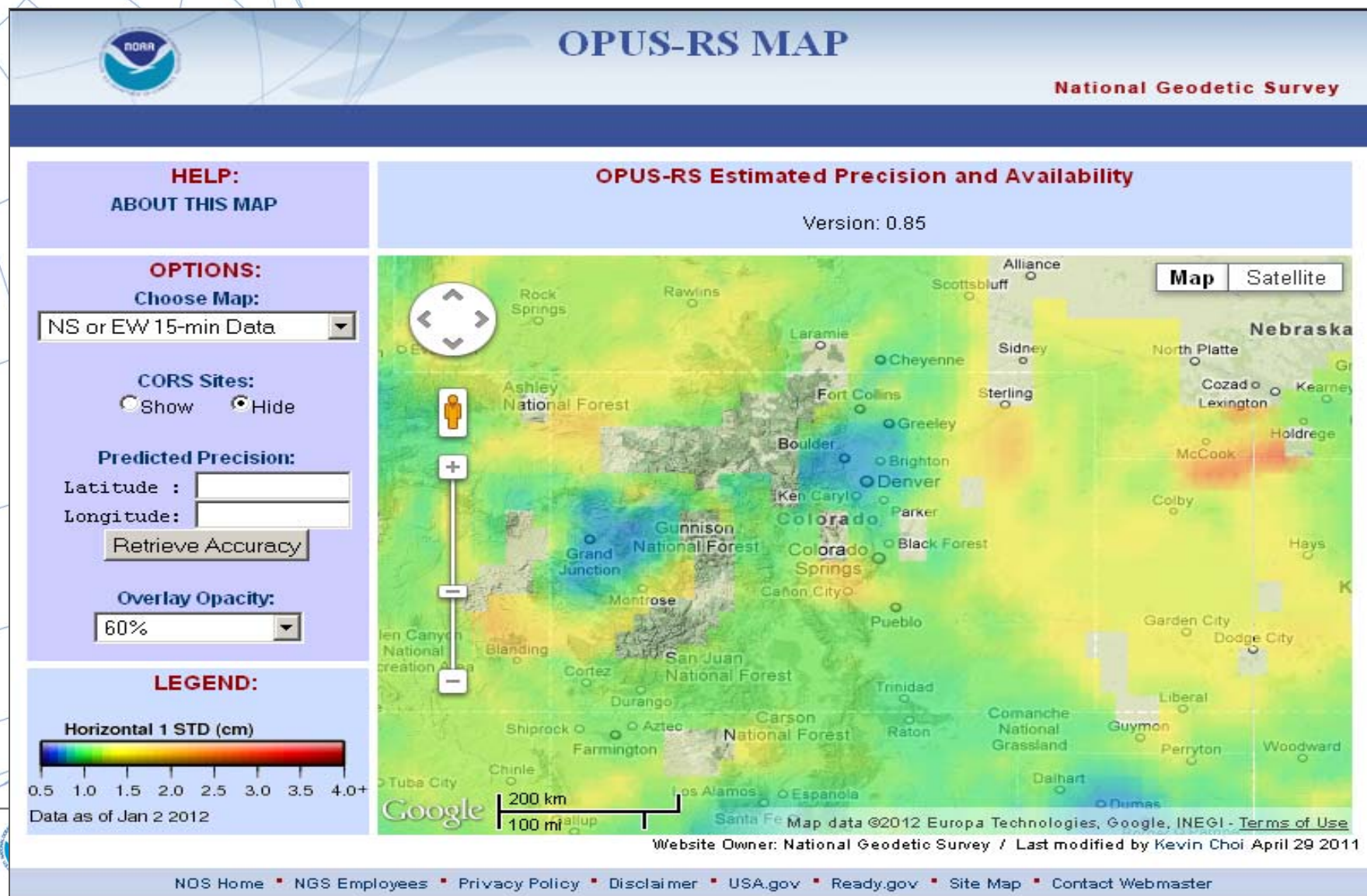
**DRAFT** Recommendations **DRAFT**

1. OPUS tools are valuable and use of them should be further explored and encouraged where appropriate and incorporated into re-write of Chapter 3.
2. Encourage publishing of control using OPUS-DB especially on NGS vertical marks to prepare the vertical datums for the future.
3. Additional CORS should be added in Colorado
4. Microstation control diagrams be edited to reflect the language in the proposed (approved) Addendum
5. Training to Support these Changes





# OPUS-RS Coverage in Colorado



# How Does OPUS-RS Work?

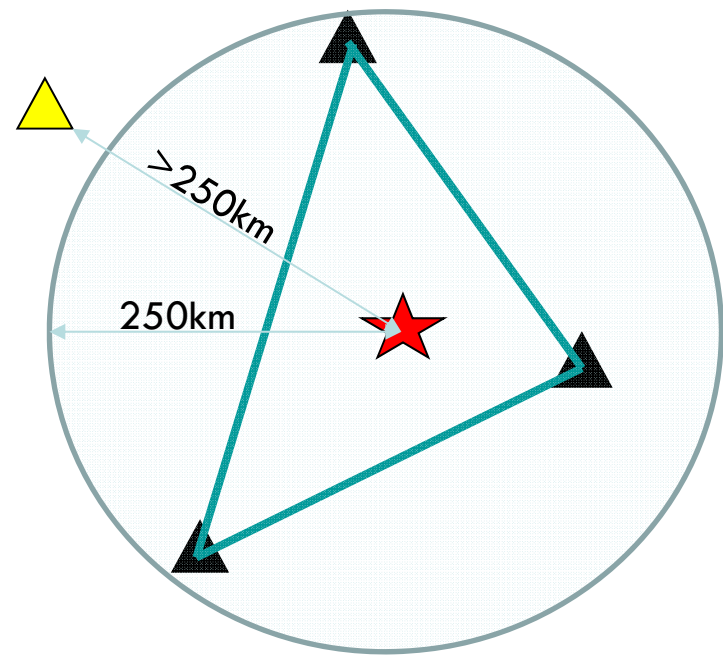
OPUS-RS selects three to nine “best” CORS based upon:

- Having common satellite visibility with the user data.
- Having distances from the user’s site <250 km.

This is shown here graphically.  
The star represents the user’s site. The triangles are CORS.

No CORS farther than 250 km from the user’s site will be included.

The three CORS minimum is shown.  
No more than nine are used.

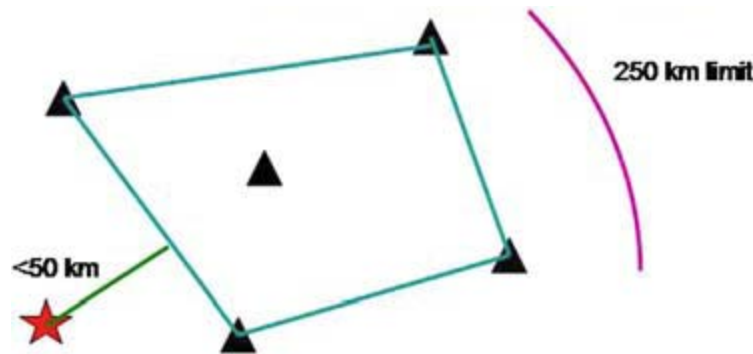


# How Does OPUS-RS Work?

In addition, user's site must be no more than 50 km from the (convex) polygon created by the selected CORS.

