Improvements to the National Spatial Reference System

2012 OGUG Workshop
GNSS Nuts and Bolts with Best Practices Panel

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NOAA's National Geodetic Survey

Topics Include

- New Coordinates and Epoch for CORS
- Review Multi-year CORS Solution
- Absolute vs. Relative Antenna Calibrations
- Access to CORS data
- Ongoing Adjustment of ~80K Passive Stations (NA2011 Project)
- Subsequent Development of GEOID12
- ...and a new Datasheet format
- DSWorld demonstration

New CORS Coordinates for the NSRS

OPUS: Online Positioning User Service

National Geodetic Survey

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On September 6, 2011 NGS's CORS group released **revised coordinates** for all CORS sites. The new coordinates update both the global frame and the National Spatial Reference Frame as follows.

New Frames		Previous Frames	
IGS08	Epoch 2005.00	ITRF00	Epoch 1997.00
NAD 83(2011)	Epoch 2010.00	NAD 83(CORS96)	Epoch 2002.00
NAD 83(MA11)	Epoch 2010.00	NAD 83(MARP00)	Epoch 2002.00
NAD 83(PA11)	Epoch 2010.00	NAD 83(PACP00)	Epoch 2002.00

NGS is in the process of completing an **adjustment of the passive control network**. Until the adjustment is complete, OPUS will allow users to choose getting coordinates in either the new or previous reference frames. Once the passive network is adjusted to NAD 83(2011, MA11, PA11) then the OPUS support for ITRF00 and NAD 83(CORS96, MARP00, PACP00) will end.

Choose a frame to upload your data:

for new frames, click below:	for previous frames, click below:
NAD 83(2011,MA11,PA11) Mexico(IGS08) epoch 2010.00 International IGS08 epoch of observation	NAD 83(CORS96,MARP00,PACP00) epoch 2002.00 ITRF00

NAD 83 (2011) And OPUS

The Online Positioning User Service (OPUS) also began offering results in the IGS08 and NAD 83(2011) reference frames in September, 2011.
http://geodesy.noaa.gov/OPUS/

Although the NAD 83 (2011) is not a new datum, the CORS coordinates used by OPUS in generating its results are different. NGS recognizes that this change poses a challenge. To help users confidently switch to the new reference frame realizations, OPUS now offers the choice to have its results reported in the IGS08 and NAD 83(2011) or in the previous ITRF2000 and NAD 83 (CORS96).

But users are ***strongly*** encouraged to switch to the improved datum as soon as possible. This transition period will end after a few months.

Why Update NSRS?

Generally can't continue to live in epoch 2002

- Generate fully consistent orbits, EOPs and CORS+global station coordinates using latest models and methods—existing history is inadequate for modern realizations of TRFs
  - **longer data spans**
  - **absolute antenna calibrations**
    - **satellite transmitting and ground receiving antennas**
  - **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**
- Contribute NGS reprocessed orbits, EOPs and global SINEX files to International GNSS Service (IGS) repro1 campaign
- Generate CORS coordinates and velocities in global framework using new orbits, EOPs and global station coords

Multi-year CORS Solution: MYCS

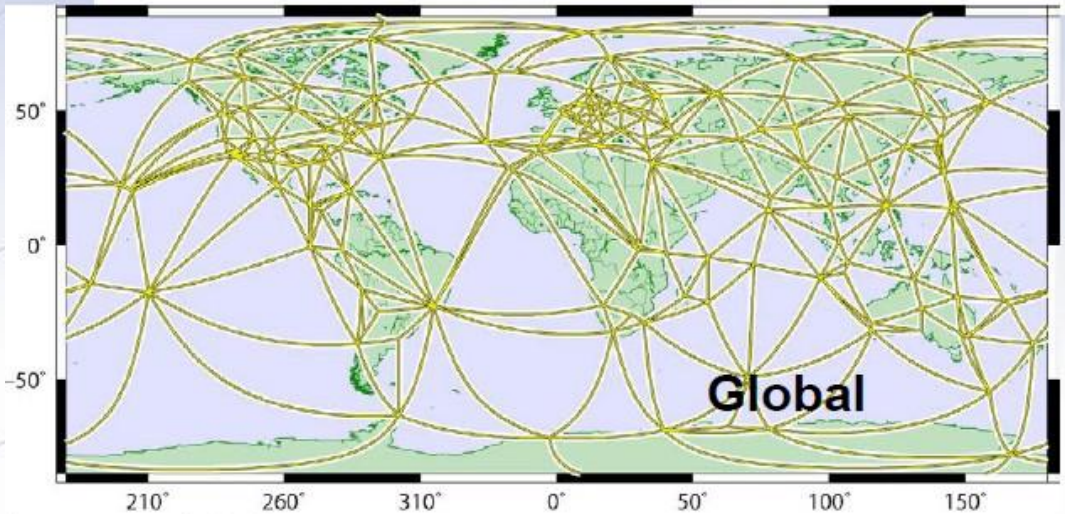
- "Multi-year" effort began 6 years ago.
- IGS proposed re-processing all data to re-compute station coordinates, orbits, and EOPs (earth orientation parameters) from 1994-2010.5 (~17 year time series).
- NGS began with a revision of PAGES software and processing strategy.
- 860 weekly (full history) CORS+ ~230 global SINEX files containing X,Y,Z positions and full variance-covariance information – <u>positions programmatically stacked to facilitate identifying discontinuities in position movement</u>.
- **Final Coordinates published (online) on Sept. 6, 2011**

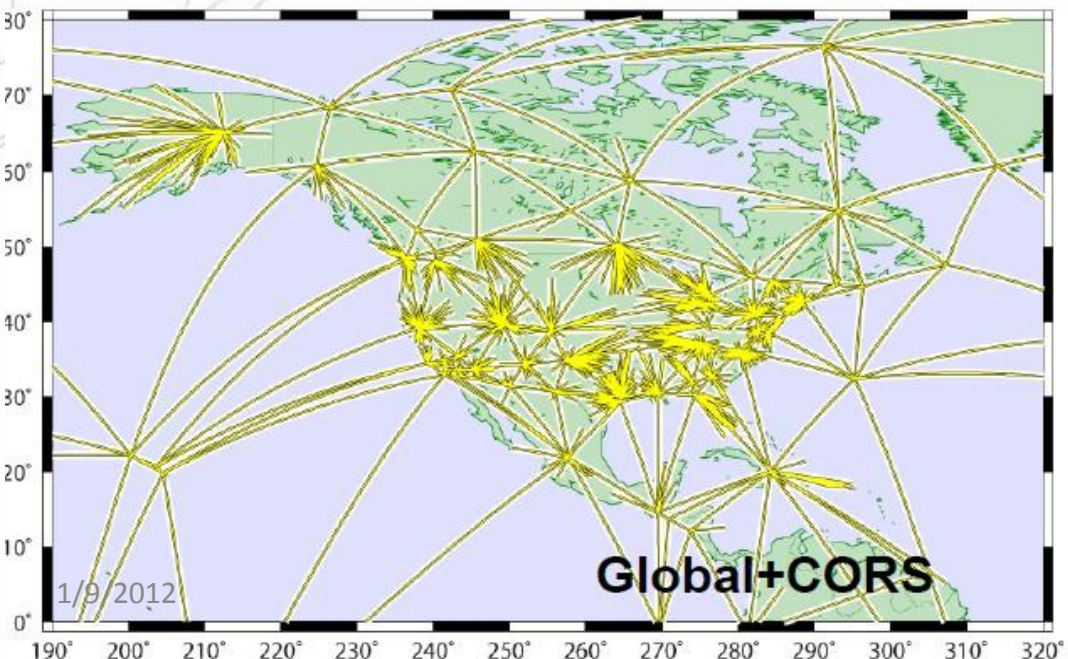
Frame Definition and Nomenclature

- ITRF frame (global) multi-technique—vlbi, slr, doris, gnss
- IGS frame (global) **GNSS only**
- NAD frame (plate fixed) transformed from IGS08
- **Critical to pay attention to frame tags and epoch dates and antenna calibration values**

Tying CORS to Global Network

(~1600 sites in recent weekly CORS+glbl SNX files)





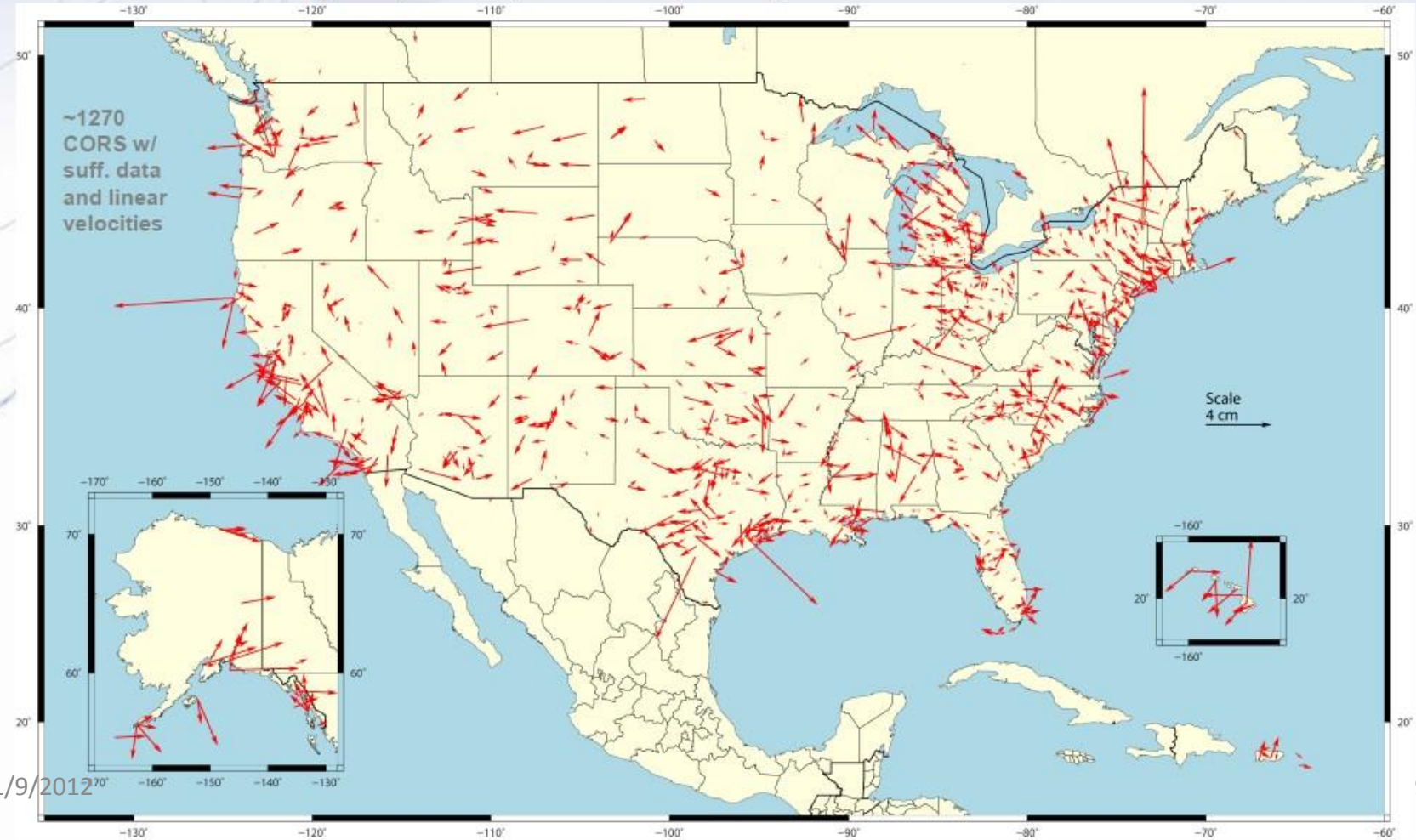
- **global tracking network used for estimating:**
  - **GPS satellite orbits (15-min intervals)**
  - **terrestrial framework**
    - **Earth Orientation (EOPs)**
    - **global station positions (weekly averages)**

