# Status update for the NGS multi-year CORS reprocessing effort

- summary of processing strategy
- updated velocity field and main use of solution at NGS
- NAD 83 position changes


by

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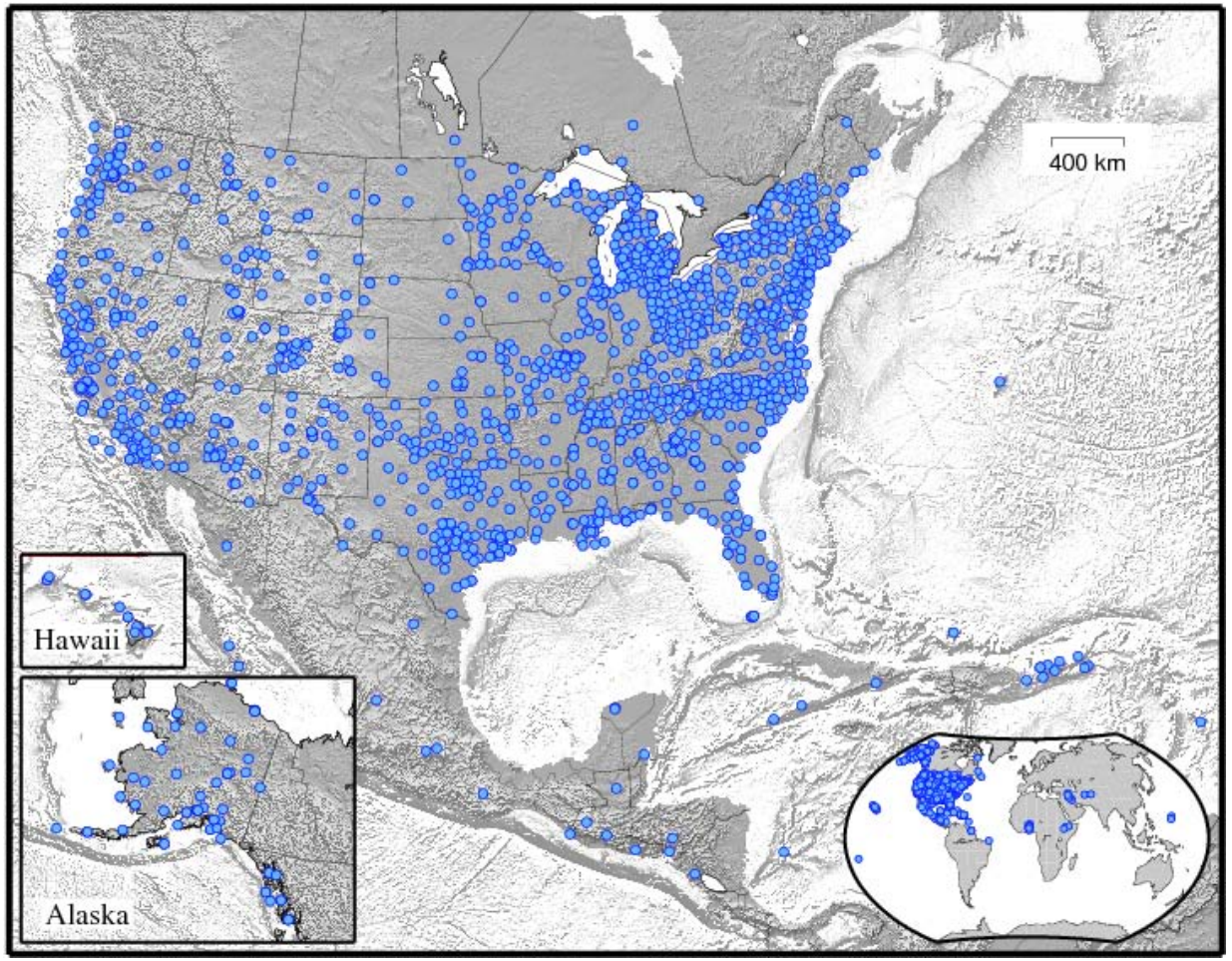
# U.S. CORS Network