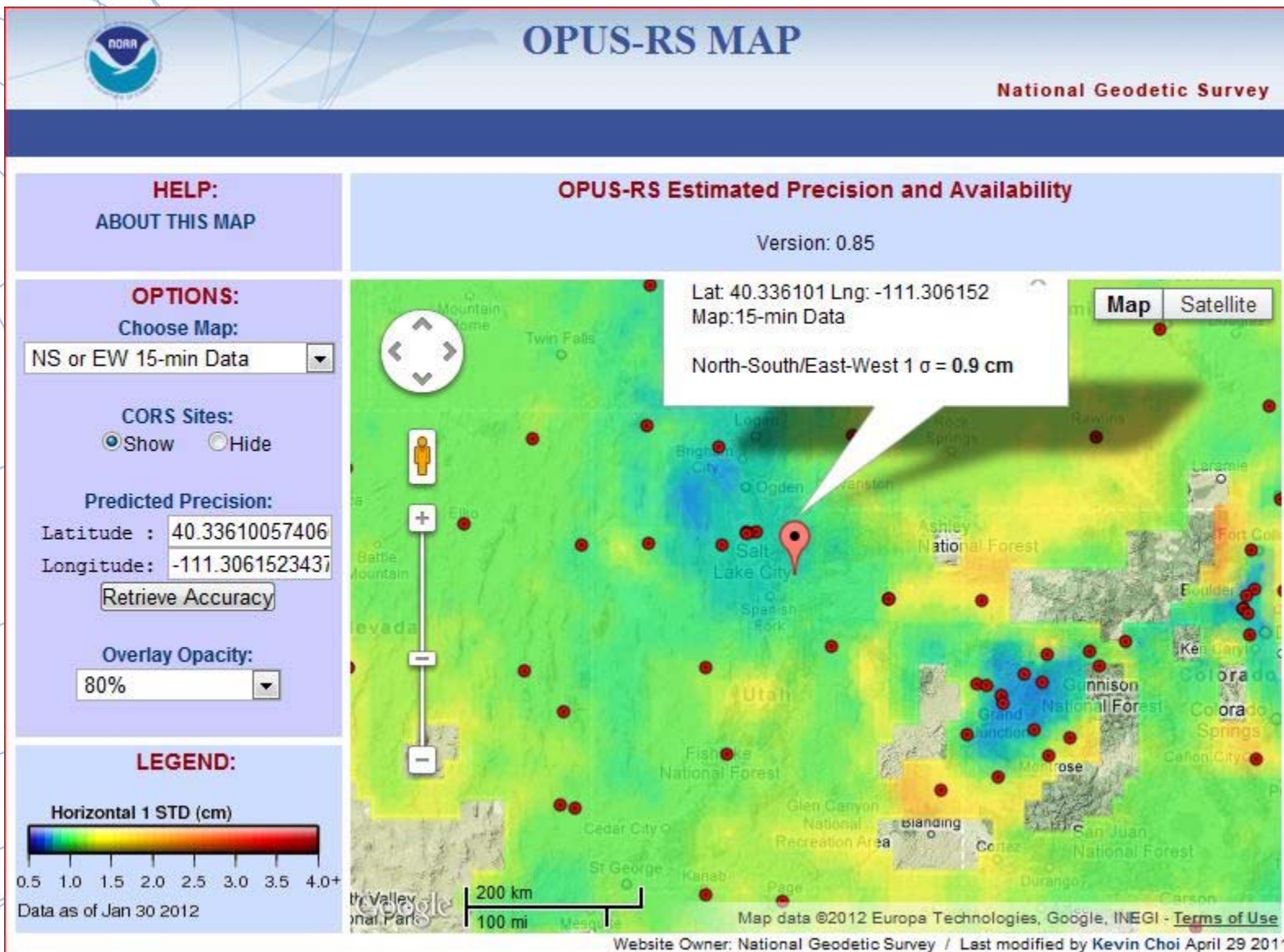
Again in this figure, the star represents the user's site; the triangles are CORS. Five CORS and their resulting polygon are shown in this example.

If the user's site, the star, is more than 50 km outside this polygon, alternate CORS will be considered. If none can be found, the processing will abort.



Schwarz et al., "Accuracy assessment of the National Geodetic Survey's OPUS-RS utility", 2009, *GPS Solutions*, 13(2), 119-132.





# CDOT Comparison Between HARN, CORS and OPUS Region 3 Data

## Comparison of Static Solution with HARN Stations to Static Solution with CORS Stations Coordinates are State Plane Colorado Central Zone Coordinates

<u>Solution</u>	<u>Station</u>	<u>Northing</u>	<u>Easting</u>	<u>Delta N</u>	<u>Delta E</u>	<u>Vector</u>	<u>Remarks</u>
Static Survey	KOEPSSELL	485019.8310	692784.1960				Held Fixed NGS Coordinates
Static (CORS)	KOEPSSELL	485019.8280	692784.1940	0.003m (0.010 ft)	0.002m (0.007 ft)	0.004m (0.012 ft)	Static Solution from CORS
Static Survey	72.30E	484813.4910	692714.6750				
Static (CORS)	72.30E	484813.4880	692714.6740	0.003m (0.010 ft)	0.001m (0.003 ft)	0.003m (0.010 ft)	
Static Survey	72.30E	484813.4910	692714.6750				
OPUS-RS Solution	72.30E	484813.4960	692714.6800	-0.005m (-0.016 ft)	-0.005m (-0.016 ft)	0.007m (0.023 ft)	
Static Survey	72.45E	485172.0020	692900.1110				
Static (CORS)	72.45E	485171.9980	692900.1090	0.004m (0.013 ft)	0.002m (0.007 ft)	0.004m (0.015 ft)	
Static Survey	72.30W	485091.9840	692644.0670				
Static (CORS)	72.30W	485091.9790	692644.0650	0.005m (0.016 ft)	0.002m (0.007 ft)	0.005m (0.018 ft)	
Static Survey	72.45W	485367.7120	692756.3640				
Static (CORS)	72.45W	485367.7060	692756.3630	0.006m (0.020 ft)	0.001m (0.003 ft)	0.006m (0.020 ft)	

	<u>Sta to Sta</u>	<u>Dist m</u>	<u>Dist ft (mi)</u>
Static Survey	72.30W to MCCARY	9614.917m	31544.9 ft (5.97 mi)
	72.30W to FABER	8901.729m	29205.1 ft (5.53 mi)
	72.30W to KOEPSSELL	157.613m	517.1 ft (0.10 mi)
Static (CORS)	72.30W to GSC1	65708.007m	215577.0 ft (40.83 mi)
	72.30W to MC07	17084.257m	56050.6 ft (10.62 mi)
	72.30W to MC08	23088.460m	75749.4 ft (14.35 mi)





# CDOT Comparison Between HARN, CORS and OPUS Region 2 Data

## Comparison of Static Solution with HARN Stations to Static Solution with CORS Stations Coordinates are State Plane Colorado Central Zone Coordinates

Project control is located in Sections 23 and 24, T 19 S, R 69 W, Fremont County CO.

<u>Solution</u>	<u>Station</u>	<u>Northing</u>	<u>Easting</u>	<u>Delta N</u>	<u>Delta E</u>	<u>Vector</u>	<u>Remarks</u>
Static Survey	32	366101.7765	952018.7728				Held 2 Fixed NGS Coordinates
Static (CORS)	32	366101.7753	952018.7777	0.001m (0.004 ft)	-0.005m (-0.016 ft)	0.005m (0.017 ft)	Static Solution from CORS
Static Survey	32	366101.7765	952018.7728				Held 2 Fixed NGS Coordinates
OPUS-RS Solution	32	366101.7580	952018.7610	0.019m (0.061 ft)	0.012m (0.039 ft)	0.022m (0.072 ft)	
Static Survey	5	366251.8198	951640.9798				Held 2 Fixed NGS Coordinates
Static (CORS)	5	366251.8207	951640.9834	-0.001m (-0.003 ft)	-0.004m (-0.012 ft)	0.004m (0.012 ft)	Static Solution from CORS
Static Survey	5	366251.8198	951640.9798				Held 2 Fixed NGS Coordinates
OPUS-RS Solution	5	366251.8090	951640.9670	0.011m (0.035 ft)	0.013m (0.042 ft)	0.017m (0.055 ft)	

	<u>Sta to Sta</u>	<u>Dist m</u>	<u>Dist ft (mi)</u>
Static Survey	32 to Newlin	7105.128m	23310.7 ft (4.41 mi)
	32 to J 430	5666.111m	18589.6 ft (3.52 mi)
	32 to N 349	5716.130m	18753.7 ft (3.55 mi)
Static (CORS)	32 to P037	5130.693m	16832.9 ft (3.19 mi)
	32 to AMC2	66407.779m	217872.9 ft (41.26 mi)
	32 to PUB6	64222.000m	210701.7 ft (39.91 mi)
Static Survey	5 to Newlin	7084.640m	23243.5 ft (4.40 mi)
	5 to J 430	5915.033m	19406.2 ft (3.68 mi)
	5 to N 349	5352.681m	17561.3 ft (3.33 mi)
Static (CORS)	5 to P037	4787.821m	15708.0 ft (2.98 mi)
	5 to AMC2	66571.061m	218408.6 ft (41.37 mi)
	5 to PUB6	64619.013m	212004.2 ft (40.15 mi)