- **U.S. CORS tied to global framework via single baselines radiating from global stations**
  - **minimizes frame distortions from local effects in dense regional networks**

Changes in *Horizontal* NAD 83 Positions

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

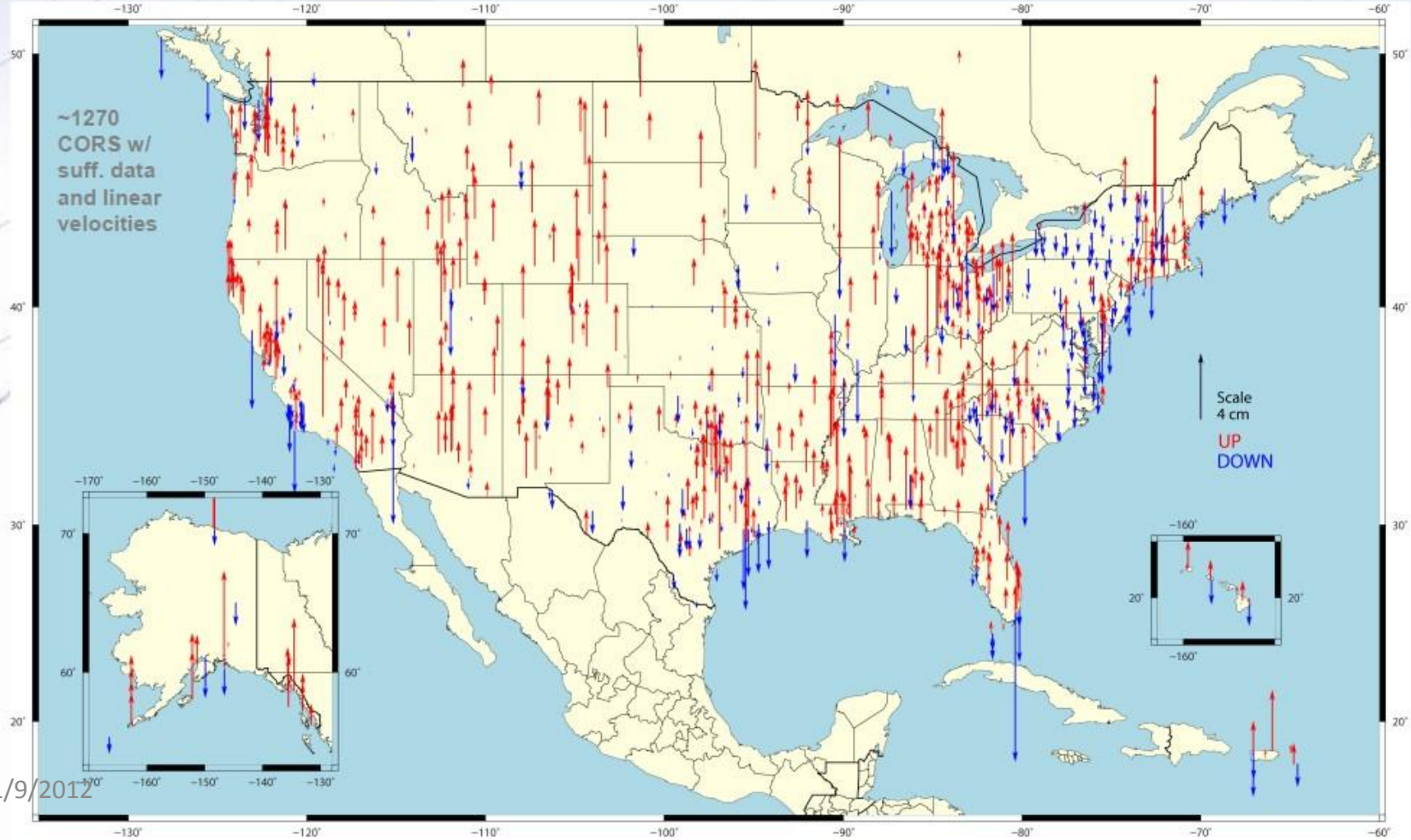
- approx. 2 cm error expected @ 2005.0 (based on σ in old solution)
- avg. horizontal shifts: ΔE = -0.18 (± 1.86) cm ΔN = 0.14 (± 1.07) cm
  - prescribing velocities using numerical models (i.e. HTDP)
  - smaller random part probably caused by change to absolute antenna calibrations



Changes in *Vertical* NAD 83 Positions

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

- avg. vertical shift: $\Delta U = 0.71$ cm ($\pm$ 2.11) cm
  - random part mostly caused by switch to absolute antenna calibrations
  - shifts also caused by assuming $V_u = 0$ in NAD 83(CORS96)



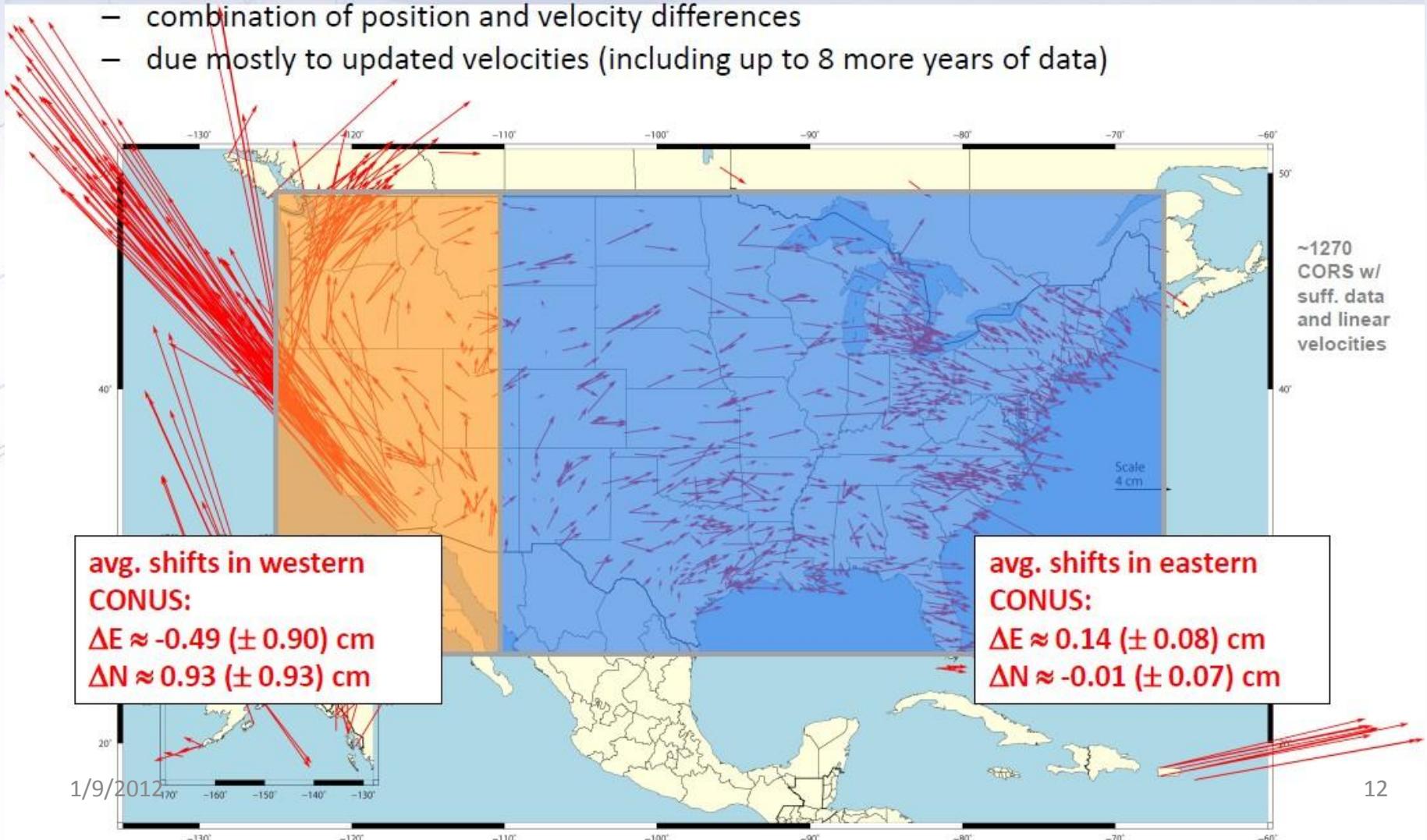
The NAD 83 datum is the same. So what will be the shifts caused by changing reference epoch to 2010?

- previous 2 slides show consequences of new realization:
  - approx. 1-2 mm avg. horiz. shift
  - less than 1 cm avg. vert. shift
- BUT reference epoch will change from 2002.0 to 2010.0
  - velocities are therefore critical
- let's compare NAD 83(CORS96) positions @ 2002.0 to NAD 83(2011) positions @ 2010.0
  - differences dominated by effects of crustal motion, i.e., NAD 83 velocities are non-zero
  - **e.g. 2 mm/yr velocity after 8 years = 1.6 cm change in position**

