Reanalysis of GPS data for a large and dense regional network tied to a global frame

- summary of processing strategy
- quality of reprocessed NGS orbits and global TRF
- quality of stacked solution for CORS+global TRF
- updated velocity field and main use of solution at NGS

by

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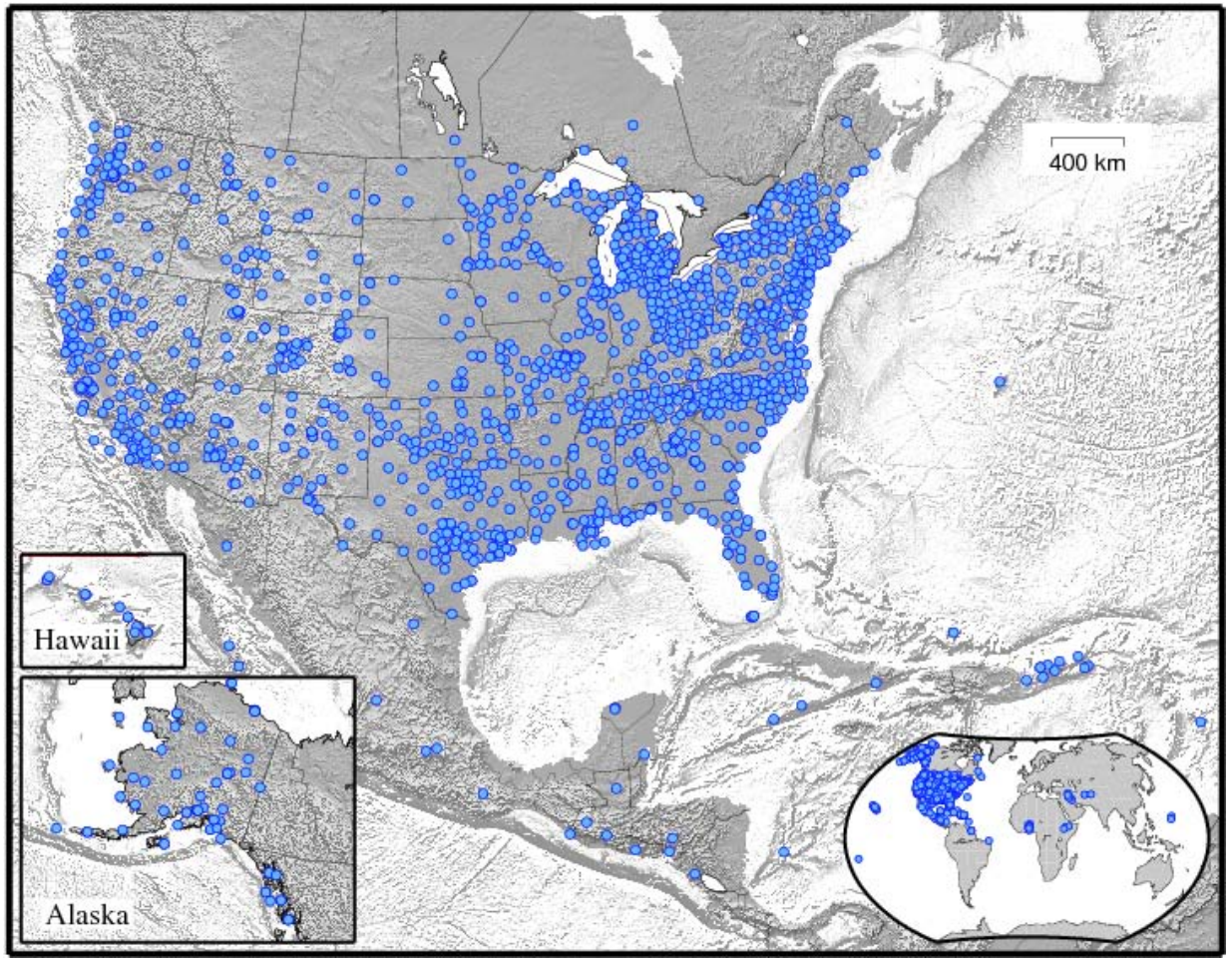
U.S. CORS Network

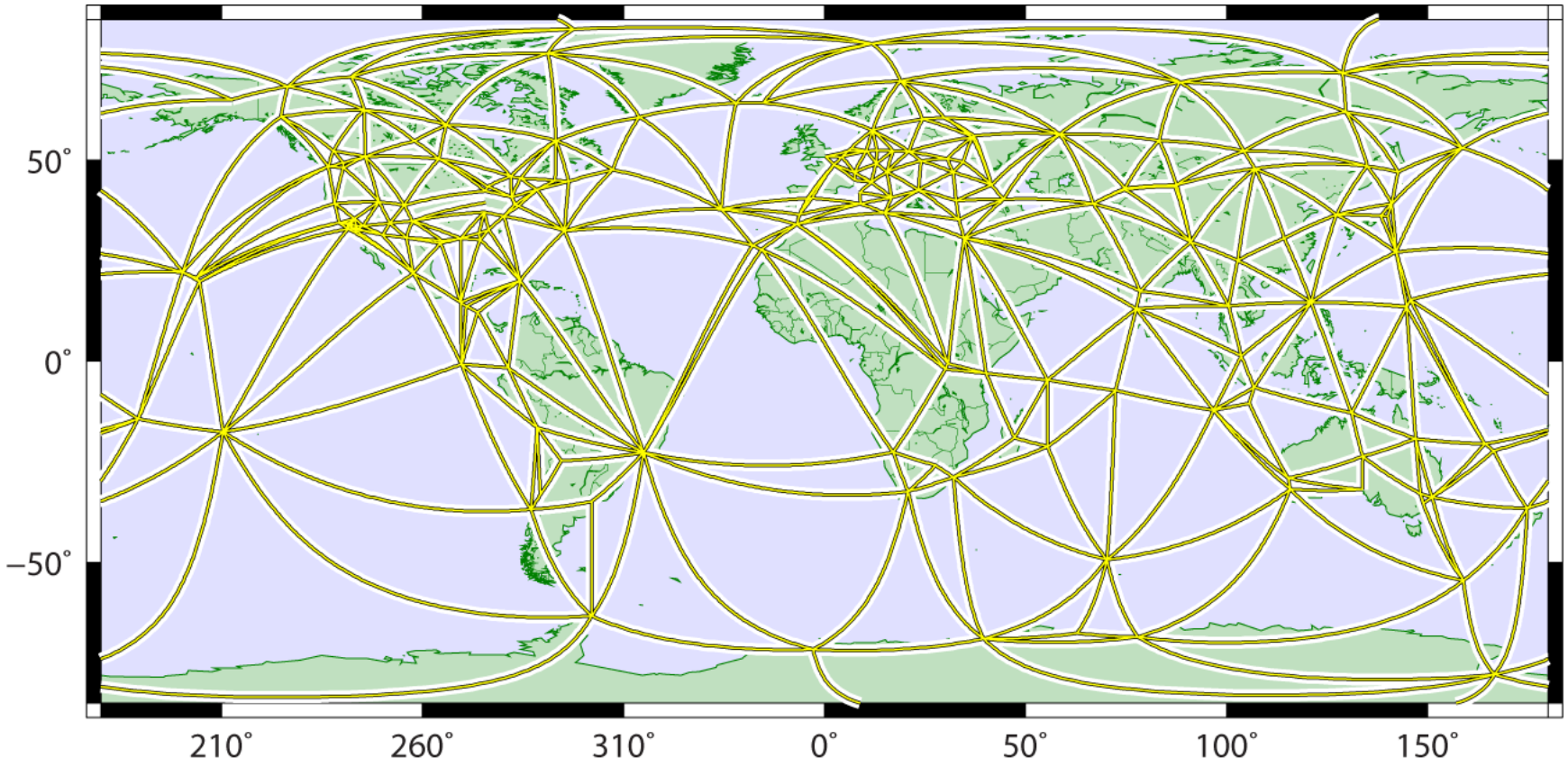
- currently >1500 sites
  - mostly in U.S.
- used to provide access to the U.S. National Spatial Reference System
  - current realization based on ITRF2000
- also supports meteorology, space weather and other geophysical applications