National Geodetic Survey

# CORS/OPUS



National Oceanic and Atmospheric Administration

# CBLs

## STATE OF COLORADO CONTENTS

BASE LINE DESIGNATION	STATE	COUNTY	QUAD
ALAMOSA CBL (2005 REMEASURED)	COLORADO	ALAMOSA	N371053
CHERRY CREEK CBL (UNUSABLE)	COLORADO	ARAPAHOE	N391044
CORTEZ CBL (2004 REMEASURED)	COLORADO	MONTEZUMA	N371083
CRAIG CBL (2004 REMEASURED)	COLORADO	MOFFAT	N401074
DURANGO CBL (2004 MEASURED)	COLORADO	LA PLATA	N371073
EL PASO CBL (2004 MEASURED)	COLORADO	EL PASO	N381044
FORT CARSON CBL (2005 REMEASURED)	COLORADO	EL PASO	N381044
HIGHLINE CBL (2004 REMEASURED)	COLORADO	ADAMS	N391044
KELIM CBL (2004 REMEASURED)	COLORADO	WELD	N401043
LAMAR CBL (2004 REMEASURED)	COLORADO	PROWERS	N381023
LIMON CBL (2004 REMEASURED)	COLORADO	LINCOLN	N391033
MEEKER CBL (2005 REMEASURED)	COLORADO	RIO BLANCO	N401073
MESA (2005 VERIFIED)	COLORADO	MESA	N391083
MONTROSE CBL (2005 REMEASURED)	COLORADO	MONTROSE	N381074
NEW CASTLE CBL (2004 VERIFIED)	COLORADO	GARFIELD	N391074
PINON CANYON CBL (2005 REMEASURED)	COLORADO	LAS ANIMAS	N371041
PUEBLO 2 CBL (2005 VERIFIED)	COLORADO	PUEBLO	N381042
STERLING CBL (2004 VERIFIED)	COLORADO	LOGAN	N401031





**BETA**  
This is a BETA Release Site

# LOCUS Leveling Online Calculations User Service

National Geodetic Survey

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## About LOCUS

The Leveling Online Calculations User Service (LOCUS) is a Web utility developed by the National Geodetic Survey (NGS). The purpose of LOCUS is to simplify the office processing and adjustment of geodetic leveling, including, as a long-term goal, the submission of leveling projects to NGS for publication. LOCUS runs the same programs that NGS uses in-house to process and adjust submitted projects.

LOCUS version 1.0 will be limited to:

1. Correction of observations for systematic errors, and
2. A minimally constrained [free] least-squares adjustment. The option for a fully constrained adjustment exists but will not be supported by analysis tools and documentation until later versions.

There is an option to select one of several datums; NAVD 88 is the default.

A correctly formatted **NGS Bluebook** vertical observation (\*.hgz) file must be submitted (the vertical observation format is described in **Chapter 6** of the NGS Bluebook). The \*.hgz file must first be checked to be error-free by the NGS program **Translev** (v4.16.07 or later). The NGS program **WinDesc** must also be used to provide positions of all marks and the Permanent Identifiers (PIDs) of published bench marks into the Translev program.

If more than one published bench mark is included in the \*.hgz file, users will see the list of all PIDs available to constrain, and they may choose to do a partially or fully constrained adjustment. However, the tools to analyze the results of a constrained adjustment will not be implemented in the first version of LOCUS. Naturally, the adjusted orthometric heights of new marks will vary according to which constraints are held. Thus, results obtained using LOCUS and adjusted with user-supplied constraints may differ somewhat from results adjusted using constraints determined by NGS for publication.

To the extent possible, corrections for systematic errors are made before the adjustment. Refer to **NOAA Technical Memorandum NOS NGS 34, "Corrections Applied By The National Geodetic Survey To Precise Leveling Observations"** and to the **LOCUS Equipment & Corrections** page for more

### LOCUS menu

[Upload data file](#)

[About LOCUS](#)

[Description of Output Files](#)

[Corrections](#)

[Sample file](#)

[Help](#)

[Contact LOCUS](#)



# **LOCUS**

## **Leveling OnLine Calculations User Service**

- Provides a means to process and adjust level data
  - Has been done at NGS Headquarters
- Requires \*.hgz file from Translev
  - Error free
- Requires Description file from WinDesc
- You pick stations to constrain
- Helps expedite entire process
- Beta Version – Needs to be tested
- Data is not submitted to NGS (at this time)



# NGS Real Time Positioning Components

GOAL:

To Ensure the Proper Geodetic  
Basis  
for Accurate Real Time Positioning  
Aligned To The NSRS



# NGS - RT Program Components

- I. NGS Streams Raw Data From The Backbone CORS
- II. Provide Outreach and Education
- III. Develop and Publish Guidelines Describing Best Practices.
- IV. Research Scientific Research Affecting Accurate Real-Time Positioning. [satellite orbits, refraction, multipath, antenna calibration, and crustal motion.]

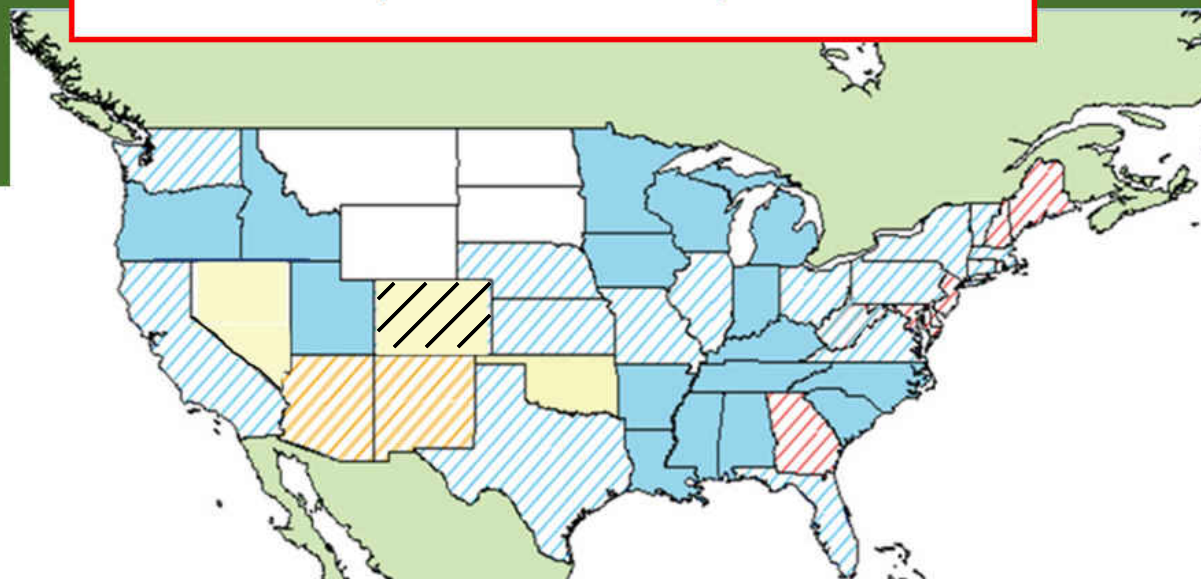




≥200 RTN WORLDWIDE  
≥107 RTN USA  
≥35 DOT

## MAJOR RTN IN THE USA (JAN 2011)

- ACADEMIC/SCIENTIFIC
- SPATIAL REFERENCE CENTERS
- VARIOUS DOTS + MACHINE GUIDANCE
- COUNTY
- CITY
- GEODETIC SURVEYS (NC, SC)
- MANUFACTURERS
- VENDOR NETWORKS
- AGRICULTURE
- MA & PA NETWORKS



- Public and Private Statewide
- Public Statewide – Planned or Operating
- Private Statewide
- Public and Private Municipal – No Statewide
- Private Municipal - No Statewide