Changes in *Horizontal* NAD 83 Positions Different Epochs

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

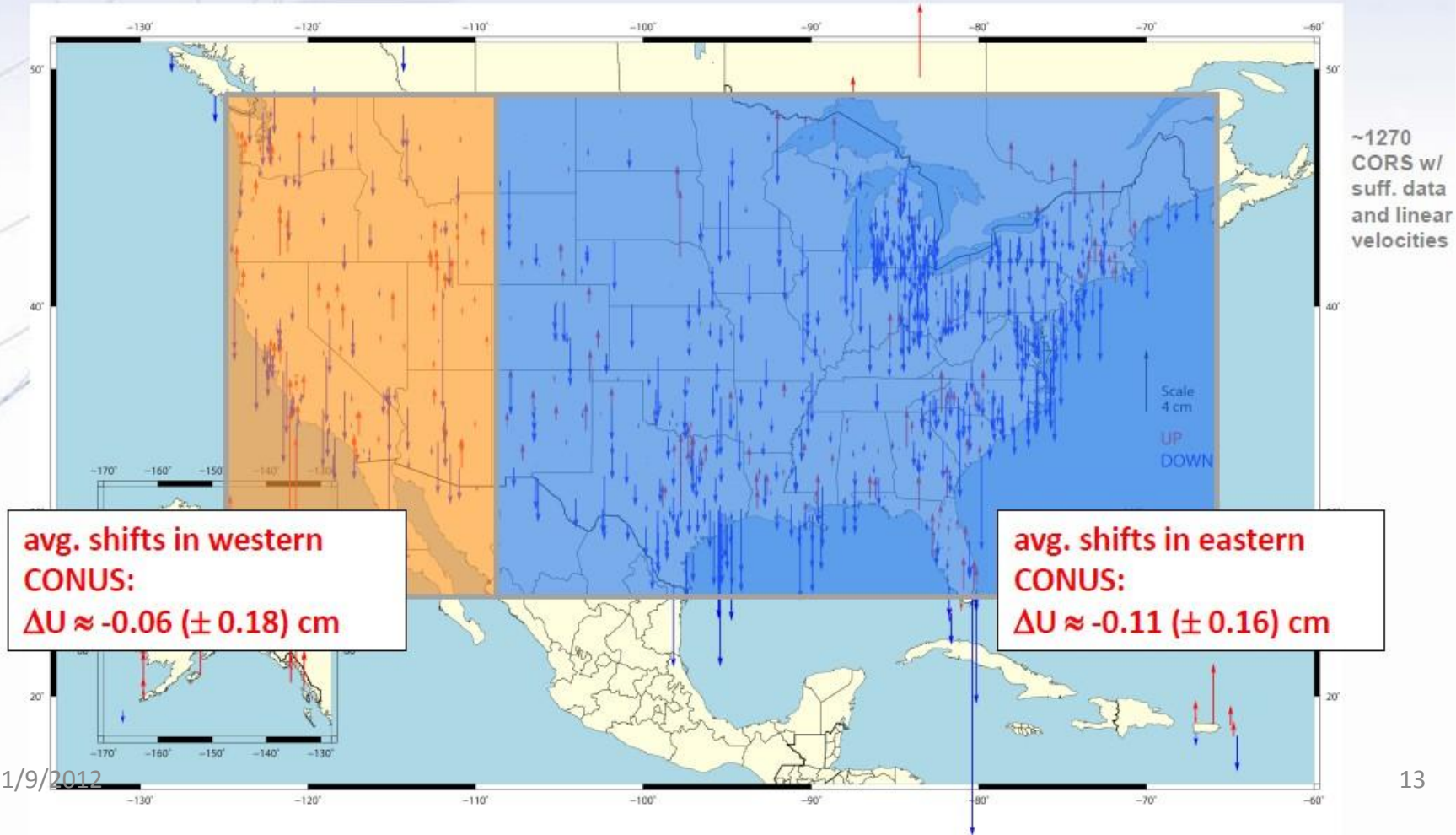
- approx. 2 cm error expected @ 2005.0 (based on σ in old solution)
- overall avg. horizontal shifts: $\Delta E = 0.09\ (\pm 5.84)$ cm $\Delta N = 2.03\ (\pm 5.98)$ cm
  - combination of position and velocity differences
  - due mostly to updated velocities (including up to 8 more years of data)



Changes in *Vertical* NAD 83 Positions Different Epochs

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

- overall avg. vertical shifts: $\Delta U = -0.79\ (\pm\ 2.09)$ cm
  - combination of position and velocity differences from additional data, tectonics
  - assuming vertical velocity ≈ 0.00 in NAD 83(CORS96)



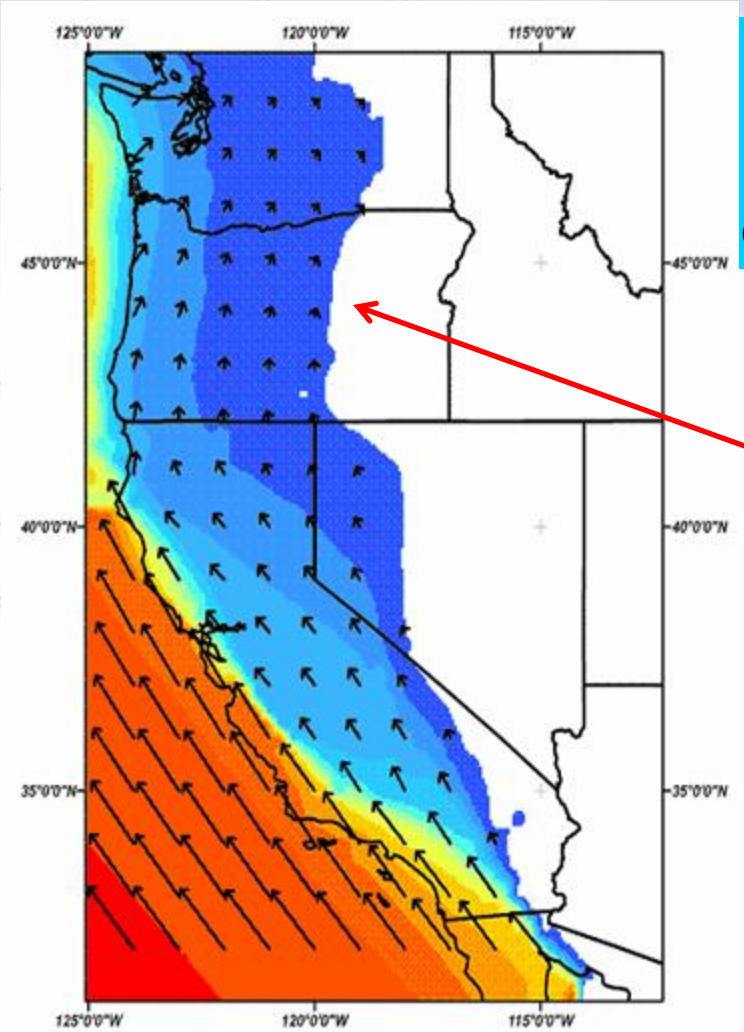
Geodetic Reference Frames past and present

- **Critical** to pay attention to frame tags and epoch dates and antenna calibration values

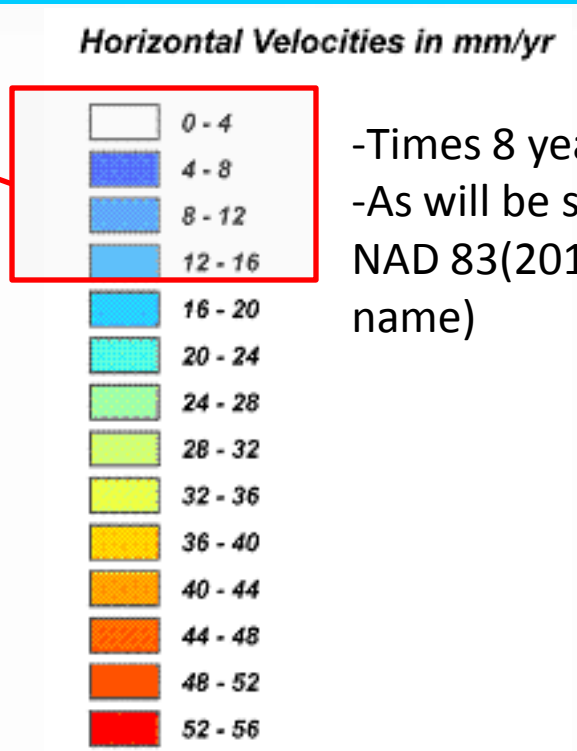
Frame Name	Epoch	Antenna PCV*	Data Duration
ITRF2000	1997.0	Rel ANTEX	1994.0-2002.0
ITRF00 (NGS's soln)	1997.0	Rel NGS ANTEX	1994.0-present
NAD 83(CORS96)	2002.0	Rel NGS ANTEX	1994.0-present
ITRF2008	2005.0	Abs IGS05 ANTEX	1997.0-2009.5
IGS08	2005.0	Abs IGS08 ANTEX	1997.0-2009.5
IGS08 (NGS's ~~tentative~~)	2005.0	Abs IGS08 ANTEX	1994.0-2010.5 (ongoing)
NAD 83(2011) ~~(tentative)~~	2010.0	Abs IGS08 ANTEX	1994.0-2010.5 (ongoing)

*PCV – phase center value; Abs-Absolute, Rel-Relative

West Coast Crustal Motion



Horizontal velocities in the western U.S. relative to the North American Datum of 1983 as derived from geodetic observations.



-Times 8 years (2002-2010)
-As will be seen realized with NAD 83(2011)Epoch2010 (tent. name)

Slide from R. Snay, NGS

Faults Experience Excessive Movement

- Pacific plate: at 5cm/yr (right at the San Andreas fault), in 20 years, that's 100cm or 1m!
- In 8 yrs, those NW arrows' max is ~40cm
- Sites experiencing significant vertical crustal motion may also shift horizontally

Relative vs. Absolute Antenna Models

Background

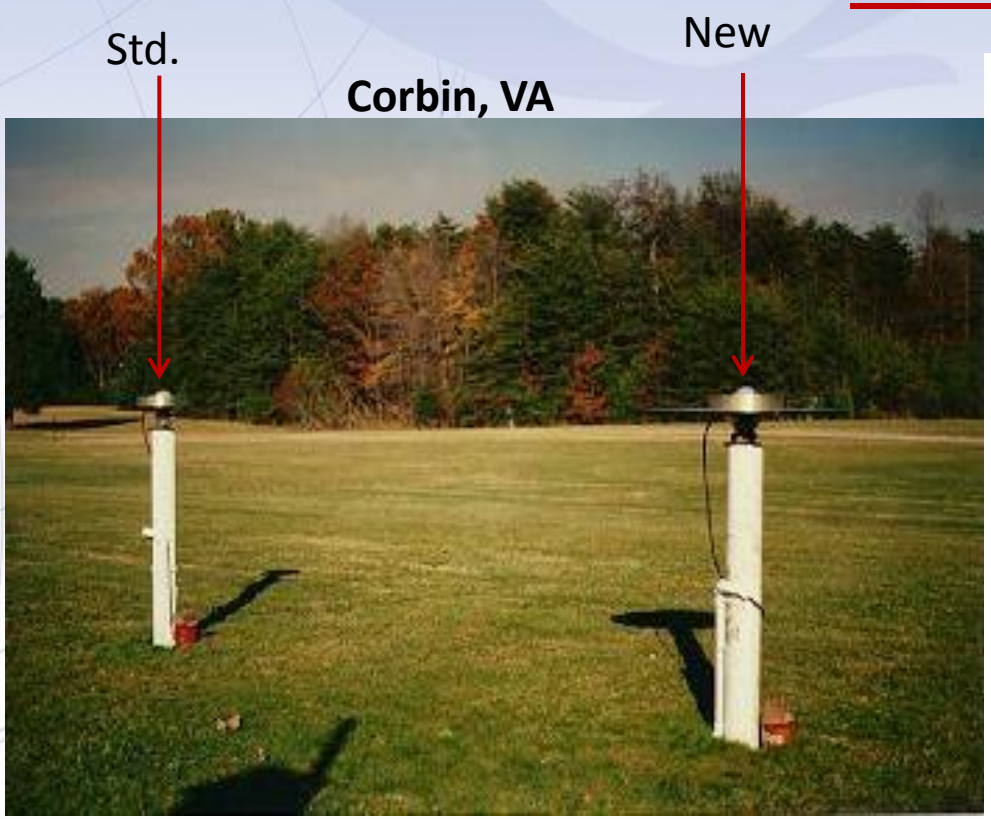
The IGS started to use absolute antenna phase center variation (PCV) patterns with GPS week 1400.