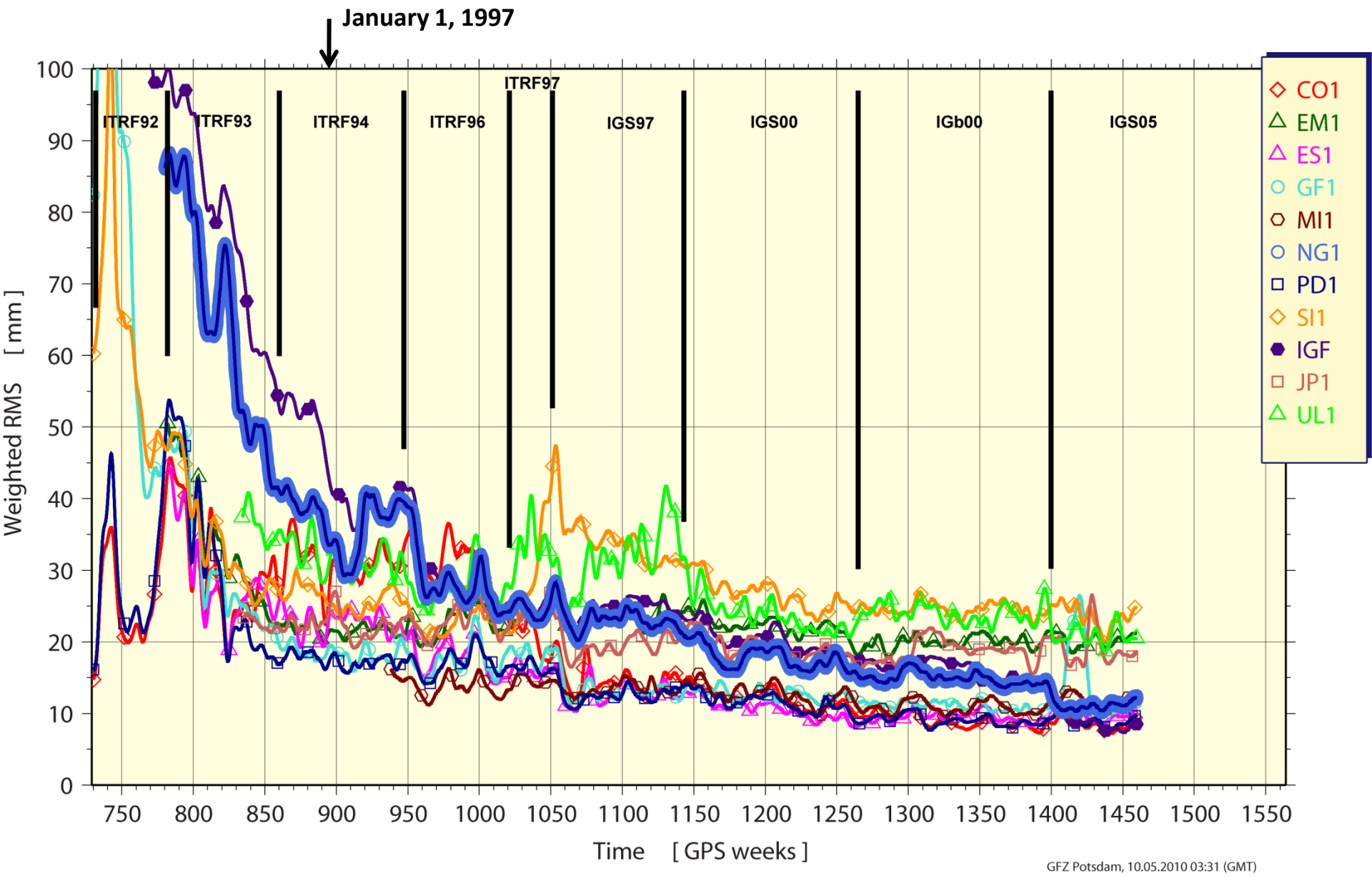
Reduction of Global Observations

- generate fully consistent orbits, EOPs and global station coordinates using latest models and methods
  - absolute antenna calibrations
    - satellite transmitting and ground receiving antennas
  - new network design—added redundancy
    - Delaunay triangulation over global and CORS backbone sites
  - 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, global SINEX (w EOPs) files to International GNSS Service (IGS) repro1 campaign
- store global NEQ for combination with CORS data—to be tied together at backbone sites