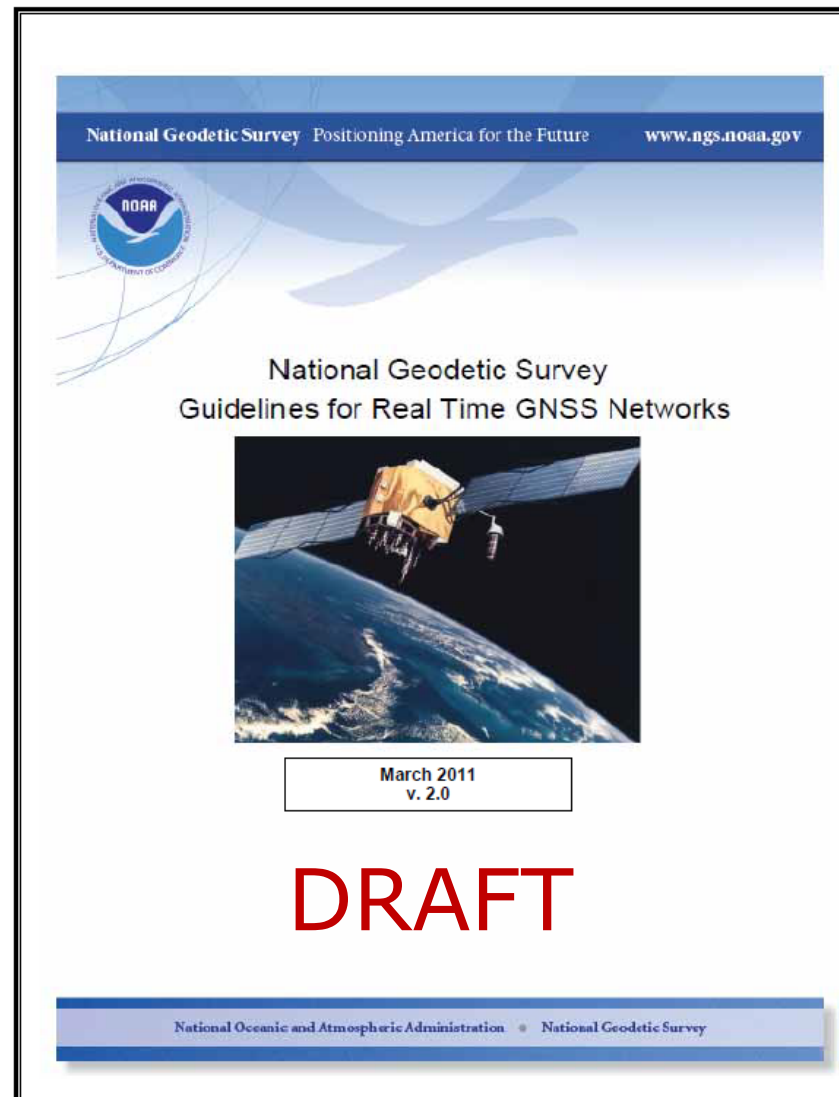
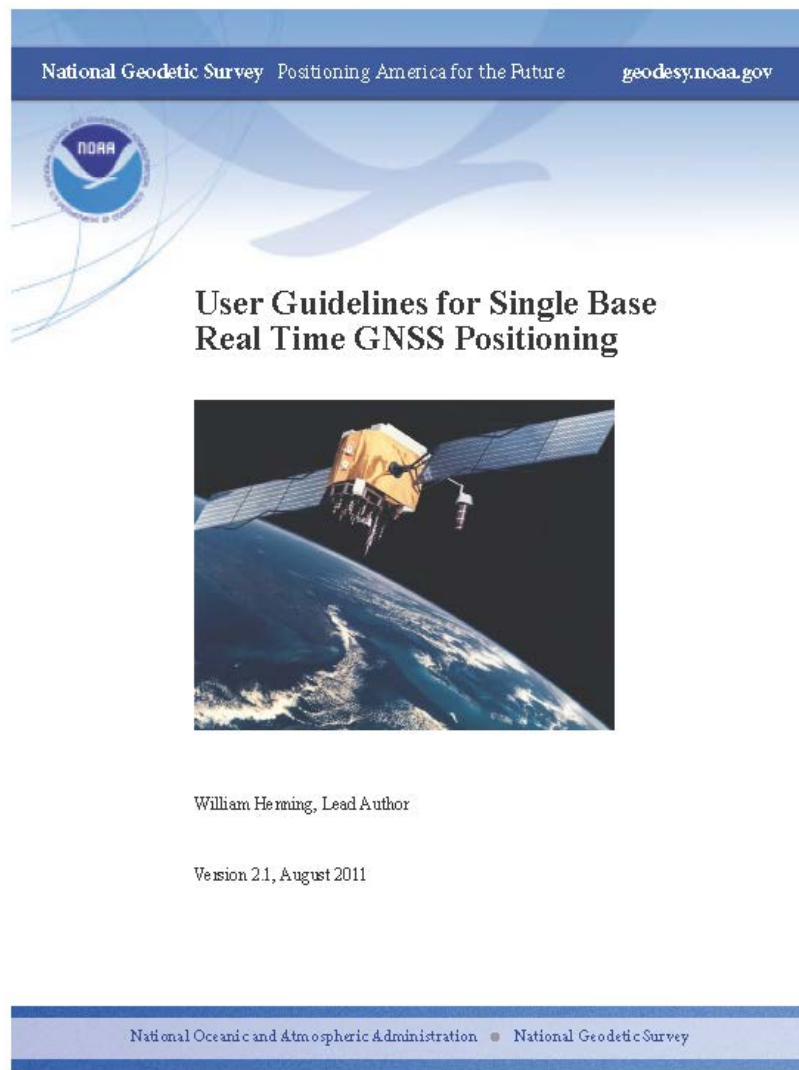
W. Henning 9/2009



# Outreach, Cooperative Efforts & Leadership



+ PUBLIC & PRIVATE RTN ADMINISTRATORS SPANNING MORE THAN 35 STATES





# Summary Table

## RT Single-Base Guidelines

ACCURACY CLASS SUMMARY TABLE

	CLASS RT1	CLASS RT2	CLASS RT3	CLASS RT4
<b>ACCURACY (TO BASE)</b>	0.015 HORIZONTAL, 0.025 VERTICAL	0.025 HORIZONTAL, 0.04 VERTICAL	0.05 HORIZONTAL, 0.06 VERTICAL	0.15 HORIZONTAL, 0.25 VERTICAL
<b>REDUNDANCY</b>	≥ 2 LOCATIONS, 4-HOUR DIFFERENTIAL	≥ 2 LOCATIONS, 4-HOUR DIFFERENTIAL	NONE	NONE
<b>BASE STATIONS</b>	≥ 2, IN CALIBRATION PROJECT CONTROL	RECOMMEND 2 IN CALIBRATION	≥ 1, IN CALIBRATION	≥ 1, IN CALIBRATION RECOMMENDED
<b>PDOP</b>	≤ 2.0	≤ 3.0	≤ 4.0	≤ 6.0
<b>RMS</b>	≤ 0.01 M	≤ 0.015 M	≤ 0.03 M	≤ 0.05 M
<b>COLLECTION INTERVAL</b>	1 SECOND FOR 3-MINUTES	5 SECONDS FOR 1-MINUTE	1 SECOND FOR 15 SECONDS	1 SECOND FOR 10 SECONDS
<b>SATELLITES</b>	≥ 7	≥ 6	≥ 5	≥ 5
<b>BASELINE DISTANCE</b>	≤ 10 KM	≤ 15 KM	≤ 20 KM	ANY WITH FIXED SOLUTION
<b>TYPICAL APPLICATIONS</b>	PROJECT CONTROL CONSTRUCTION CONTROL POINTS CHECK ON TRAVERSE, LEVELS SCIENTIFIC STUDIES PAVING STAKE OUT	DENSIFICATION CONTROL TOPOGRAPHIC CONTROL PHOTOPPOINTS UTILITY STAKE OUT	TOPOGRAPHY CROSS SECTIONS AGRICULTURE ROAD GRADING SITE GRADING	SITE GRADING WETLANDS GIS POPULATION MAPPING ENVIRONMENTAL



# **NGS Guidelines Real Time GNSS Networks**

- Site Considerations
- Planning and Design
- Administration
- Obtaining Station Coordinates  
Consistent with NAD83 and ITRS
- User Best Methods



# Obtaining Station Coordinates Consistent with NAD83 and ITRS

1. Include a subnetwork of the RTN into the National CORS network. This would be three stations if RTN has less than 30 stations, 10% of RTN with greater than 30 stations. NGS will not distribute/broadcast RTN reference station data.
2. Align all RTN reference stations coordinates to the CORS network at 2-cm horizontal and 4-cm vertical
3. For each reference station in the RTN, use the Online Positioning User Service (OPUS) at <http://www.ngs.noaa.gov/OPUS/> to test for the continued consistency of its adopted positional coordinates and velocity on a daily basis, and revise the station's adopted coordinates and/or velocity if the tests reveal a need to do so.





## **Best methods from the Guidelines: The 7 “C’S” of NOAA’s NGS**

### *The Control is at the Pole*

- Check Equipment
- Communication
- Conditions
- Calibration (or not)
- Coordinates
- Collection
- Confidence



# Expediting The Guidelines

The NGS Encourages RTN Users and Administrators to become Cooperative Partners to Provide Input that will Enable Valuable Documents to be Drafted that will Benefit the Public Welfare.

- Establishing Reference Stations
- Adjusting Networks
- Accuracy Expectations Vs. Obtained
- Baseline Distances
- Error Modeling
- Communication Issues



# Real Time Networks (RTN) Considerations

- How Are They Established?
- How Are Their Coordinates Computed? Are They Consistent?
- How Is The Network Adjusted?
- How Does The RTN Align To The NSRS?
- Can Users Use Any Manufacturers' Equipment In The RTN?
- Do Overlapping Networks Give The Same Coordinates?
- What Are The Field Accuracies?