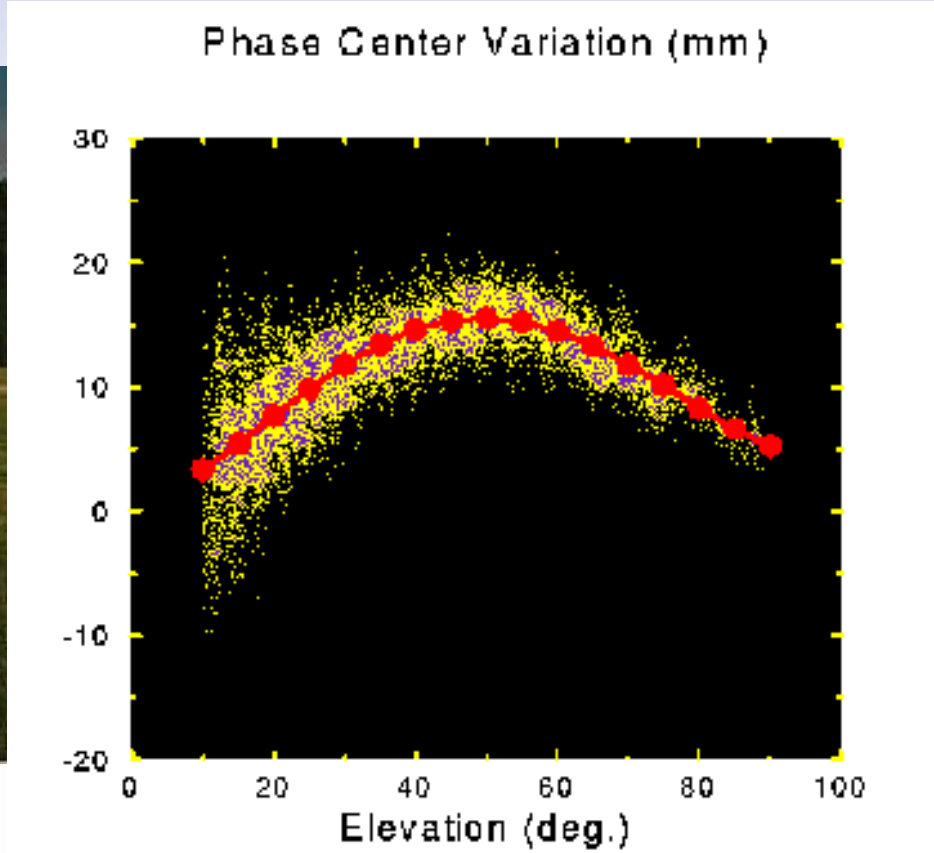
Coordinates of IGS reference stations are consistently based on the official IGS absolute PCVs.

As a consequence, a user should use the identical pattern for these sites as used by the IGS in order to get a consistent tie to the reference frame.

Relative vs. Absolute GNSS Antenna Calibration

RELATIVE





Relative means all new antennae compared with the standard reference antenna Dorne Margolin Type, e.g. AOAD/MT. The standard being the "ZERO" fixed mean offset.

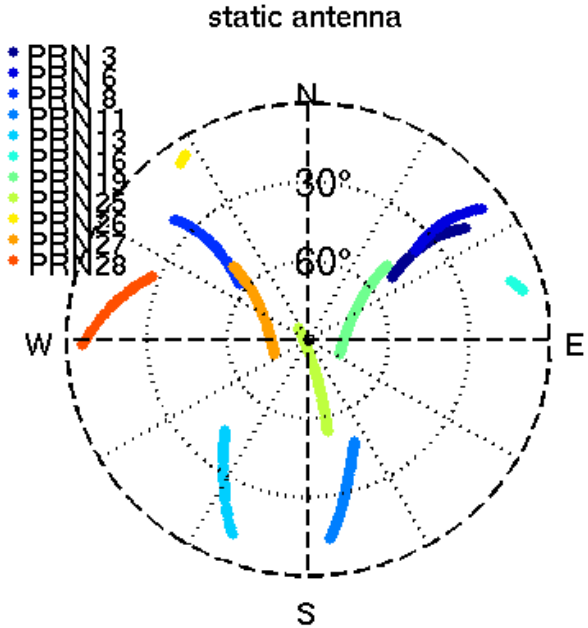
Relative vs. Absolute GNSS Antenna Calibration

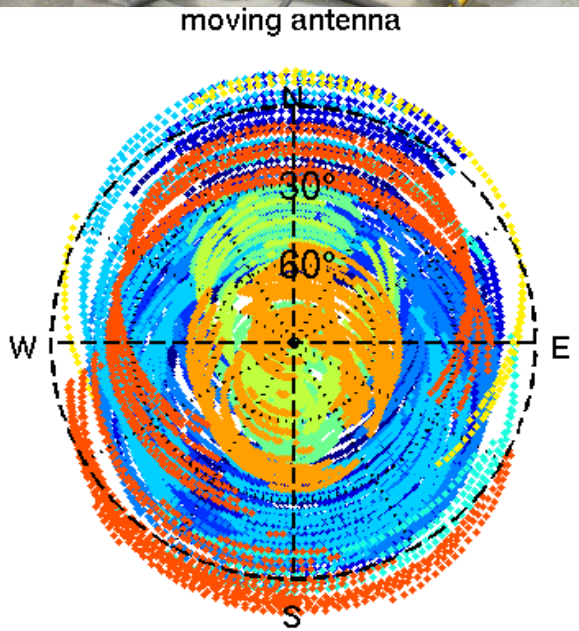
ABSOLUTE

Robotic Arm

rotation introduces angle changes for time difference of single difference (TDSD) phase observables.

Speeds up the process!





Advantages of the absolute antenna calibration

- The robot carries out fast rotations on different axes
- Saves time

– absolute 3D-offset and PCV

– high resolution and precision (sub mm)

– free of multipath

– PCV from 0 -90 elevation, also azimuthal PCV

– site and location independent

Influence of the antenna dome

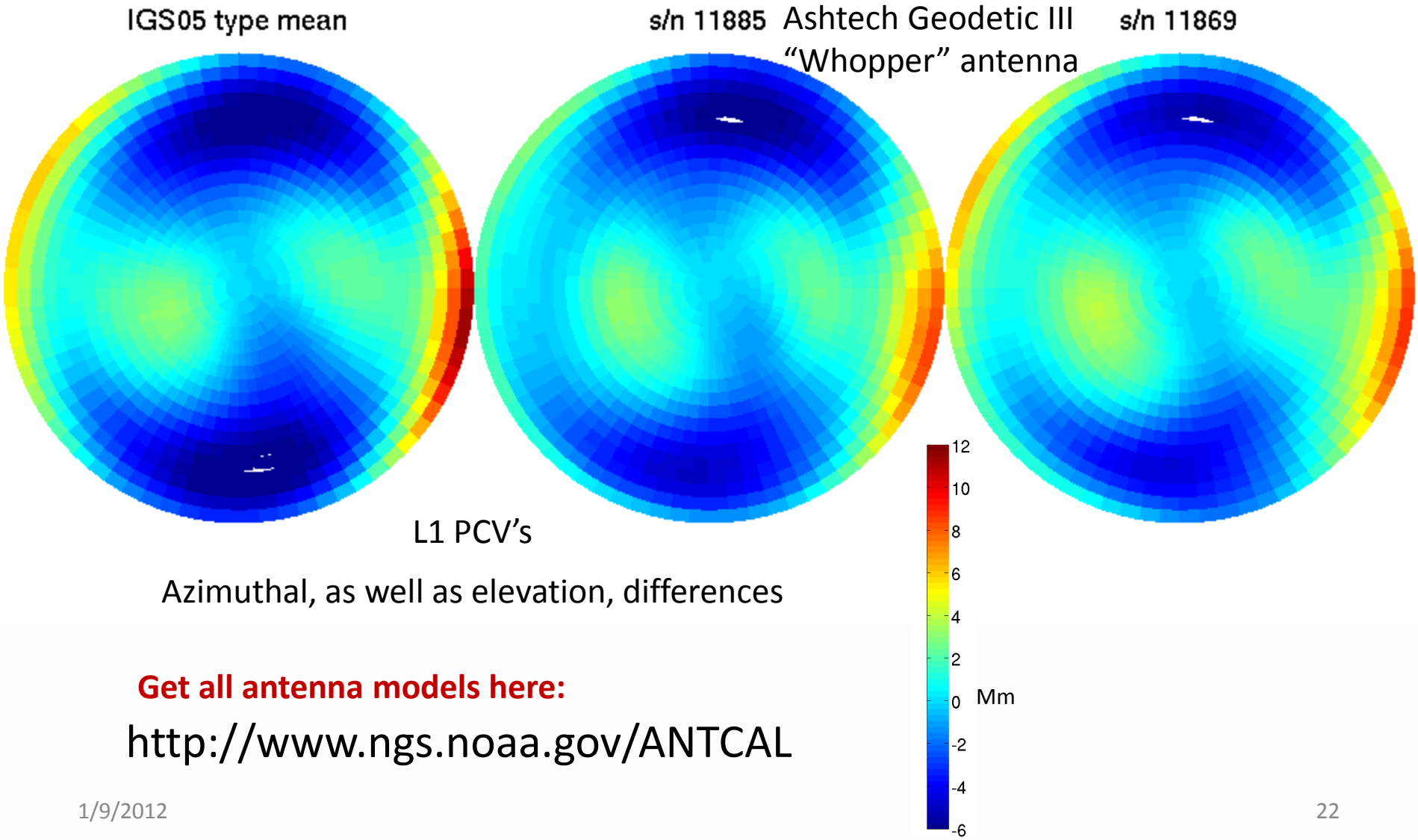
Site AB24 - Alaska

1st model antenna model without dome. (absolute)
2nd model with dome relative to model without dome.

Studies have shown that domes can affect network horizontal change in position < 5 mm… and vertical network changes can be as large as < 3 cm.

The position error caused by domes is not a constant but depends on the satellite geometry observed at the specific site. **(CH. Volken, F. Menge, Impact of Differenent GPS Antenna Calibr Models on EUREF)**

NGS Calibrations compared to IGS type mean



L1 PCV's

Azimuthal, as well as elevation, differences

Get all antenna models here:

http://www.ngs.noaa.gov/ANTCAL

So, what's different about the CORS coordinates?

- Change to absolute antenna calibrations
  - Use absolute cal. in your processing: DON'T MIX!