Design of Global Tracking Network

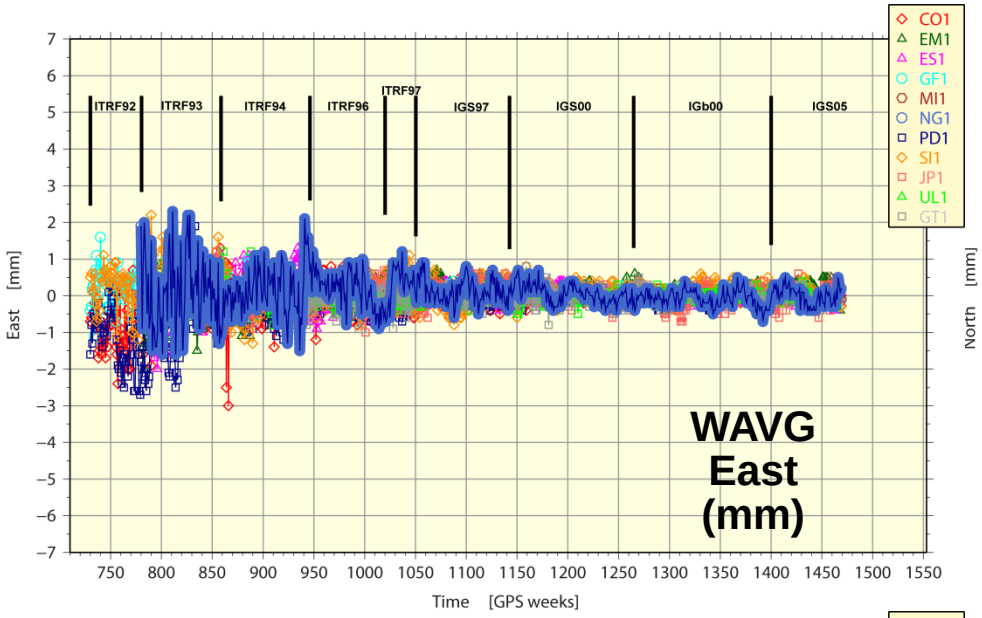


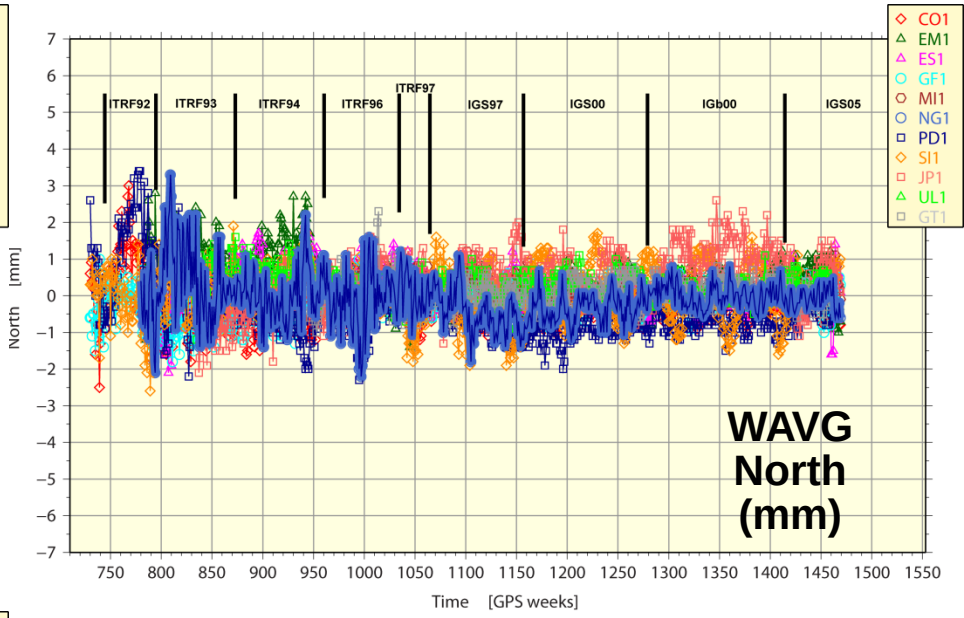
Quality of NG1 Orbits: WRMS of AC Orbits (w.r.t. IG1)

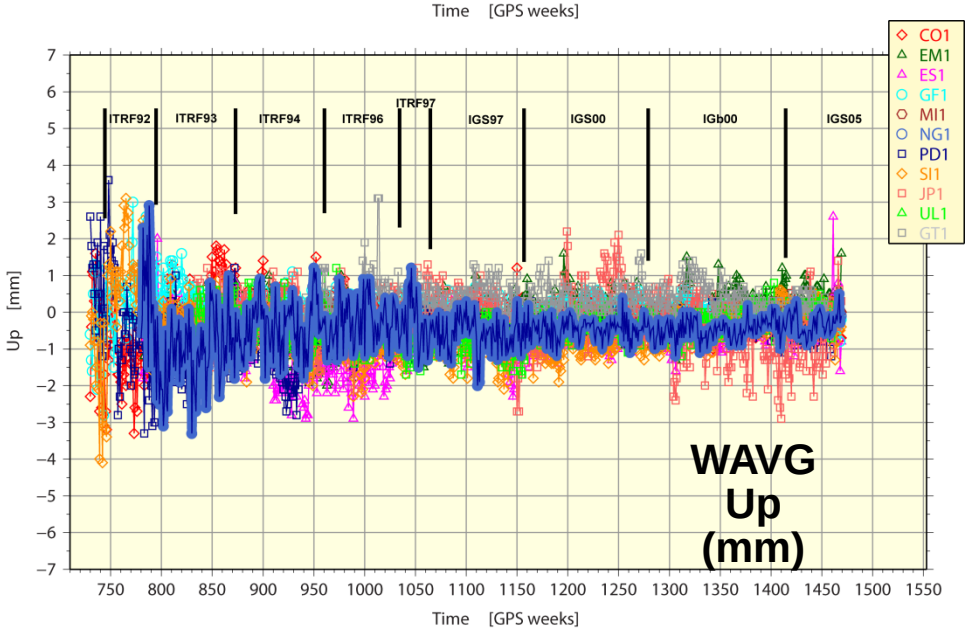


Courtesy: IGS Analysis Center Coordinator [2010]

