New Coordinates for CORS Sites

Giovanni Sella and Jake Griffiths
NOAA-National Geodetic Survey

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Coordinates and Velocities they move!

Preliminary CORS Multiyear soln.

Plate fixed

Vertical Vels.

Horz. Residual Vel.

C.I. 2mm/yr

2mm/yr

Rigid

GIA-affected.

tectonic/other
Current CORS Coord. and Vel.

- Mixed coordinates and velocities from: last reprocessing (1994-2002), and adjustments using 8-3 IGS ref. sites
- Mixed HTDP vs. computed vel.; Vertical vel. = 0 mm/yr
- NGS’s current global frame is ITRF00 epoch 1997.0 projecting 13 yrs is unrealistic; NAD 83(CORS96) epoch 2002.0 projecting 8 yrs becoming a problem
- Metadata issues, discontinuities/offsets
- Significant software changes
- Absolute vs relative antenna phase center values
- Need to revise CORS coordinates and velocities
Solution: “multiyear”

• “Multiyear” effort began 5 years ago
• Began with a revision of PAGES and processing strategy driven by weak NGS orbit contribution to IGS.
• IGS proposed re-processing all data to re-compute station coordinates, orbits and EOPs from 1994-present
• Richard Snay provided resources and managed the effort of the “multiyear” effort till May 2010
Frame Definition and Nomenclature

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

<table>
<thead>
<tr>
<th>Frame Name</th>
<th>Epoch</th>
<th>Antenna PCV*</th>
<th>Data Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITRF2000</td>
<td>1997.0</td>
<td>Rel ANTEX</td>
<td>1994.0-2002.0</td>
</tr>
<tr>
<td>ITRF00 (NGS’s soln)</td>
<td>1997.0</td>
<td>Rel NGS ANTEX</td>
<td>1994.0-present</td>
</tr>
<tr>
<td>NAD 83(CORS96)</td>
<td>2002.0</td>
<td>Rel NGS ANTEX</td>
<td>1994.0-present</td>
</tr>
<tr>
<td>ITRF2008</td>
<td>2005.0</td>
<td>Abs IGS05 ANTEX</td>
<td>1997.0-2009.5</td>
</tr>
<tr>
<td>IGS08</td>
<td>2005.0</td>
<td>Abs IGS08 ANTEX</td>
<td>1997.0-2009.5</td>
</tr>
<tr>
<td>IGS08 (NGS’s tentative)</td>
<td>2005.0</td>
<td>Abs IGS08 ANTEX</td>
<td>1994.0-2010.5 (ongoing)</td>
</tr>
<tr>
<td>NAD 83(2011) (tentative)</td>
<td>2010.0</td>
<td>Abs IGS08 ANTEX</td>
<td>1994.0-2010.5 (ongoing)</td>
</tr>
</tbody>
</table>

*PCV – phase center value; Abs-Absolute, Rel-Relative*
Jake Griffiths will now describe our reprocessing strategy and the results for CORS coordinates.
Work Completed

- CORS RINEX observations from 1994 thru 2010.5 processed in fully consistent global framework
  - evaluated approx. 90 billion double-difference observation eqs.
  - using latest IERS models and processing methods
    - switch to absolute antenna calibrations
    - reduced positioning errors and distortions of global frame

- 860 weekly (full history) CORS+global SINEX files containing X,Y,Z positions and full variance-covariance information

- used CATREF software from Institut Géographique National (IGN) to stack weekly CORS+global SINEX files in three steps:
  - step 1: focused on attenuating aliasing of Helmerts from local non-linear motions
  - step 2: impose “unbiased” Helmert parameters on whole network & stack
  - step 3: obtain MYCS—i.e., align “unbiased” stacked TRF to ITRF2008 via GPS sites common to both SNXs

- resulted in a set of new positions and velocities for CORS
  - 4,906 position and velocity estimates for 2,264 CORS+global stations
  - solution aligned to ITRF2008 with negligible distortions of the frame
  - solution calibrated to be used with impending igs08.atx
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
CORS IGS08 Velocity Field

~1270 CORS w/ suff. data and linear velocities
What is the new NAD 83 frame?

• Same datum, so no need for transformation between NAD 83(CORS96) epoch 2002.0 and NAD 83(2011) epoch 2010.0
  – NAD 83 (2011) velocities should be used to move positions through time
• So, first to assess differences, need to compare at same epoch date (2002.0) using NAD 83(2011) velocities to move new positions to 2002
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: \( \Delta E = -0.18 \pm 1.86 \) cm \( \Delta N = 0.14 \pm 1.07 \) cm
  - prescribing velocities using numerical models (i.e. HTDP)
  - smaller random part probably caused by change to absolute antenna calibrations

~1270 CORS w/ suff. data and linear velocities
Changes in *Vertical* NAD 83 Positions

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

- avg. vertical shift: $\Delta U = 0.71 \text{ cm} \ (\pm 2.11) \text{ cm}$
  - 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 $\sigma$ in old solution)
- overall avg. horizontal shifts: $\Delta E = 0.09 \ (\pm 5.84) \ cm \quad \Delta N = 2.03 \ (\pm 5.98) \ cm$
  - combination of position and velocity differences
  - due mostly to updated velocities (including up to 8 more years of data)

Avg. shifts in western CONUS:
$\Delta E \approx -0.49 \ (\pm 0.90) \ cm$
$\Delta N \approx 0.93 \ (\pm 0.93) \ cm$