- Better because 8 more years of data:
  - International IGS sites
  - CORS data: about 1600 total, ~1000 w/ >2.5 yrs
  - Orbit determination sophistication
  - CORS velocity data
  - Better HTDP modeling for those w/ <2.5 yrs
  - Better processing algorithms

Called COMPUTED CORS

Called MODELED CORS

How do I find the coordinates?

- Individual CORS Coordinate page, as before

http://www.ngs.noaa.gov/CORS/coords.shtml

- TWO basic divisions:
  - One with COMPUTED velocities, one MODELED
- TWO basic Ref Frames: IGS08, NAD83
- Two types of coordinates/vel for each of those:
  - X,Y,Z *AND* lat/long/ht (N,E,U)

- Recommend using only CORS w/ **computed** velocities when performing network adjustments.

Lists of CORS Coord. & Velocities

- LETS LOOK AT THE LISTS….
  - As of September, 3rd, 2011
  - GO TO:

http://www.geodesy.noaa.gov/CORS/coords.shtml

IGS08

Computed

IGS08 epoch 2005.00
x, y, z; V_x, V_y, V_z

IGS08 epoch 2005.00
lat, lon, height; V_n, V_e, V_u

Modeled

IGS08 epoch 2005.00
x, y, z; V_x, V_y, V_z

IGS08 epoch 2005.00
lat, lon, height; V_n, V_e, V_u

Note: Vu = 0 as HTDP can only model Horiz vel. At this time

NAD 83

Computed

NAD 83 (2011) epoch 2010.00
x, y, z; V_x, V_y, V_z

NAD 83 (2011) epoch 2010.00
lat, lon, height; V_n, V_e, V_u

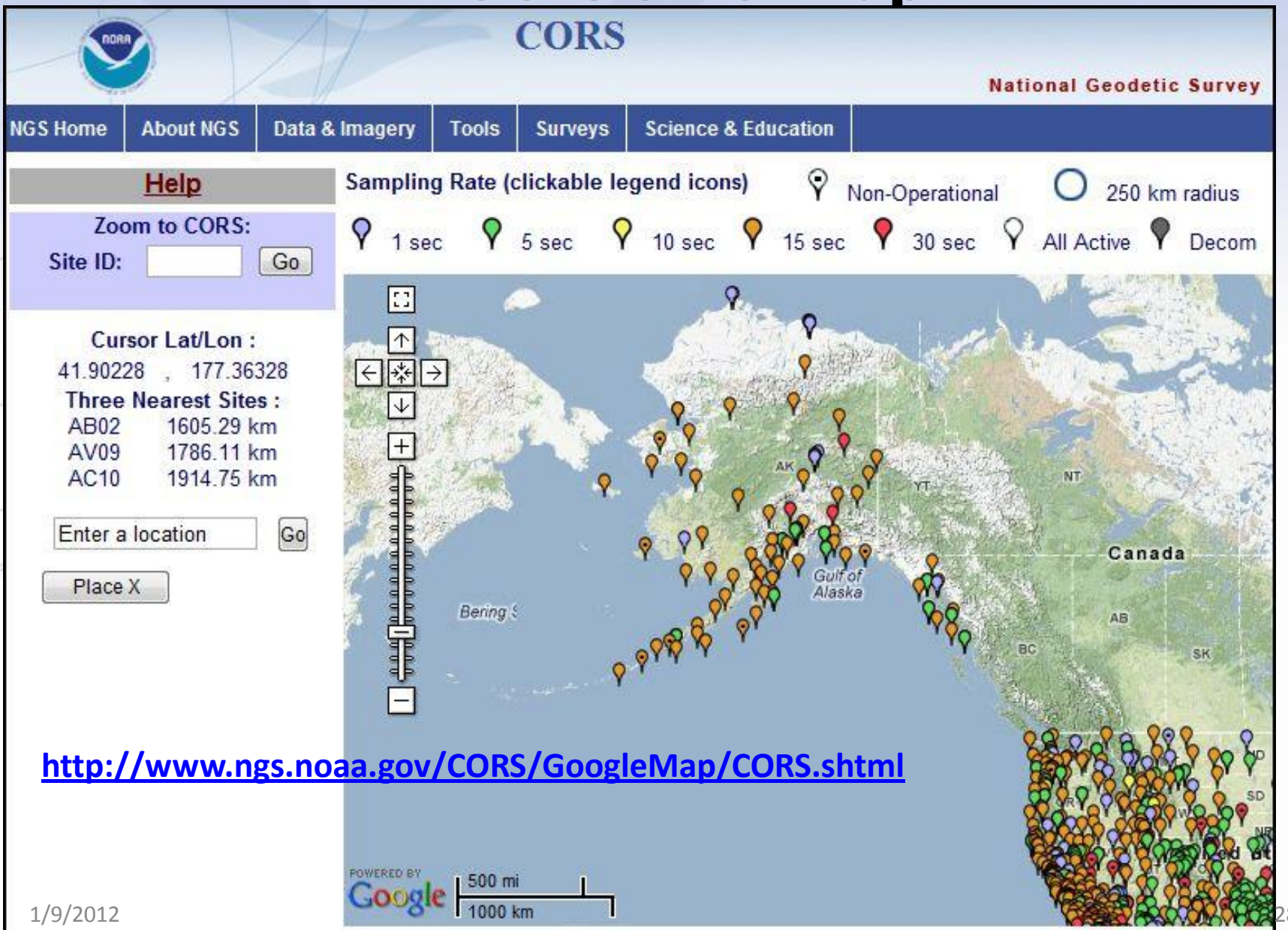
Modeled

NAD 83 (2011) epoch 2010.00
x, y, z; V_x, V_y, V_z

NAD 83 (2011) epoch 2010.00
lat, lon, height; V_n, V_e, V_u

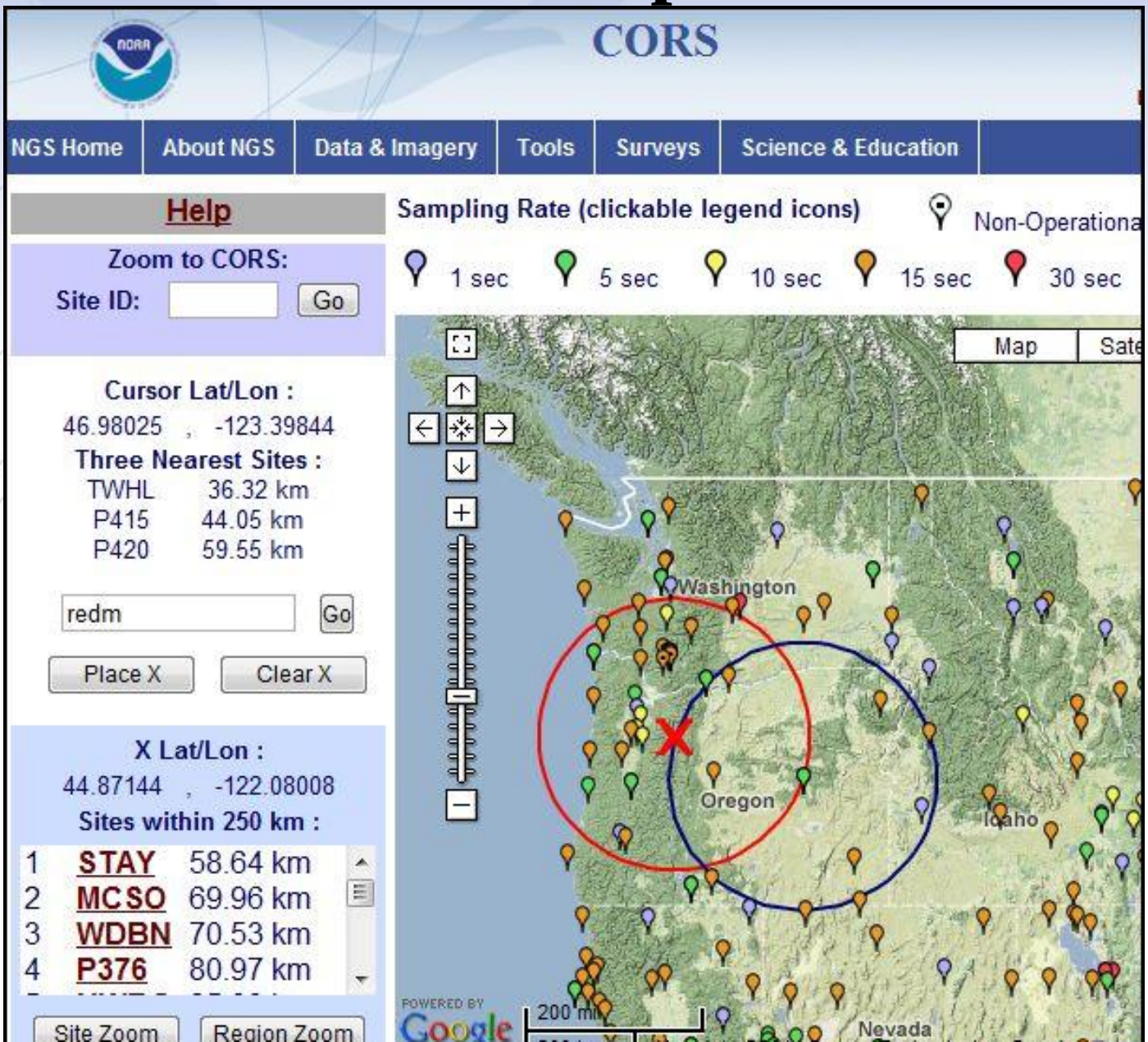
Note: Vu is not 0 as transformation to NAD 83 yields a Vu value – Not Reliable