Quality of global TRF: NG1 w.r.t. IG1 Weekly Combo







- avg. coordinate residuals for NGS show very good agreement with IGS frame, esp in recent years
- errors associated with old frames have been removed
- agreement with IGS frame is critical for aligning to ITRF in downstream processing

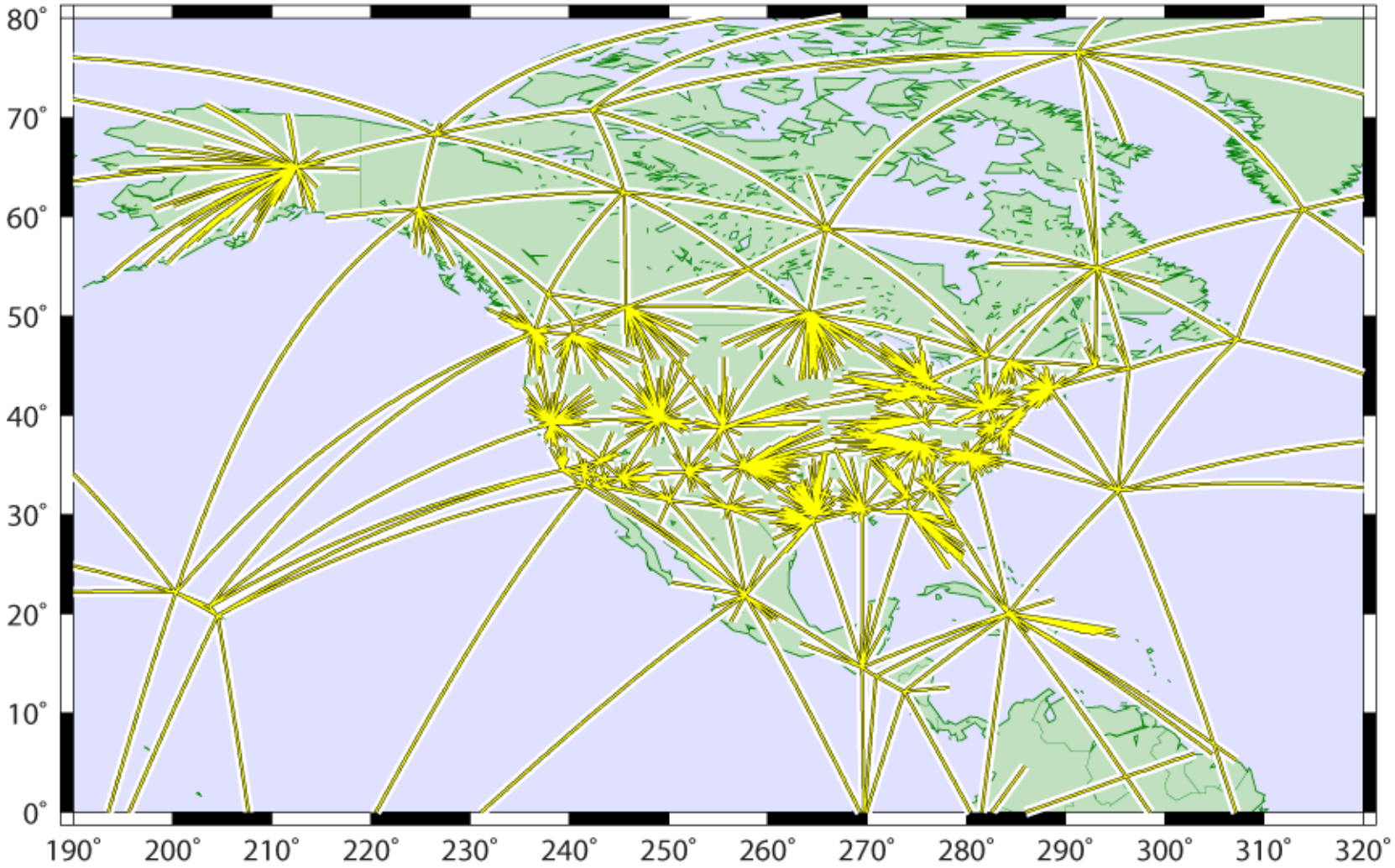
Courtesy: IGS Reference Frame Coordinator [2010]

Tie CORS to Global Frame & Stack

- CORS RINEX observations reduced in global framework
  - tie remaining CORS to backbone sites via single baselines
  - hold fixed NGS reprocessed orbits & EOPs
  - adjust CORS+global station coordinates (NNR over IGS05 sites)
- full history of consistent weekly CORS+global SINEX files
- use CATREF software to stack weekly CORS+global SINEX files:
  - step 1: attenuate aliasing effects caused by local non-linear motions
    - sub-network of ~90 sites
    - derive "unbiased" weekly Helmert parameters by stacking over sub-network
    - weekly scale changes are assumed to be zero for this step
  - step 2: impose "unbiased" Helmert parameters on whole network & stack
  - step 3: align "unbiased" stacked TRF to ITRF2008
    - scale is inherited from ITRF
    - variance-covariance re-scaled w.r.t. ITRF
  - overall stacking strategy follows one developed by X. Collilieux (IGN); more details of procedure at http://beta.ngs.noaa.gov/myear/