# Real-Time Considerations

- Passive / Active
- Datums & Adjustment Epochs
- Geoid + Ellipsoid / Calibrate
- Single Base / RTN
- GNSS / GPS
- Grid / Ground



# Some RT Field Considerations

- Multipath
- Position Dilution of Precision (PDOP)
- Baseline Root Mean Square (RMS)
- Number of satellites
- Elevation mask (or cut-off angle)
- Base accuracy (datum level, local level)
- Base security
- Redundancy, redundancy, redundancy
- Part(s) Per Million Error (ppm) – iono, tropo models, orbit errors
- Space weather- sunspot numbers, solar maximum
- Geoid quality
- Site calibrations (a.k.a. Localizations)
- Bubble adjustment
- Latency, update rate
- Fixed and float solutions
- Accuracy versus Precision
- Signal to Noise Ratio (S/N or C/N0)
- Carrier phase
- Code phase
- VHF/UHF radio communication
- CDMA/SIM/Cellular TCP/IP communication
- WGS 84 versus NAD 83, local datums,
- GPS, GLONASS, Galileo, Compass Constellations



# Metadata

The RT Practitioner must record items not recorded in the Field. For instance:

- ✓ What is the Source of the Data?
- ✓ What is the Datum/Adjustment Epoch?
- ✓ What are the Field Conditions?
- ✓ What Equipment was used, especially what Antenna?
- ✓ What firmware was in the receiver and collector?
- ✓ What redundancy, if any, was used?