NGS CORS Map



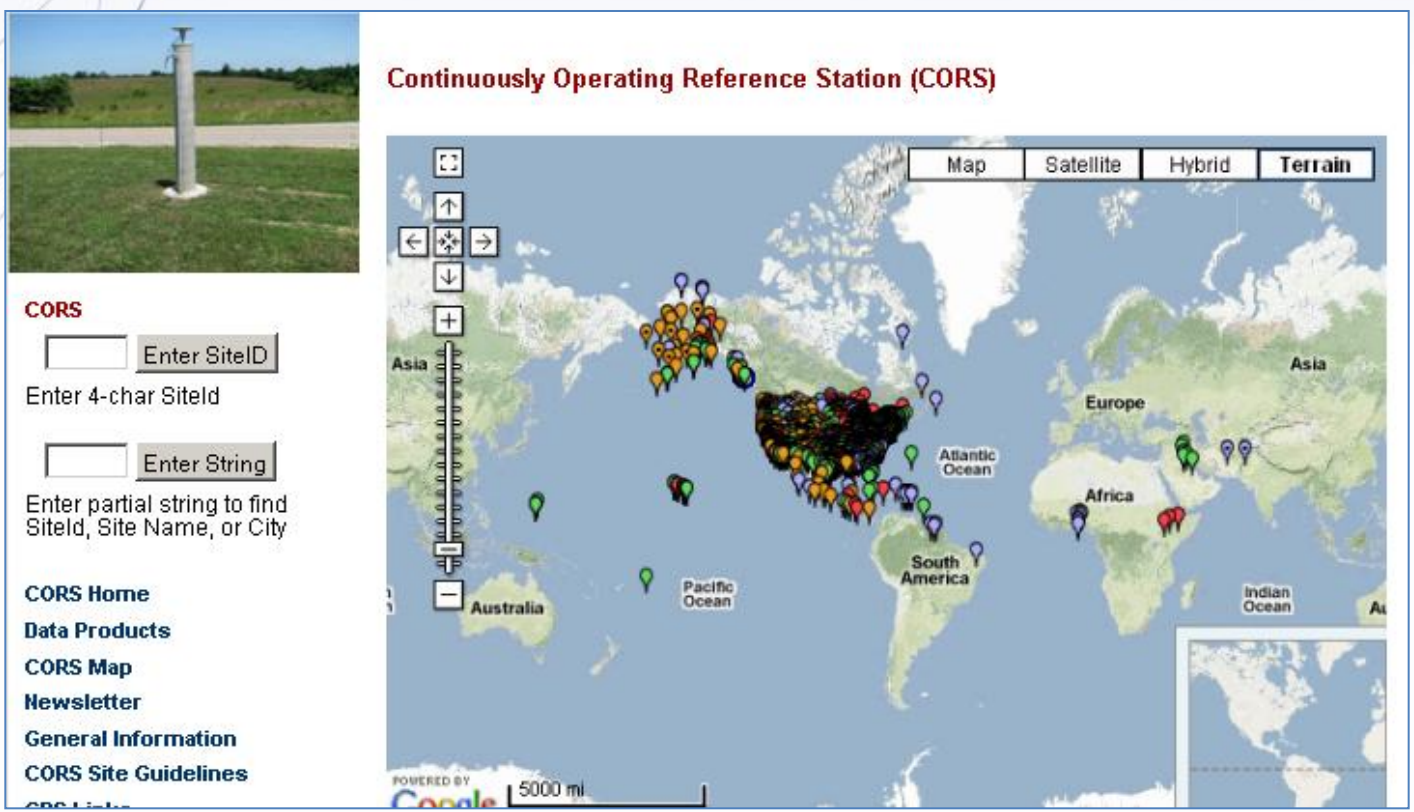
http://www.ngs.noaa.gov/CORS/GoogleMap/CORS.shtml

CORS Map Tools



CORS Data And Information

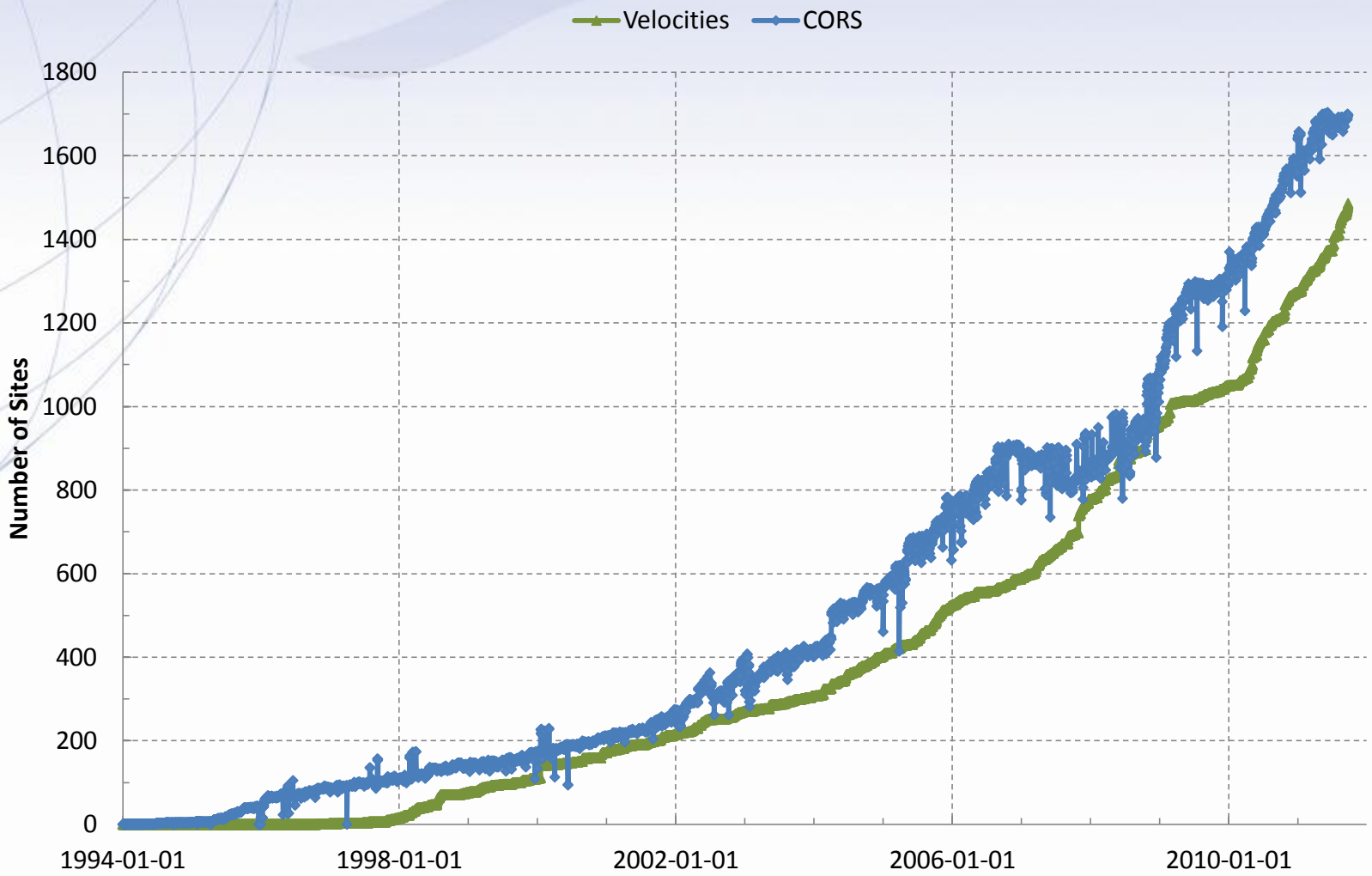
- Many, many partners freely share their GNSS data.
- These data are available with a short latency.
- The NGS acts as a data center offering a newsletter, data, coordinates, site equipment histories, photos and time series.



http://www.ngs.noaa.gov/CORS/

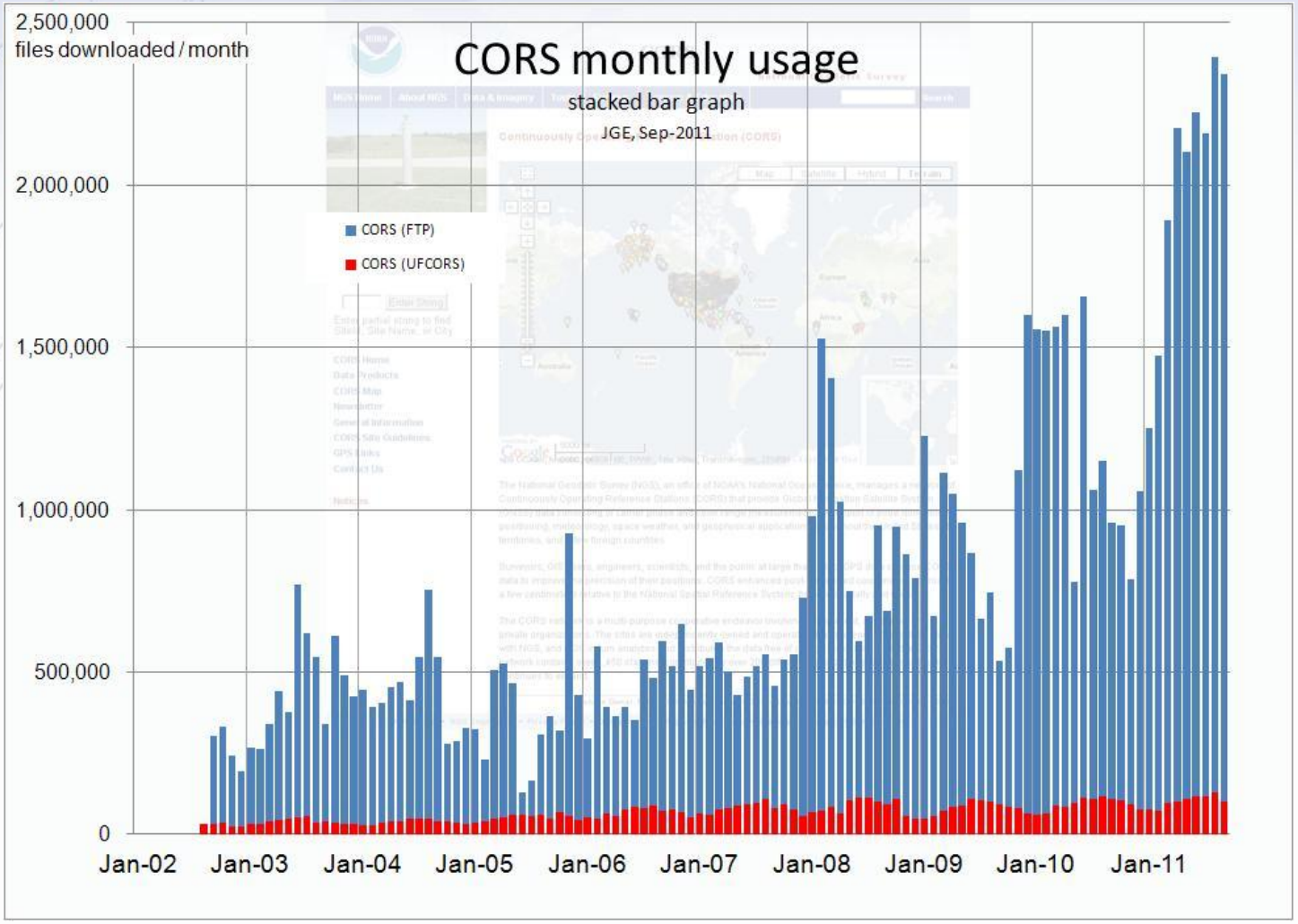
CORS Network

- Increasing with no end in sight.



CORS Use

- Increasing with no end in sight.