Design for tying CORS to Global Network

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

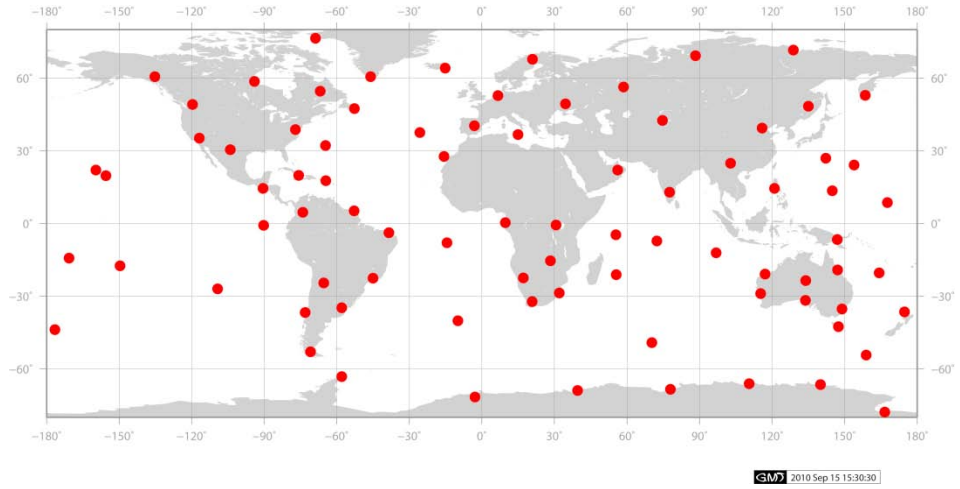


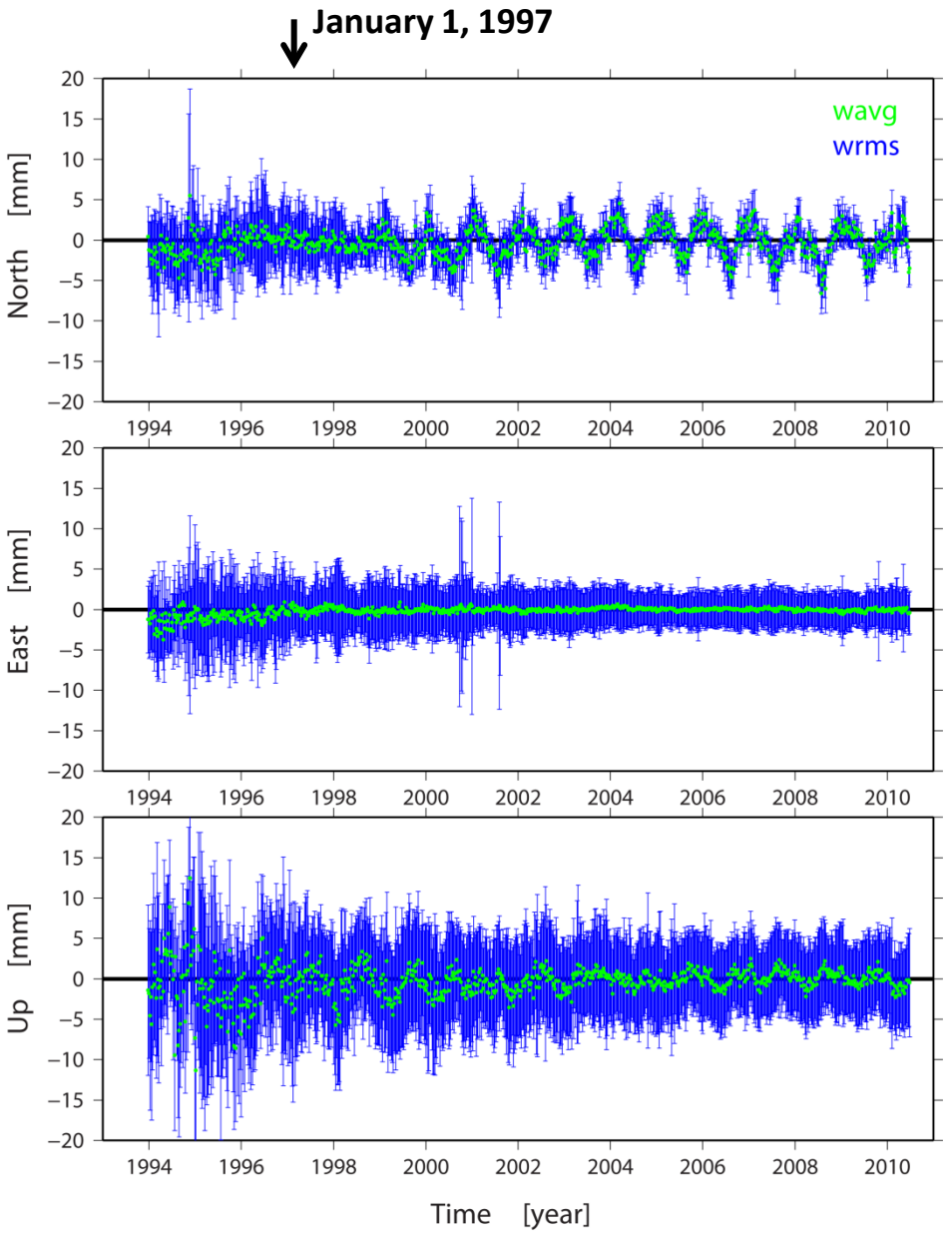
Discontinuities

- Global (or non-CORS) sites
  - adopted those in ITRF2008 for overlap period
    - added discontinuities for 30 sites
  - for periods before (1994.0 –> 1997.0) and after (2009.5 –> 2010.5) overlap
    - equip. changes & physical events
- CORS sites
  - equip. changes, physical events & empirical jumps
- automated procedures used for detecting empirical discontinuities:
  - SIGSEG [Vitti, 2009]
    - analytical method can detect position & velocity jumps
    - finds segments described by a smooth, general function
    - works on noisy series—manual tuning of input parameters
    - currently requires evenly spaced-data & no data gaps
  - Change-point Analysis [Taylor, 2000]—impl. by X. Collilieux (IGN) & K. Senior (NRL)
    - analytical method detects position jumps
    - segments are smooth linear functions—requires de-trending
    - implementation introduces explicit handling of white & flicker noise
    - can handle time series with “short” data gaps
  - potential issue of mixing different definitions for what is a “discontinuity”
- only “significant” jumps are inserted—iterative approach used

Attenuating Aliasing Effects in Helmerts

- coord. residuals averaged over subnet sites (see map below)
- amp. of "deterministic" annual signal:
  - North, in-phase ≈ 1.45 mm
  - North, out-of-phase ≈ 0.99 mm
  - East, in-phase ≈ 0.07 mm
  - East, out-of-phase ≈ -0.05 mm
  - Up, in-phase ≈ -0.20 mm
  - Up, out-of-phase ≈ -0.70 mm
- slight bias in N??
  - subnet selection less than optimal
  - signal in U may be masked by noise/error
- early years scattered
- long-term stability is quite good