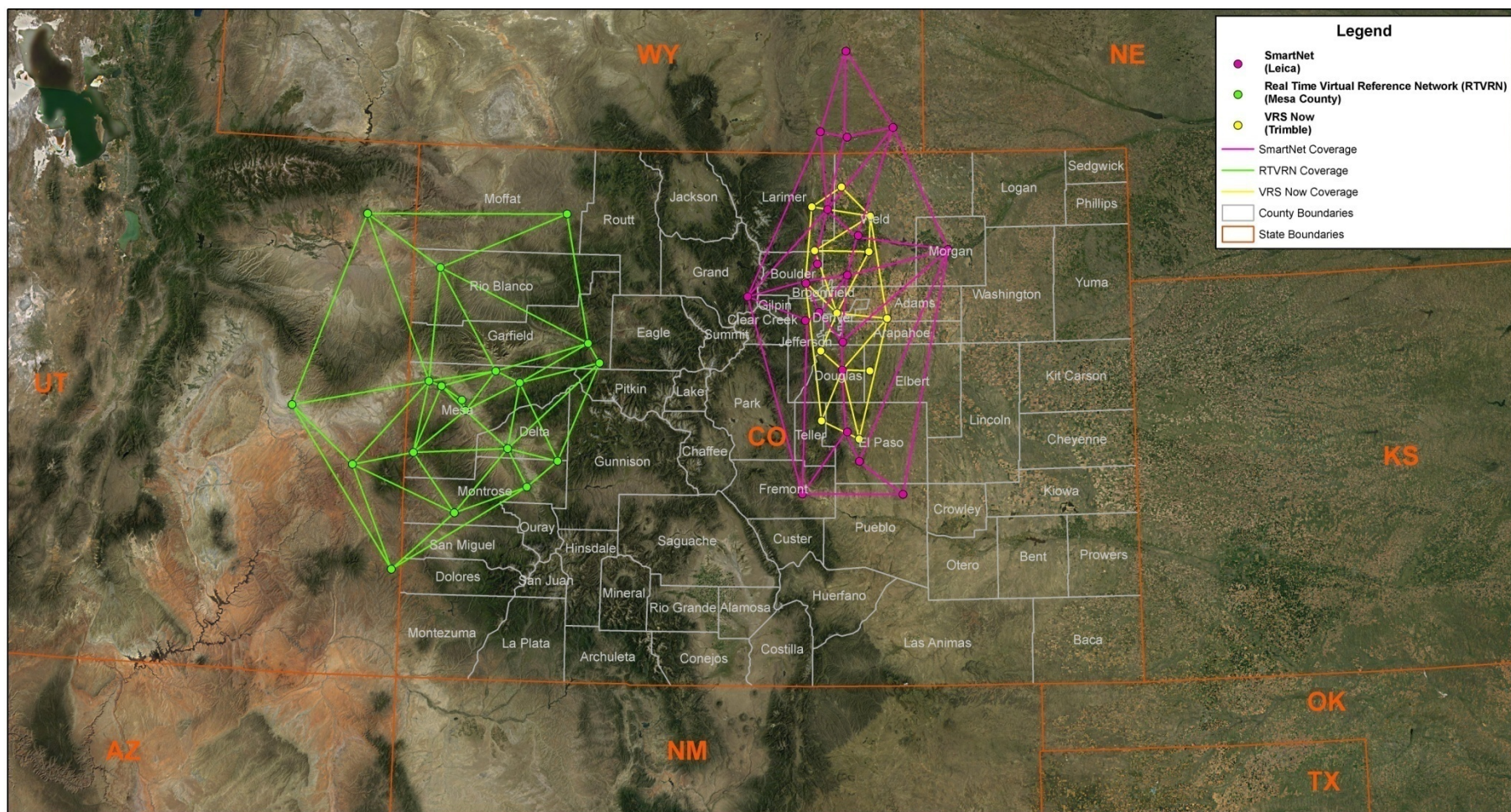






# Real Time Global Navigation Satellite System (GNSS) Reference Networks for the State of Colorado

Map Units: Meters  
Coordinate System: NAD 83, UTM Zone 13N

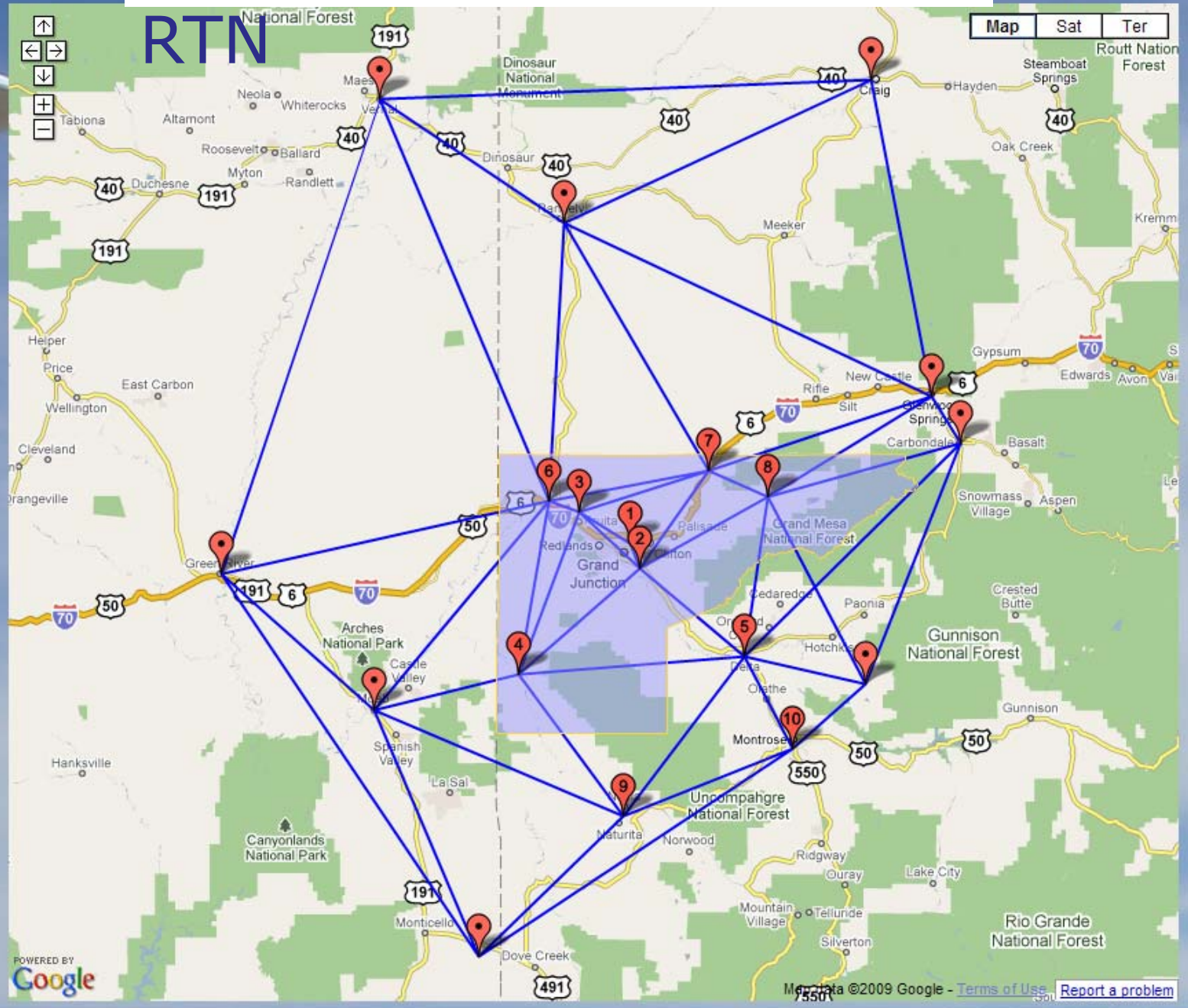


National Oceanic and Atmospheric Administration



# Mesa County, Colorado

## RTN











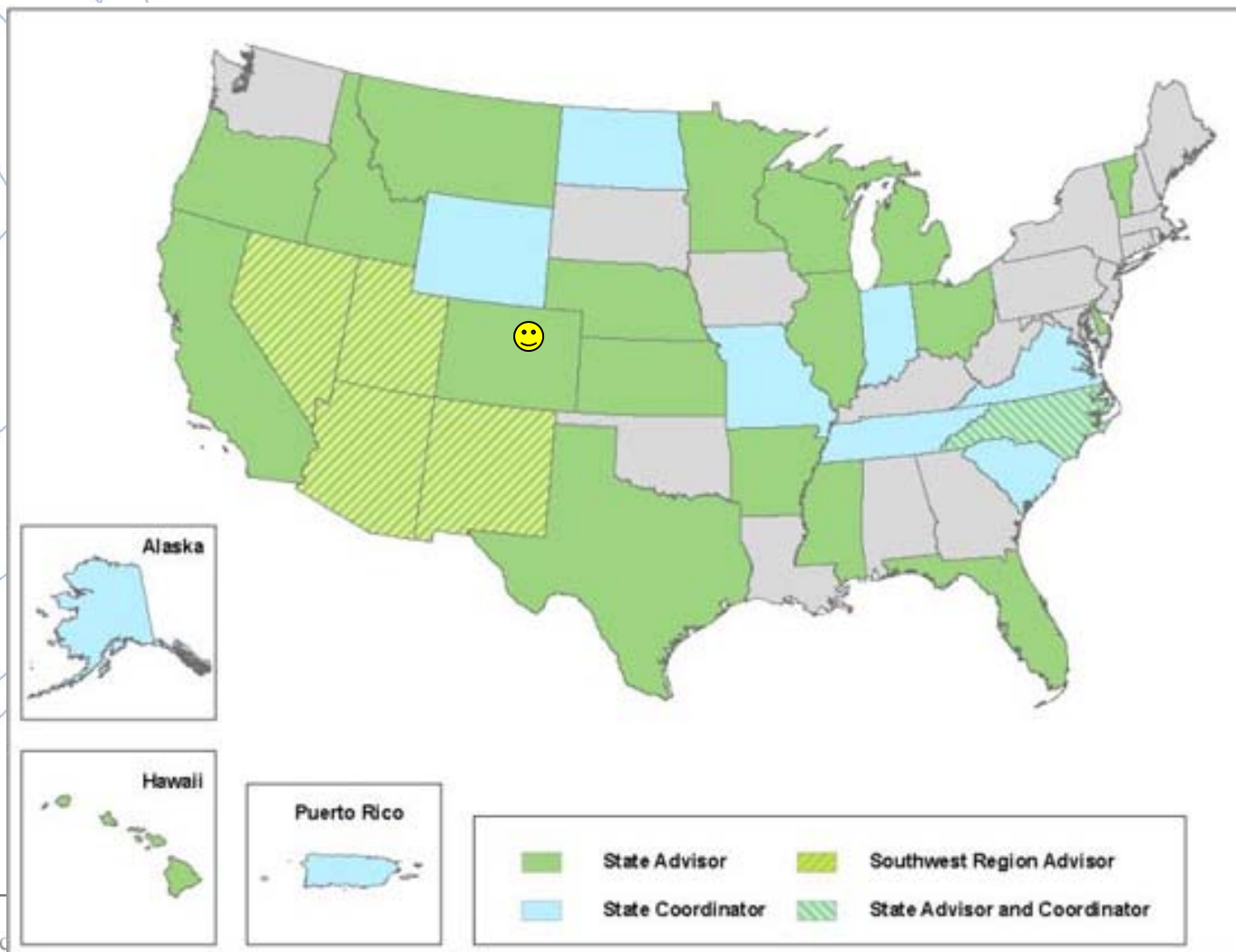


## CSRN GPS DAY

- CSRN- Colorado Spatial Reference Network (Chapter of the PLSC)
- June 9, 2012 Saturday
- 10:00 – 2:00
- Utah Park Aurora, CO (1800 S. Peoria St)
- Free Food, Vendors, Boy and Girl Scouts



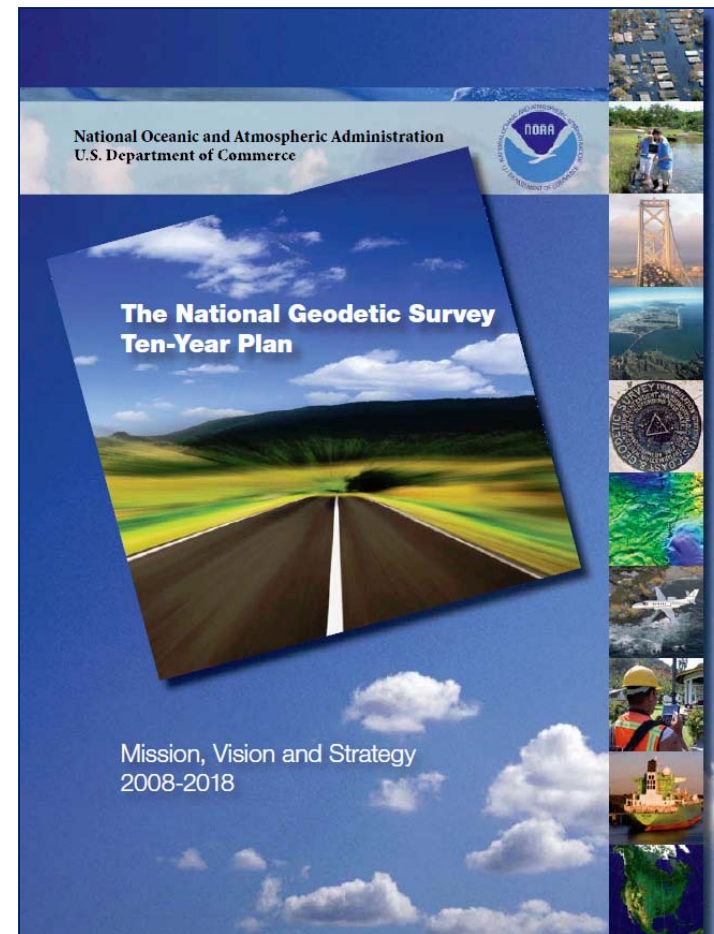
## Advisor Status In Your State





# National Geodetic Survey Ten-Year Plan

- Official NGS policy as of January 2008
- Replace NAVD 88 with a GPS/geoid datum
- Replace NAD 83 with a geocentric GPS based datum



## NGS 10-Year Plan (excerpts)

Vision 1# Summary:  
By 2020?, NGS has defined a **new geometric datum** (classically called “horizontal”) **to replace NAD 83** with its many systematic errors. The primary means of accessing this new datum is GNSS technology.

Vision #2 Summary:  
By 2020?, a new **geopotential datum** (for orthometric and dynamic heights) is defined and realized through the combination of **GNSS technology and gravity field modeling.**

Note: Vision #2 can not happen without Vision #1.



## NGS 10-Year Plan (more excerpts)

“NGS redefines the national horizontal datum to remove gross disagreements with the ITRF.”

“The primary means of accessing this new datum is GNSS technology. While passive control continues to be used as a secondary method to access the NSRS, such control will be “tied to”, not a “part of”, the NSRS.”

“Furthermore, NGS will provide simple transformation tools between historic and current datums and reference frames used by NGS, in four dimensions, wherever practical and possible.”

“In order to support users of NAVD 88, NGS will provide transformation tools between the new datum and NAVD 88 based predominantly on the few thousand measurements of GPS derived ellipsoid heights on NAVD 88 benchmarks.”