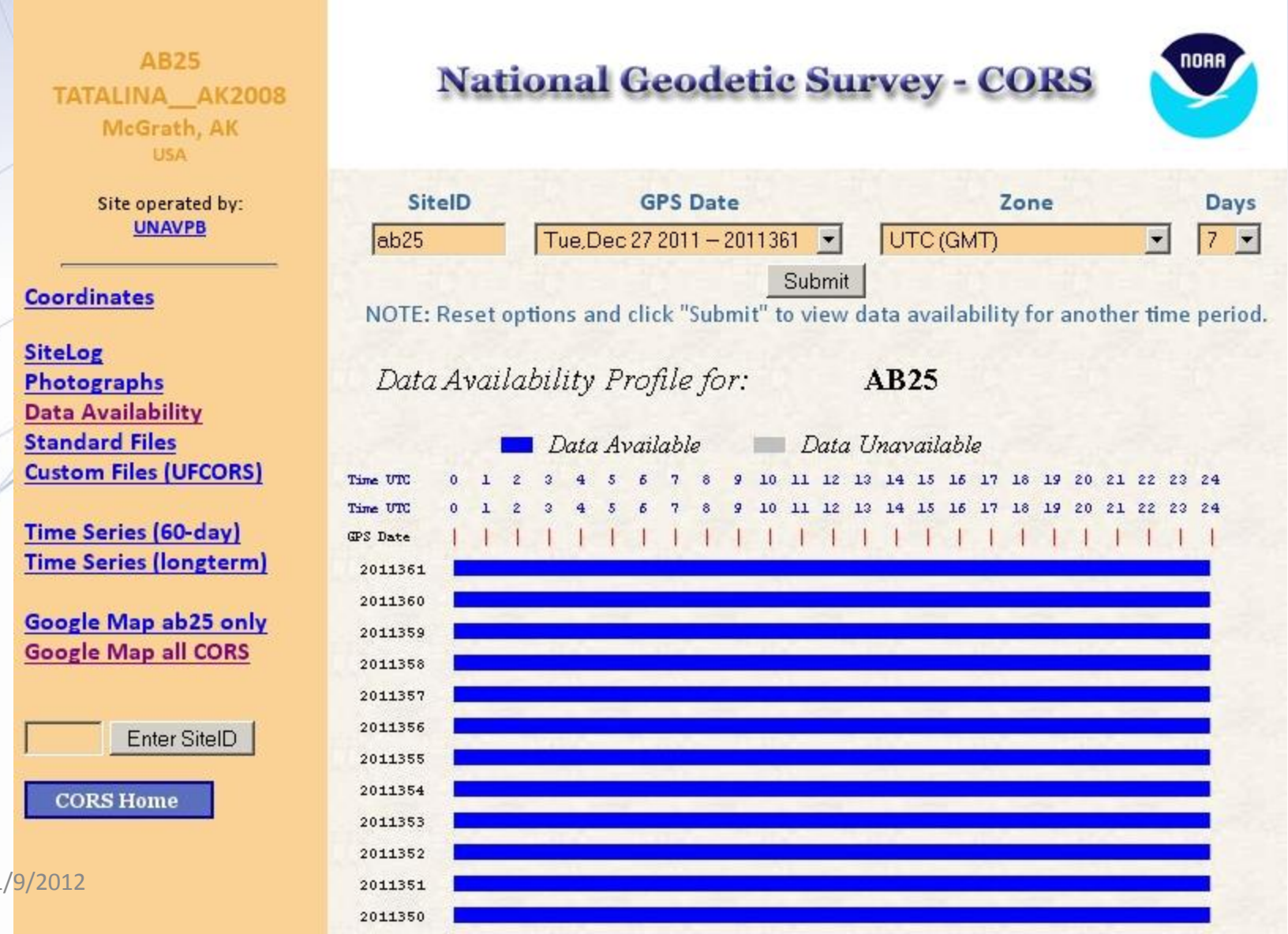
Monitoring CORS Coordinates

The CORS are monitored daily to help insure the correctness and continuity of their coordinates and other information.

As new CORS come on-line, their positions are computed relative to the entire network using a brief span of data, then the data, coordinates with a model velocity, hardware descriptions and other information are made available.

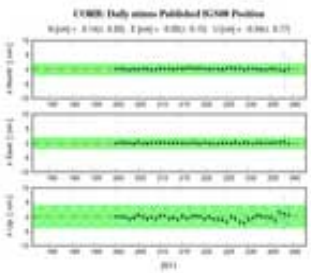
This method of including new CORS is more than adequate but not optimal.

CORS Data Availability



Look at CORS Repeatability Plots

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



CORS

Enter SiteID

Enter 4-char SiteId

Enter String

Enter partial string to find SiteId, Site Name, or City

CORS Home

Data Products

CORS Map

Newsletter

General Information

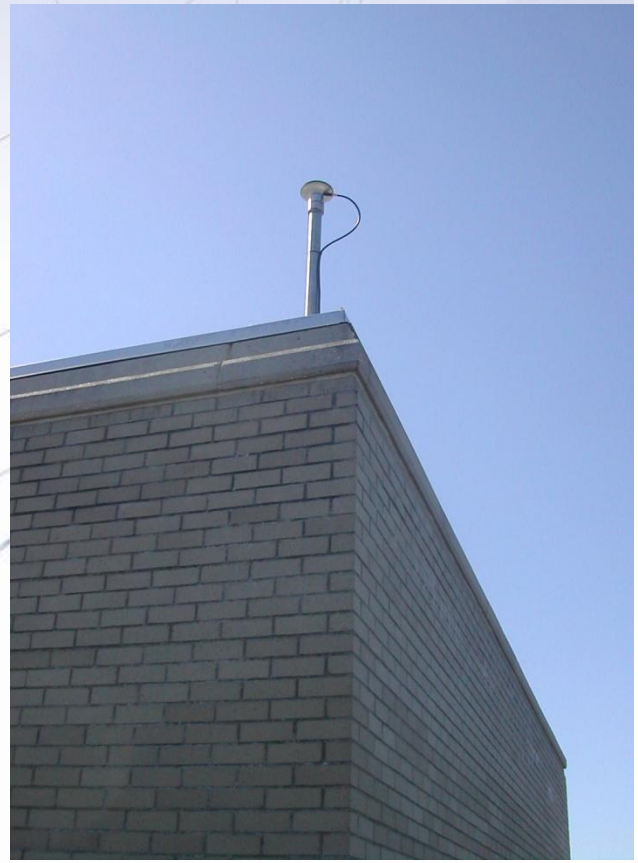
CORS Repeatability Plots

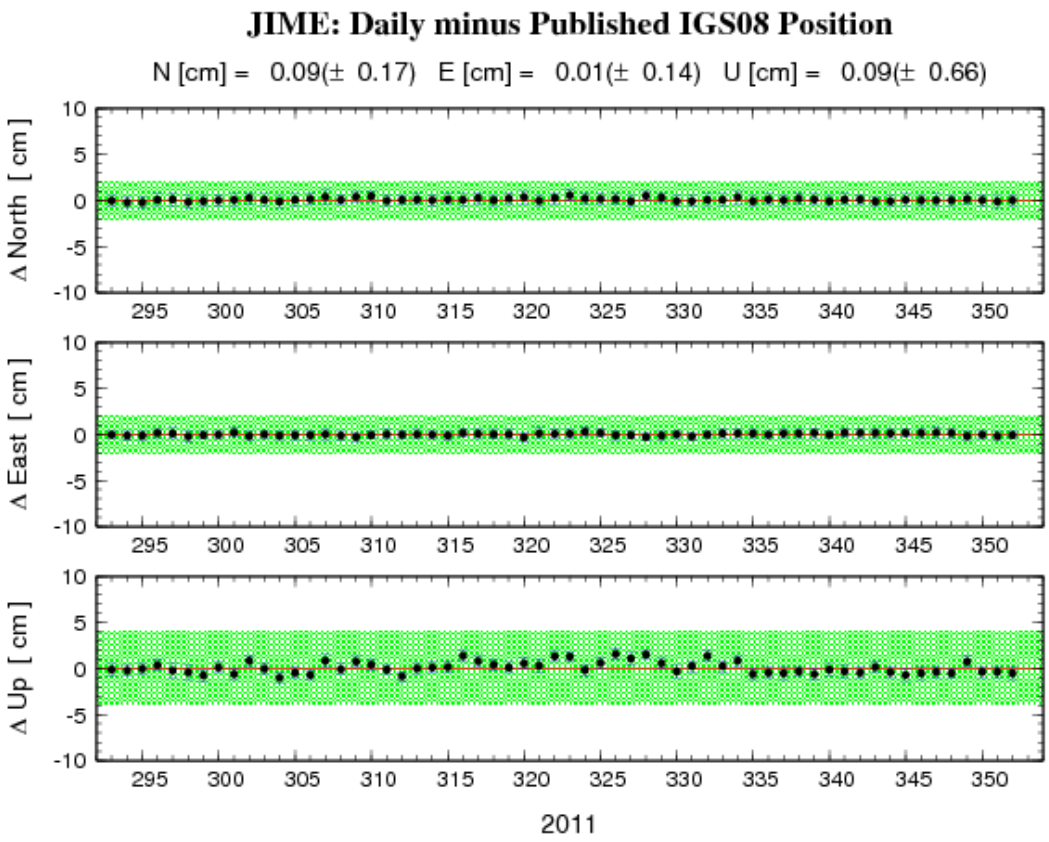
60-day plots show the repeatability of a site for the last 60-days with respect to the published IGS08 position corrected for the effect of the published velocity. These plots are updated daily. For a detailed explanation of these plots go here.

Long-term plots show the show weekly residual positions with respect to the published IGS08 coordinates from our stacked solution. Newer sites may not have a long-term plot if they were added after 16 April 2011. For a detailed explanation of these plots go here.

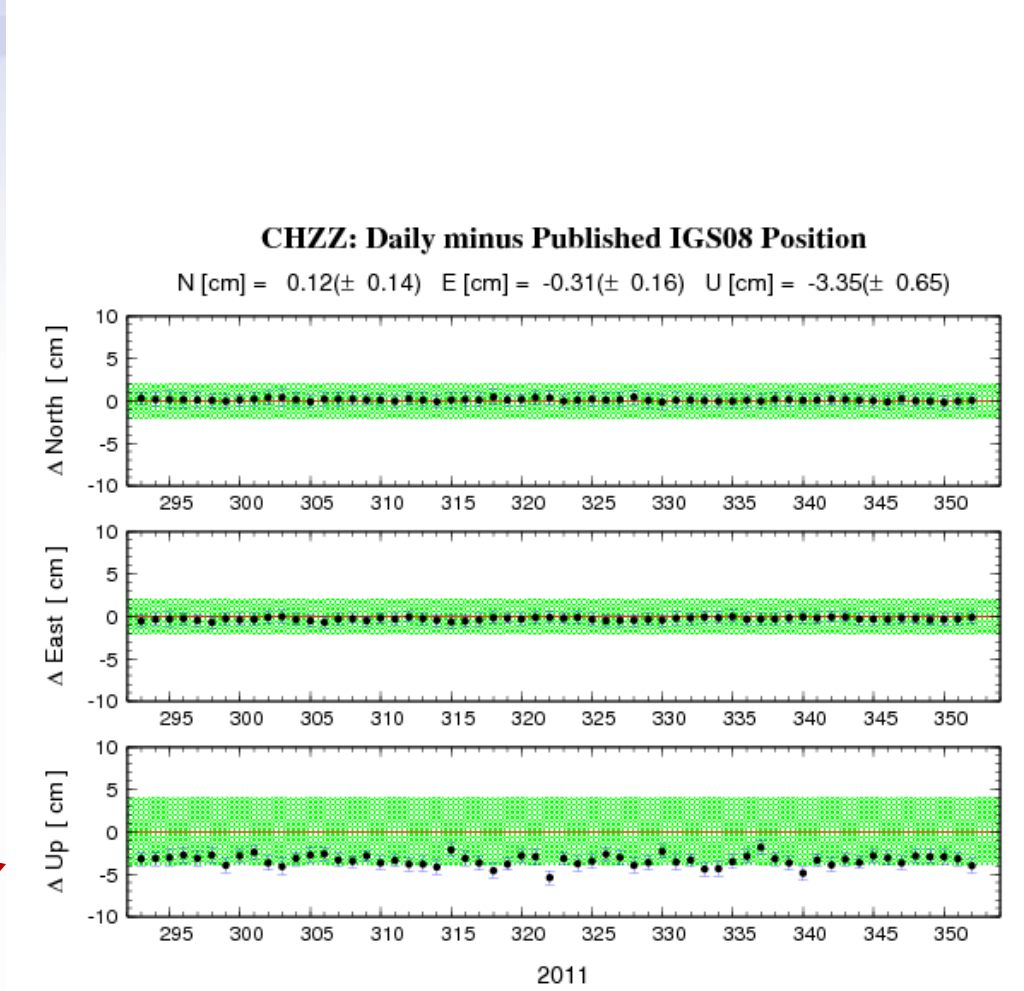
1lsu 60-day long-term	1nsu 60-day long-term	1ulm 60-day long-term	ab07 60-day long-term
ab11 60-day long-term	ab12 60-day long-term		
ab14 60-day long-term	ab15 60-day long-term	ab17 60-day long-term	ab18 60-day long-term
ab22 60-day long-term	ab27 60-day long-term	ab33 60-day long-term	
ab37 60-day long-term	ab39 60-day long-term	ab41 60-day long-term	ab45 60-day long-term
ab48 60-day long-term	abq5 60-day long-term	abq6 60-day long-term	
abvi 60-day long-term	ac07 60-day long-term	ac09 60-day long-term	