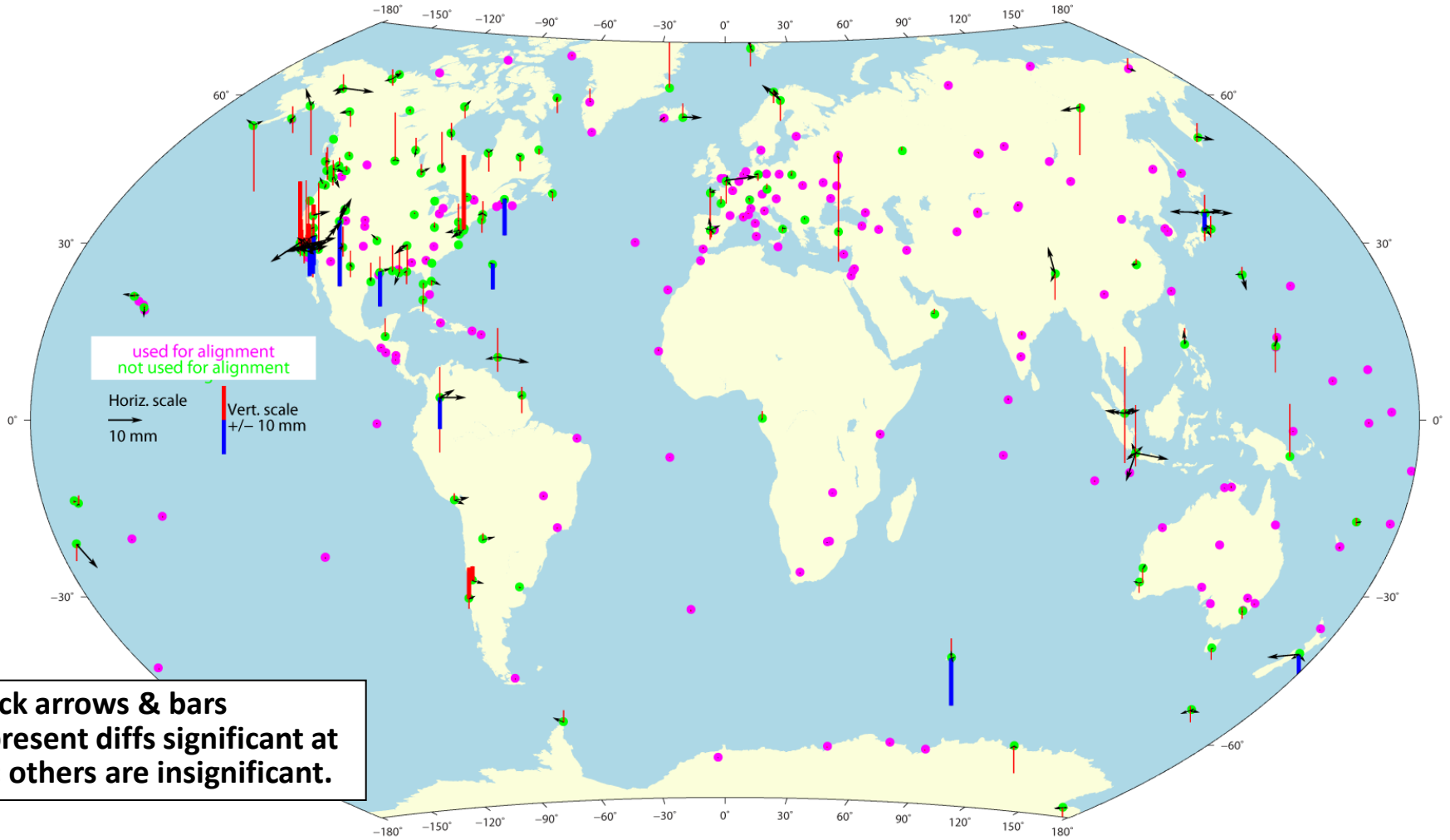


Alignment to ITRF2008: Position Differences

ITRF2008 – $TRF_{CORS+glbl}$

- larger diffs due to discontinuities & longer data spans in $TRF_{CORS+glbl}$
- diffs < 10 mm (horiz) & 25 mm (vert) mm shown below—larger diffs insignificant at 2σ
- avg. diffs for all sites used in alignment (magenta dots):