*Underlining added for emphasis*





## Why a New Datum(s)?

- NAD 83
  - non-geocentric, i.e. inconsistent with GNSS positioning
  - NAD 83 coordinates of the Continuously Operating Reference Station (CORS) network inconsistent with passive marks
  - Lack of velocities, i.e. NAD 83 does not report station motion for passive marks



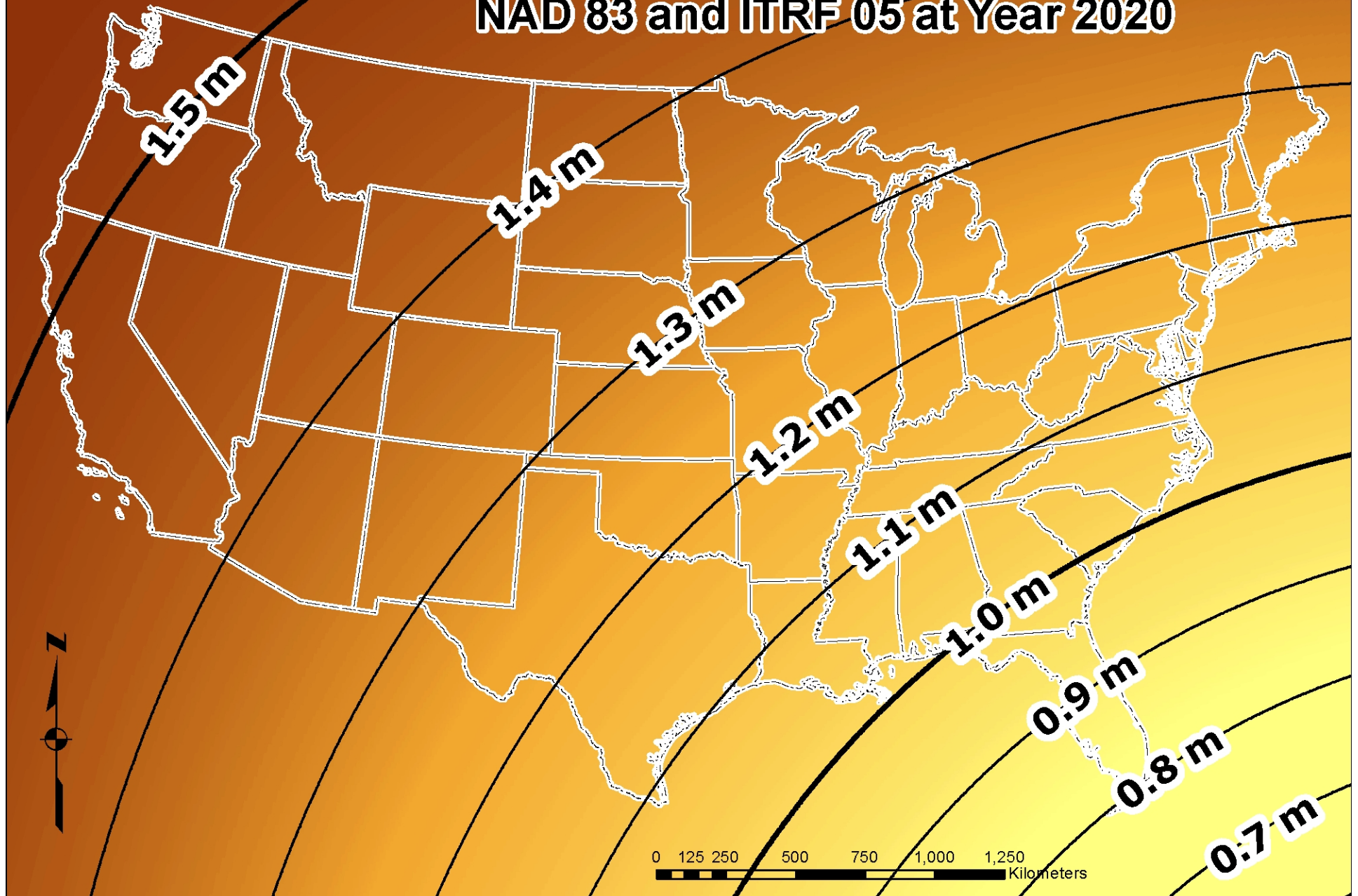
## Why a New Datum(s)?

### ○ NAVD 88

- cross-country build up of errors (“tilt” or “slope”) from geodetic leveling
- Passive marks inconveniently located and vulnerable to disturbance and destruction
- A 0.5 m bias in the NAVD 88 reference surface from the geoid surface best approximating global mean sea level
- Subsidence, uplift, freeze/thaw, and other crustal motions invalidate heights of passive marks, and can make it difficult to detect such motions.
- Passive marks without adequate geophysical models make it difficult to reliably detect sea level change
- Changes to Earth’s gravity field cause changes in orthometric heights, but NAVD 88 does not allow/account for those changes (because it is based on a static gravity model)
- The gravity model and modeling techniques used to determine NAVD 88 are not consistent with those currently used for geoid modeling



# Horizontal Position Difference Between NAD 83 and ITRF 05 at Year 2020





## New Datums

“NGS redefines the national horizontal datum to remove gross disagreements with the ITRF.”

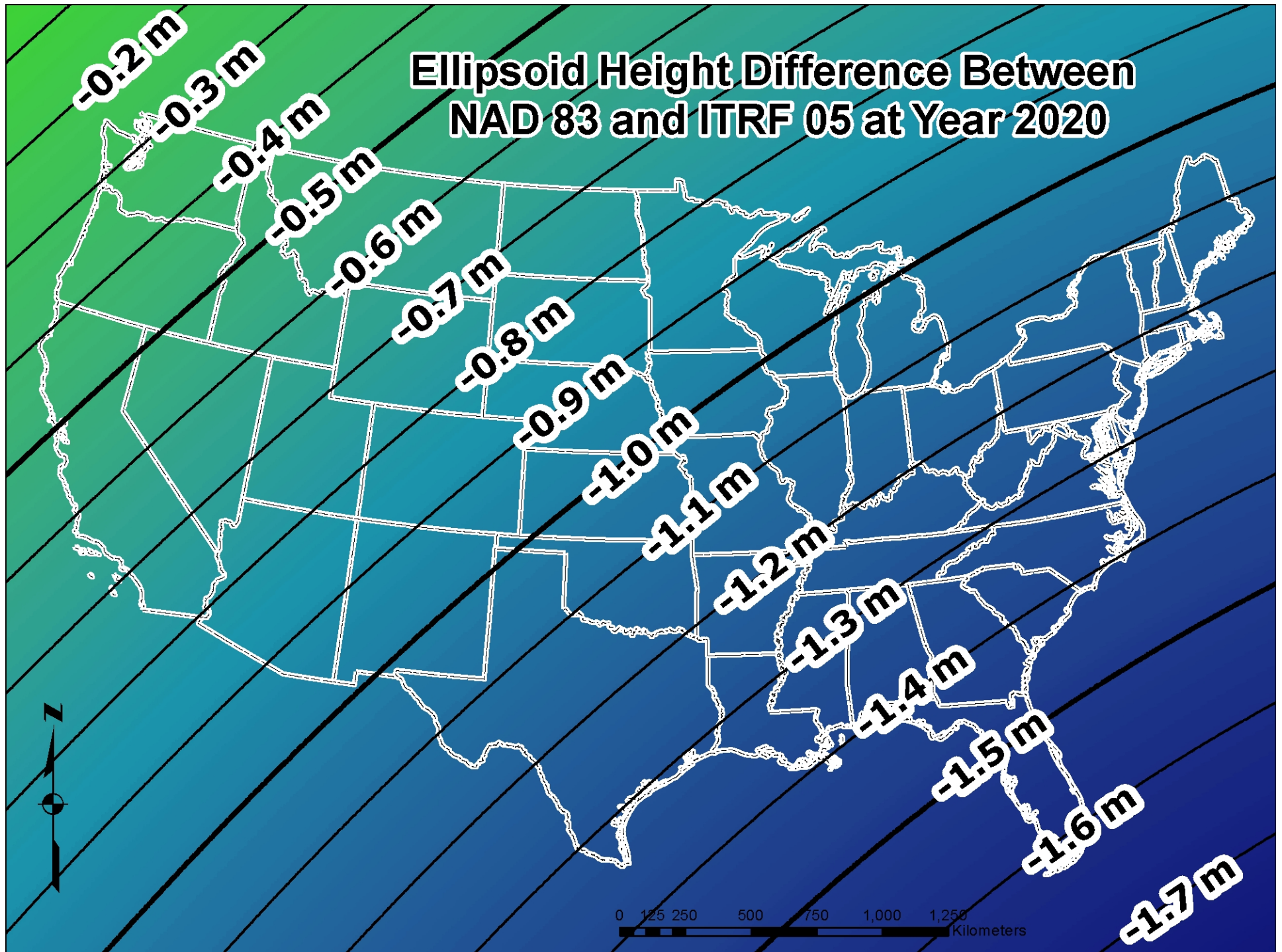
*In other words, ellipsoid heights will change.*

“By 2020(?), a new geopotential datum (for orthometric and dynamic heights) is defined and realized through the combination of GNSS technology and gravity field modeling.”