Review the plots!





Review the plots!



Is there an issue here?…
Multi-path??
Does the Published IGS08 Position need updating??

Check the Log File for Accuracy!

- Antenna Type : TRM59800.80 NONE
- Serial Number : 0220373000
- Antenna Reference Point : BPA
- Marker->ARP Up Ecc. (m) : 0.0440
- Marker->ARP North Ecc(m) :
- Marker->ARP East Ecc(m) :
- Alignment from True N : deg
- Antenna Radome Type : NONE
- Radome Serial Number : N/A
- Antenna Cable Type : (vendor & type number) Antenna Cable Length : (m)
- Date Installed : 2010-02-04T12:30Z

Review the CORS Newsletter

- Provides updates about new CORS
- Changes to CORS Products and Services
- News that impacts the CORS program
- Publications relating to the CORS program
- Statistics and usage maps
- Partners list

Subscribe to the CORS Newsletter

- To add yourself to the list, send an empty email message to:

  requests@willamette.nos.noaa.gov

  with subject **"Subscribe NGS_CORS_news"**

  Your name will be added to the list and you will receive all posts

National Adjustment of the Passive Marks

NA2011 project

- Optimally **align** passive control with CORS
- >1000 new projects submitted since 2007 adjustment. Number of stations increased by 1/3 in just 5 years!
  - Plus Observations for Alaska, Hawaii & other Pacific islands
- More consistent results in tectonically active areas
  - Longer time series for CORS
  - More current data for passive, and better tectonic modeling

Benefits of a new national adjustment for passive geodetic stations

- Network and local accuracies on stations
  - Including future submitted projects
  - But not for excluded (rejected) stations
- Better computations and analysis techniques
  - Improved outlier detection
  - Incorporation of lessons learned from previous national adjustment

What are some of the checking and cleaning techniques and processing?

- Unexclude previous 'no-check' stations if new data came in to cross tie and verify
- Exclude other 'no-check' stations
- Exclude PIDs for L1PC when antenna replaced at a CORS
- Caution in subsidence areas because no model for vertical velocity; exclude as necessary.

Current status of NA2011, Dec. 2011

- Cutoff date for projects was moved back
- Minimal constraint adj's have run successfully
- 4152 projects and 79,107 stations; includes 954 CORS w/ >2.5 yrs data
- 371,962 enabled vectors (+42,493 rejected = 414,455 total vectors)
- Standard error of unit weight = **1.26**
- Starting constrained adjustments, using errors from CORS solution (not 'perfect', not 0 error)

Detailed info about NA2011 on website

- Surveys tab, near bottom, National Adjustment or Quick link in left column, main page. FAQ page:

http://www.ngs.noaa.gov/web/surveys/NA2011/NA2011_FAQ.shtml

NA2011 Quick Links

Contact Us

Home

NA2011 FAQs

NA2011 Project Plan

NA2011 Presentations

Maps of NA2011 Data and Results (Coming Soon)

NA2011 Results and Statistics (Coming Soon)

National Adjustment of 2011 (NA2011) Project

Frequently Asked Questions (FAQs)

Last updated November 8, 2011

List of abbreviations used in these Frequently Asked Questions:

CNMI	Commonwealth of the Northern Mariana Islands
CONUS	Conterminous United States
CORS	Continuously Operating Reference Stations
FGDC	Federal Geographic Data Committee
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HTDP	Horizontal Time-Dependent Positioning (NGS software)
IGS	International GNSS Service
MYCS	Multi-Year CORS Solution
NA2011	National Adjustment of 2011

Next steps, 2012

- NA2011 Adjustment thought to be completed, fully published by spring 2012
- Testing network accuracy calcs for subsequent submitted projects and database procedures
- Until NA2011 Adjustment is complete and ready to be published:
  - OPUS solutions will continue to produce coordinates in both former and current ref frames
  - New DS format will not go into effect
  - Next Geoid model cannot be finalized

New GEOID12

- Since NA2011 will yield ellipsoid heights that are inconsistent with the existing geoid model (GEOID09), a new hybrid geoid model, GEOID12, is currently being developed at NGS. GEOID12 will be based on NAD 83(2011) epoch 2010.00 ellipsoid heights, so its release must, therefore, occur after the completion of NA2011.

GEOID12 (or 11) Development

- Model will be based on ellipsoid heights published from NA2011 project
- Proposed stations, different than for GEOID09, for inclusion/exclusion just distributed to geodetic advisors for review
- Currently being developed using preliminary NA2011 "results"
- NOTE: Two months after GEOID12 released, project submissions must use NAD83(2011)

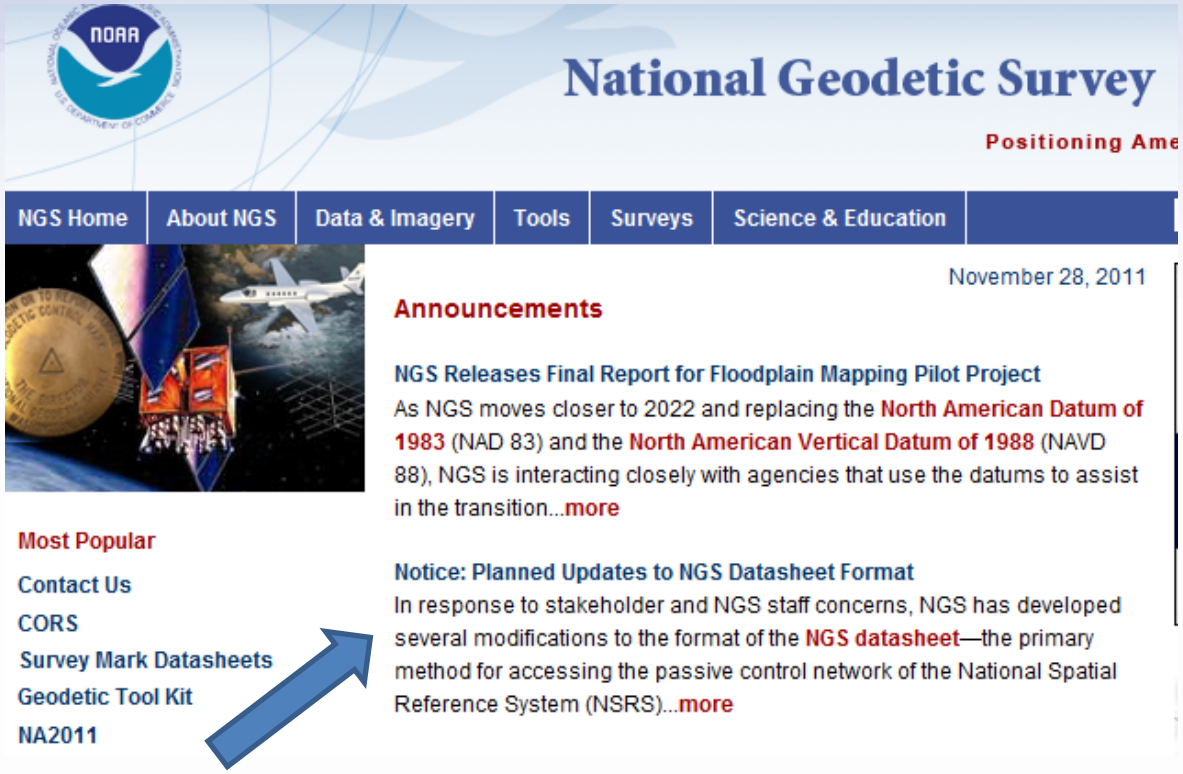
QUESTIONS? then Datasheet format changes

Updating the Datasheet Format

Second news story; won't migrate for awhile…

Can sign up for announcements (news subscription service) via emails;

Front page, bottom Right column



Datasheet Update

News Item

National Geodetic Survey

Tuesday, September 06, 2011

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). Many developers use NGS datasheets in their products, and NGS recognizes the importance of keeping the public informed of datasheet format changes. The format change announcement is available here. Sample Datasheets in the new format are available.

Height mod example AC6803

Bench mark example UA0024

For more information, contact Burt Smith.

Datasheet Change Highlights

- Better grouping of geometric elements, eg, ellipsoid height and epoch date
- CLARITY about geoid model usage, including for superceded ortho height data
- Note: earlier this year, NGS started publishing superceded GPS-derived ortho heights
- Inclusion (hyperlink) to Local Ties & Accuracies
- http://www.ngs.noaa.gov/web/surveys/datasheet/AC6803_htmod.pdf

Datasheet Changes

The NGS Data Sheet

See file dsdata.txt for more information about the datasheet.

```
DATABASE =  ,PROGRAM = datasheet, 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 (this for example only, not app 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
```

Datasheet Changes

```
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.
```

DSWorld: Program Mapping Tool

- Map the NGS Databases in Google Earth
- Need to have Google Earth installed
- Tools, Download PC Software, USER-CONTRI-BUTED SOFTWARE, DSWorld
- http://www.ngs.noaa.gov/

- **FIRST:** Tools, Update program to 4.10.16
- Enhancement enables you to distinguish VERTCON NAVD88 from other(control) NAVD88

DS World Demonstration

http://www.ngs.noaa.gov/PC_PROD/PARTNERS/index.shtml

Create your own Google Earth .kmz files

Map horizontal and vertical passive marks in the NGSIDB and OPUS-DB.

Map by state and county

ICONs produced in GE are interactive:

-bring up current datasheet

-icon type represents status of mark

Questions

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