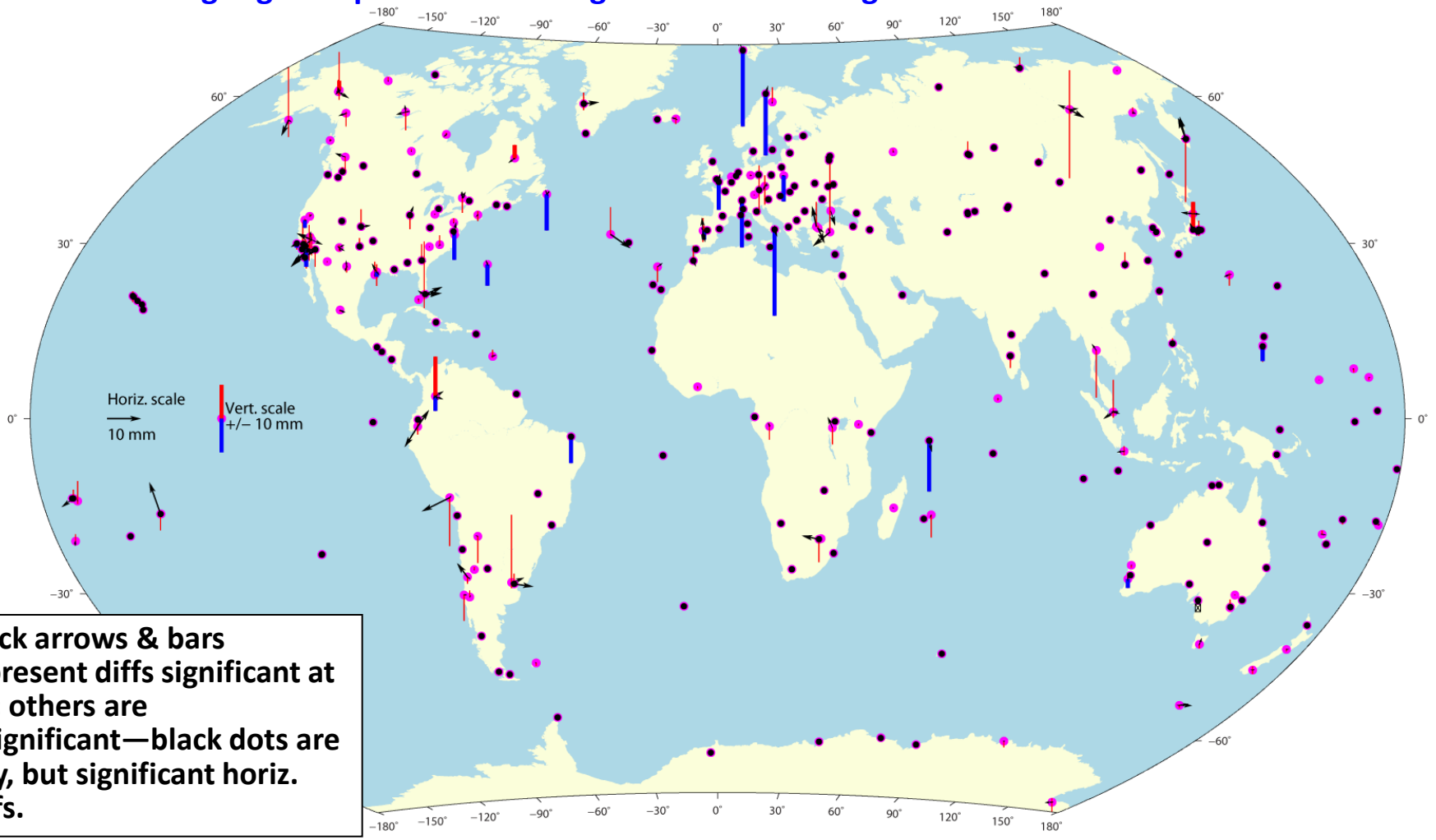
$\Delta E = 0.00 (\pm 0.12)$ mm $\Delta N = 0.00 (\pm 0.19)$ mm $\Delta U = 0.05 (\pm 0.41)$ mm



Thick arrows & bars represent diffs significant at 2σ; others are insignificant.

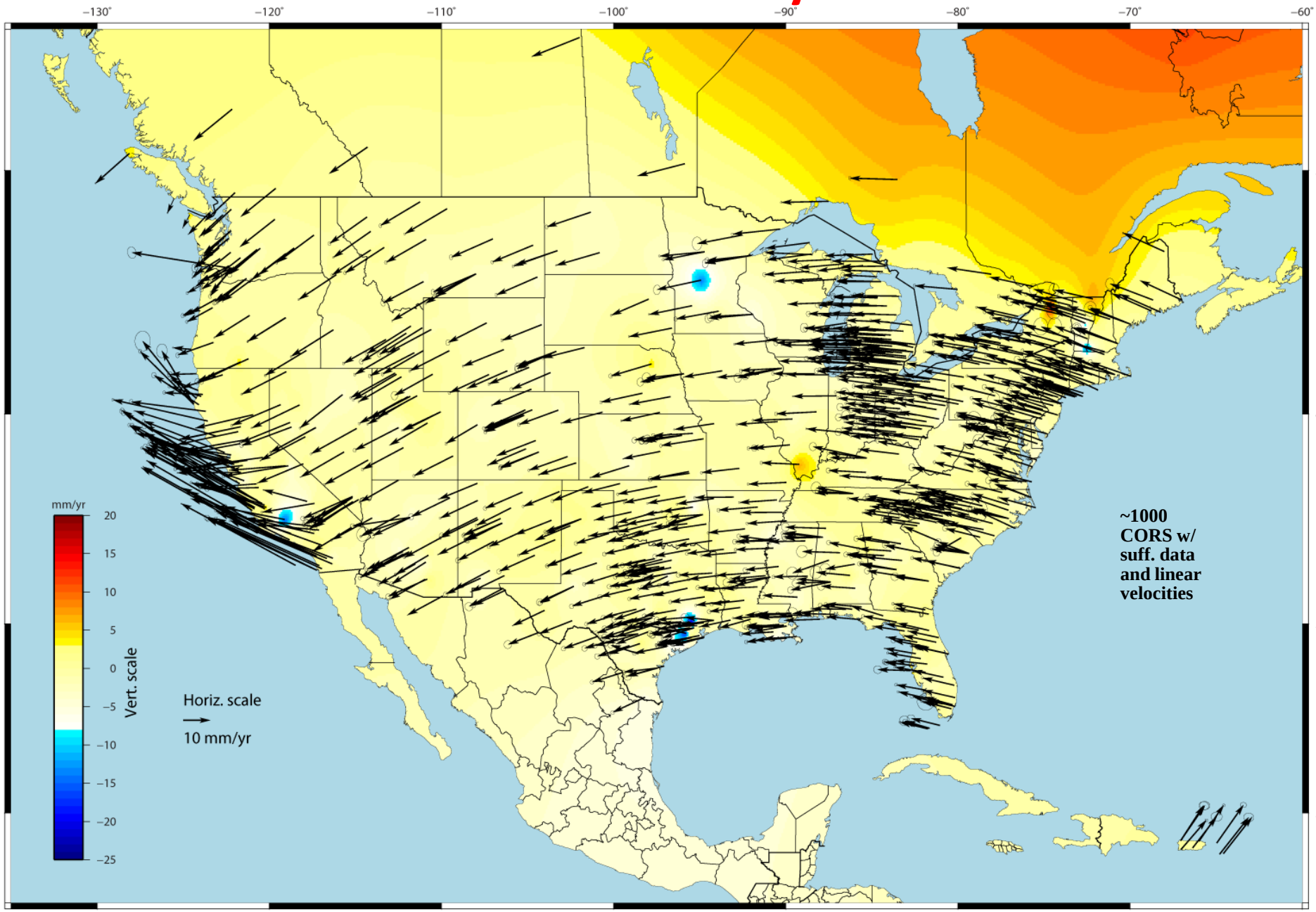
Distortions of TRF from adding CORS?