Avg. shifts in eastern CONUS:
$\Delta E \approx 0.14 \ (\pm 0.08) \ cm$
$\Delta N \approx -0.01 \ (\pm 0.07) \ cm$
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 $\approx 0.00$ in NAD 83(CORS96)

avg. shifts in eastern CONUS:
$\Delta U \approx -0.11 (\pm 0.16)$ cm

avg. shifts in western CONUS:
$\Delta U \approx -0.06 (\pm 0.18)$ cm
Done and To Do

• Fall 2005: First discussion and start of software overhaul
• Mar 2008: Start of re-analysis of orbits and CORS data
• Feb 2009: First results
• Feb 2010: NGS submits final solution to IERS
• Apr 2010: Full solution and frame discussion begin
• May 2010: IERS publishes ITRF2008
• Jun-Oct: Verification of time-series for discontinuities
• Nov-Feb: Incorporate IGS08 absolute antenna calib., adjust ITRF2008-aligned coordinates for IGS08 calib.
• Mar-Apr: Update tools in and out of NGS, and get final IGS08
• May-Jun: Coord. beta site, feedback 😊😊, modify?
• July: Publish and integrate coord. into NGS prods.
Key Changes

• Change from relative to absolute antenna phase center values (PCV)
• NGS global frame pos/vels are aligned to full global frame (IGS08)
• Distinction between computed and modeled velocities must be maintained and **emphasized** to users
• Ability to robustly/consistently re-compute pos/vels
• More robust discontinuity identification and resolve metadata issues quickly (**site operators are key**)
• Change in pos/vel NAD 83(2011) change epoch from 2002.0 to 2010.0
Reference Frames Used

• Basis is global and inherited from ITRF2008
  – NGS has more discontinuities and weekly solutions than ITRF2008; and has applied IGS05_ATX -> IGS08_ATX corrections to be consistent w/ IGS08
  – Name IGS08 (tentative)
  – Epoch date 2005.0 (same as ITRF2008, IGS08)
• Related to ITRF, but plate fixed (NAD 83)
  – Name NAD 83(2011) (tentative)
  – Epoch date 2010.0
  – NAD 83(CORS96) to NAD 83(2011) is identity transformation (i.e. same axes)
  – NAD 83(2011) axes origin different (~2m) from ITRF (expect 2022)
Transition Multiyear to Operations

- Multiyear processing method will become operational method, old method stops after beta period
- 2 sets of processing:
  Fast next day, to produce “60 day plots” and catch metadata errors, aligned to same frame (not stacked) so noisier
  Slow ~24 days later final solution (metadata issues resolved), stacked weekly solutions, used to define positions and velocities
Changes with New Frame

Two types of CORS coordinates

• >2.5 yrs of data with positions and velocities from stacked solution (i.e. *computed*). Valid for “fixed” coordinates.
• <2.5 yrs of data positions from stacked solution, but velocities via HTDP (i.e. *modeled*).

• Users encouraged **not** to use CORS with *modeled* velocities, until computed vels. are avail. (may take up to 3 yrs). Important if holding coordinates fixed.
• CORS with unexplained coordinates changes marked as “questionable” until resolved/stable.
Changes with New Coordinates

• Coordinates will be rigorously reviewed every 6 months.

• On a weekly basis if a problem with a site is identified, site flagged as problem, e.g. currently do not have an automated way to deal with earthquake offsets/velocity changes, undocumented/unexplained equipment change

• What amount of change/tolerance are permitted?
  - Current 2 cm horizontal, 4 cm vertical
  - Considering 1 cm horizontal, 2 cm vertical

• All users should use IGS08 consistent absolute antenna PCV values (see next slide)
Outstanding Items
tentative timeline

• **Next 1-2 weeks** revise New Coordinates web page
gerodesy.noaa.gov/CORS
Click on “Data Products,
Scroll to bottom and follow “Beta Products” links

• **March-April**, Update NGS IDB, test NGS prod. & serv.,
provide beta Antenna Calibration page with IGS08
consistent PCV’s both ANT_INFO and ANTEX format,
final check on coordinates and consistency with IGS08

• **May-June**, Release beta coordinates, update all
coordinates through May 2011, implement HTDP 3.1

• **July** release new coordinates and update NGS products
to be consistent
Questions/Comments

• We recognize that NGS and the public want CORS to be the primary access to the NSRS, but accuracy and constancy are not always possible.

• We are keen to hear your comments/concerns
• Check: geodesy.noaa.gov/CORS/news.shtml
  geodesy.noaa.gov/CORS
  Choose Data Products
  Scroll down to Beta Products
  Choose New Realization of NAD 83

  giovanni.sella@noaa.gov, jake.griffiths@noaa.gov
Questions?

- What does NGS intend to do about the relationship between CORS and passive networks?
- What is the reliability of new velocities compared with current published values - especially in the vertical?
- If the new reference frame is called NAD 83(2011) epoch 2010.0 what efforts will NGS make to educate the user to minimize confusion with NAD 83(CORS96) epoch 2002.0?
- What period of overlap will occur with solutions in both NAD 83(CORS96) epoch 2002.0 and NAD 83(2011) epoch 2010.0?
- What format changes occur to NGS products e.g. data sheets, coordinate page, OPUS output?
- Will there be a transformation between NAD 83(CORS96) and NAD 83(2011)?