*In other words, orthometric heights will NOT be based on leveling data and they too will change.*




# Ellipsoid Height Difference Between NAD 83 and ITRF 05 at Year 2020



<http://www.ngs.noaa.gov/>


[www.geodesy.noaa.gov](http://www.geodesy.noaa.gov)



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Positioning America for the Future

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### Announcements

February 16, 2012

**NGS Releases Beta LOCUS for Testing**  
NGS has released a Beta version of the **Leveling Online Computations User Service**, LOCUS, for a 90-day comment period. Through the end of March 2012, NGS is requesting our stakeholders and constituents to test their leveling projects with LOCUS and provide feedback to us at...[more](#)

**NGS Announces New Photo Submission Guidelines:**  
[http://geodesy.noaa.gov/web/surveys/photo\\_submissions/](http://geodesy.noaa.gov/web/surveys/photo_submissions/)

**NGS Releases Final Report for Floodplain Mapping Pilot Project**  
As NGS moves closer to 2022 and replacing the **North American Datum of 1983** (NAD 83) and the **North American Vertical Datum of 1988** (NAVD 88), NGS is interacting closely with agencies that use the datums to assist in the transition...[more](#)

**Notice: Planned Updates to NGS Datasheet Format**  
In response to stakeholder and NGS staff concerns, NGS has developed several modifications to the format of the **NGS datasheet**—the primary method for accessing the passive control network of the National Spatial Reference System (NSRS)...[more](#)

**Trial Version of the New NOAA Shoreline Data Explorer Available:**  
[http://beta.ngs.noaa.gov/shoreline\\_raster](http://beta.ngs.noaa.gov/shoreline_raster)

**2010 Federal Geospatial Summit Proceedings on Improvements to the National Spatial Reference System available:**  
<http://www.ngs.noaa.gov/2010Summit/proceedings.shtml>

A 2009 independent study shows the benefits to the U.S. economy from NOAA's positioning products and services are in the billions of dollars.  
Click [here](#) for a one page overview of the study  
Click [here](#) for a copy of the full report

### In The News


02/16/2012 - NGS Presents at Geodesy Meeting in Austria  
The National Geodetic Survey recently represented the United States at the joint meeting of two International Association of Geodesy working groups in Vienna, Austria. The meeting focused on how absolute gravimeter comparisons are conducted...[more](#)

### Most Popular


- Contact Us
- CORS
- Survey Mark Datasheets
- Geodetic Tool Kit
- NA2011
- OPUS
- Publications
- Geodetic Advisors
- Storm Imagery
- UFCORS

### Upcoming Events

### NRC Highlights Importance of NGS Products...



### Federal Geodetic Control Subcommittee of the fgdc



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**[geodesy.noaa.gov](http://www.geodesy.noaa.gov)**

CORS Webpage: <http://www.ngs.noaa.gov/CORS/>

CORS newsletter

OPUS Webpage: <http://www.ngs.noaa.gov/OPUS/>

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[www.ngs.noaa.gov/ADVISORS/AdvisorsIndex.shtml](http://www.ngs.noaa.gov/ADVISORS/AdvisorsIndex.shtml)

This presentation will be uploaded to:

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FAQs on the various webpages

# Next Steps/Priorities NGS-CDOT

- CBL
- OPUS-DB (Begin implementing)
- CORS (Begin Implementing)
- OPUS – CDOT Survey Manual
- Heights -Study





**Thank You**

[pamela.fromhertz@noaa.gov](mailto:pamela.fromhertz@noaa.gov)  
240-988-6363



# Questions? Comments?

## Multi-Year CORS Solution

## National Adjustment of 2011

## New NGS Datasheet Format



Data Sheet

for more information about the datasheet.

SIDB , PROGRAM = datasheet95, VERSION = 7.87.4  
 National Geodetic Survey, Retrieval Date = AUGUST 19, 2011  
 \*\*\*\*\*  
 ID - This is a Height Modernization Survey Station.  
 This is a Primary Airport Control Station.  
 DESIGNATION - AZC A  
 - AC6803  
 STATE/COUNTY - AZ/MOHAVE  
 QUAD - LOST SPRING MTN EAST (1988)

\*CURRENT SURVEY CONTROL

	36 57 59.55377(N)	113 00 32.22917(W)	ADJUSTED
83(2007)-	36 57 59.55377(N)	113 00 32.22917(W)	ADJUSTED
88 -	1485.56 (meters)	4873.9 (feet)	GPS OBS

DATE - 2007.00  
 - -1,994,789.496 (meters) COMP  
 - -4,697,388.731 (meters) COMP  
 - 3,815,306.819 (meters) COMP  
 AGE CORR- 3.37 (seconds) DEFLEC09  
 P HEIGHT- 1462.787 (meters) (02/10/07) ADJUSTED  
 D HEIGHT- -22.80 (meters) GEOID09

--- Accuracy Estimates (at 95% Confidence Level in cm) ---  
 PID Designation North East Ellip  
 DRK AC6803 AZC A 0.74 0.61 1.37

mark is at Colorado City Municipal Airport (AZC)

Horizontal coordinates were established by GPS observations  
 adjusted by the National Geodetic Survey in February 2007.

Datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).

National Readjustment for more information.

Horizontal coordinates are valid at the epoch date displayed above.  
 Epoch date for horizontal control is a decimal equivalence  
 Year/Month/Day.

Orthometric height was determined by GPS observations and a  
 resolution geoid model.

Derived orthometric heights for airport stations designated as  
 or SACS are published to 2 decimal places. This maintains  
 meter relative accuracy between the PACS and SACS. It does  
 indicate centimeter accuracy relative to other marks which are  
 of the NAVD 88 network.

AC6803  
 AC6803.The X, Y, and Z were computed from the position and the ellipsoidal ht.  
 AC6803

### The NGS Data Sheet

See file [dsdata.txt](#) for more information about the datasheet.

DATABASE = NGSIDB , PROGRAM = datasheet95, VERSION = 8.00  
 1 National Geodetic Survey, Retrieval Date = JANUARY 1, 2012  
 \*\*\*\*\*  
 AC6803 HT\_MOD - This is a Height Modernization Survey Station.  
 AC6803 PACS - This is a Primary Airport Control Station.  
 AC6803 DESIGNATION - AZC A  
 AC6803 PID - AC6803  
 AC6803 STATE/COUNTY - AZ/MOHAVE  
 AC6803 COUNTRY - USA  
 AC6803 USGS QUAD - LOST SPRING MTN EAST (1988)  
 AC6803  
 AC6803 \*CURRENT SURVEY CONTROL  
 AC6803  
 AC6803 NAD 83(2007) POSITION- 36 57 59.55377(N) 113 00 32.22917(W) ADJUSTED  
 AC6803 NAD 83(2007) ELLIP HT- 1462.787 (meters) (02/10/07) ADJUSTED  
 AC6803 NAD 83(2007) EPOCH - 2007.00  
 AC6803 NAVD 88 ORTHO HEIGHT - 1485.56 (meters) 4873.9 (feet) GPS OBS  
 AC6803 NAVD 88 EPOCH - 2006.81 (feet) (meters) (feet) GPS OBS  
 AC6803  
 AC6803 NOTE: NAVD 88 ortho height was determined from prior model GEOID03.  
 AC6803 GEOID03 HEIGHT - -22.75 (meters)  
 AC6803 GEOID09 HEIGHT - -22.80 (meters)  
 AC6803 NAD 83(2007) X - -1,994,789.496 (meters) COMP  
 AC6803 NAD 83(2007) Y - -4,697,388.731 (meters) COMP  
 AC6803 NAD 83(2007) Z - 3,815,306.819 (meters) COMP  
 AC6803 LAPLACE CORR - 3.37 (seconds) DEFLEC09  
 AC6803  
 AC6803 FGDC Geospatial Positioning Accuracy Standards (95% confidence, cm)  
 AC6803 Type Horiz Ellip Dist(km)  
 AC6803  
 AC6803 NETWORK ACCURACY 0.86 1.37  
 AC6803 MEDIAN LOCAL ACCURACY AND DIST ( 11 points) 0.67 1.22 1.64  
 AC6803  
 AC6803 NOTE: Individual local accuracy values and other accuracy information  
 AC6803 are available [here](#).  
 AC6803  
 AC6803 This mark is at Colorado City Municipal Airport (AZC)  
 AC6803  
 AC6803 The horizontal coordinates were established by GPS observations  
 AC6803 and adjusted by the National Geodetic Survey in February 2007.  
 AC6803  
 AC6803 The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).  
 AC6803 See [National Readjustment](#) for more information.  
 AC6803 The horizontal coordinates are valid at the epoch date displayed above.  
 AC6803 The epoch date for horizontal control is a decimal equivalence  
 AC6803 of Year/Month/Day.  
 AC6803  
 AC6803 The orthometric height was determined by GPS observations and a  
 AC6803 high-resolution geoid model.  
 AC6803  
 AC6803 GPS derived orthometric heights for airport stations designated as