- comparison of TRF_{glbl} & $TRF_{CORS+glbl}$ (i.e., TRF_{glbl} - $TRF_{CORS+glbl}$)
  - 14 Helmert parameters are zero
  - most diffs are small (<< 10 mm)
    - larger diffs due to weak frame prior to 1997 and poorly resolve velocities following eqs.
  - no strong regional patterns—adding CORS caused insignificant distortions



Thick arrows & bars represent diffs significant at 2σ; others are insignificant—black dots are tiny, but significant horiz. diffs.

U.S. CORS Velocity Field



Conclusions

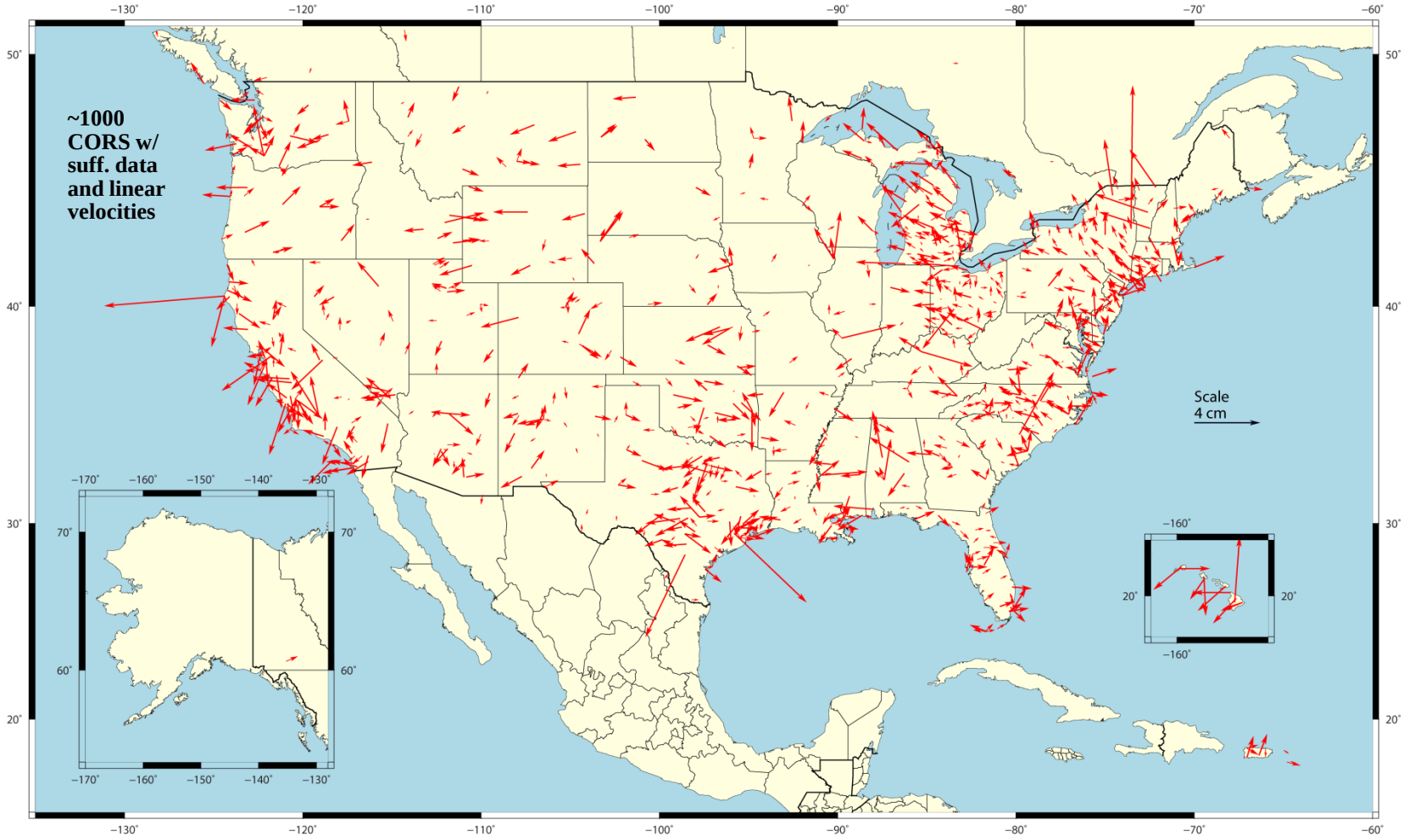
- 1st reprocessing at NGS of global and U.S. CORS GPS data collected since 1994 is complete
- provisional solution, aligned to ITRF2008, is complete
- overall excellent alignment to ITRF2008
  - large differences at individual sites caused by earthquakes, longer data spans and different discontinuities
- insignificant distortions caused by tying U.S. CORS to global frame
- main challenges
  - metadata—probably only getting more difficult, esp. for U.S. CORS
  - tying large and dense network to global frame
    - NGS strategy seems to work well
    - excellent agreement with ITRF2008
    - distortions caused by adding CORS are likely much smaller than inaccuracy of ITRF2008
  - position and velocity discontinuities
    - equipment changes causing significant position jumps are included
    - undocumented jumps handled by inserting empirically determined disc. parameters
    - community must define what is a "discontinuity" for next repro (e.g., DOGEx)
- clean 3D velocity field
  - can hopefully be used for studies on crustal deformations in U.S.
  - good sign that NGS' contribution to NAREF is OK
- official solution, consistent with IGS08, expected to be complete by early 2011

Backup Slides

Changes in *Horizontal* NAD 83 Positions

NAD 83 (CORS96a @ 2002.0) – NAD 83 (CORS96 @ 2002.0)

- approx. 2 cm error expected @ 2005.0 (based on σ in old solution)
- avg. horizontal shifts: $\Delta E = -0.17 (\pm 1.86)$ cm $\Delta N = 0.20 (\pm 2.31)$ cm
  - prescribing velocities using HTDP
  - smaller random part probably caused by change to absolute antenna calibrations



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Changes in *Vertical* NAD 83 Positions

NAD 83 (CORS96a @ 2002.0) – NAD 83 (CORS96 @ 2002.0)

- **avg. vertical shift: $\Delta U = 0.65$ cm ($\pm$ 2.08) cm**
  - **random part mostly caused by switch to absolute antenna calibrations**
  - **shifts also caused by assuming $V_u = 0$ in NAD 83(CORS96)**