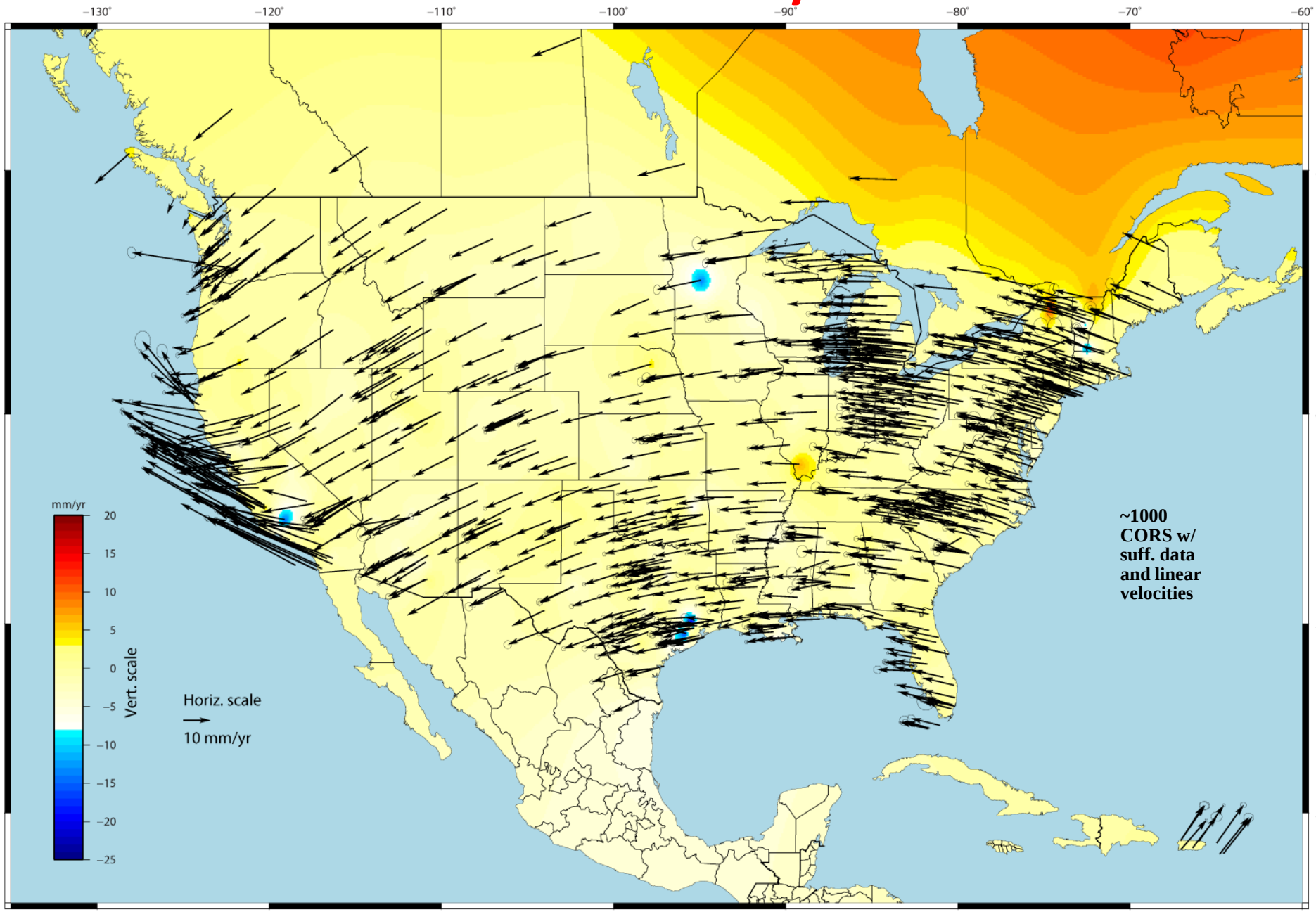
- currently ~1500 sites
  - mostly in U.S.
- used to provide access to the U.S. National Spatial Reference System
  - current realization based on ITRF2000
- also supports meteorology, space weather and other geophysical applications



# How is Multi-year CORS Solution Obtained?

- CORS RINEX observations processed in global framework using NGS reprocessed orbits, EOPs and global station coordinates
  - global frame realized by:
    - switch to absolute antenna calibrations; and
    - estimating GPS satellite orbit ephemerides, Earth Orientation Parameters (EOPs) and global station positions (no net rotation; NNR)
- resulting in full history of weekly CORS+global SINEX files containing X,Y,Z positions and full variance-covariance information
- use 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
    - scale is inherited from ITRF
  - Step 4: (TBD) apply ITRF2008 -> IGS08 position corrections to account for impending switch to IGS08 absolute antenna calibration
- Result is a new positions and velocities for CORS

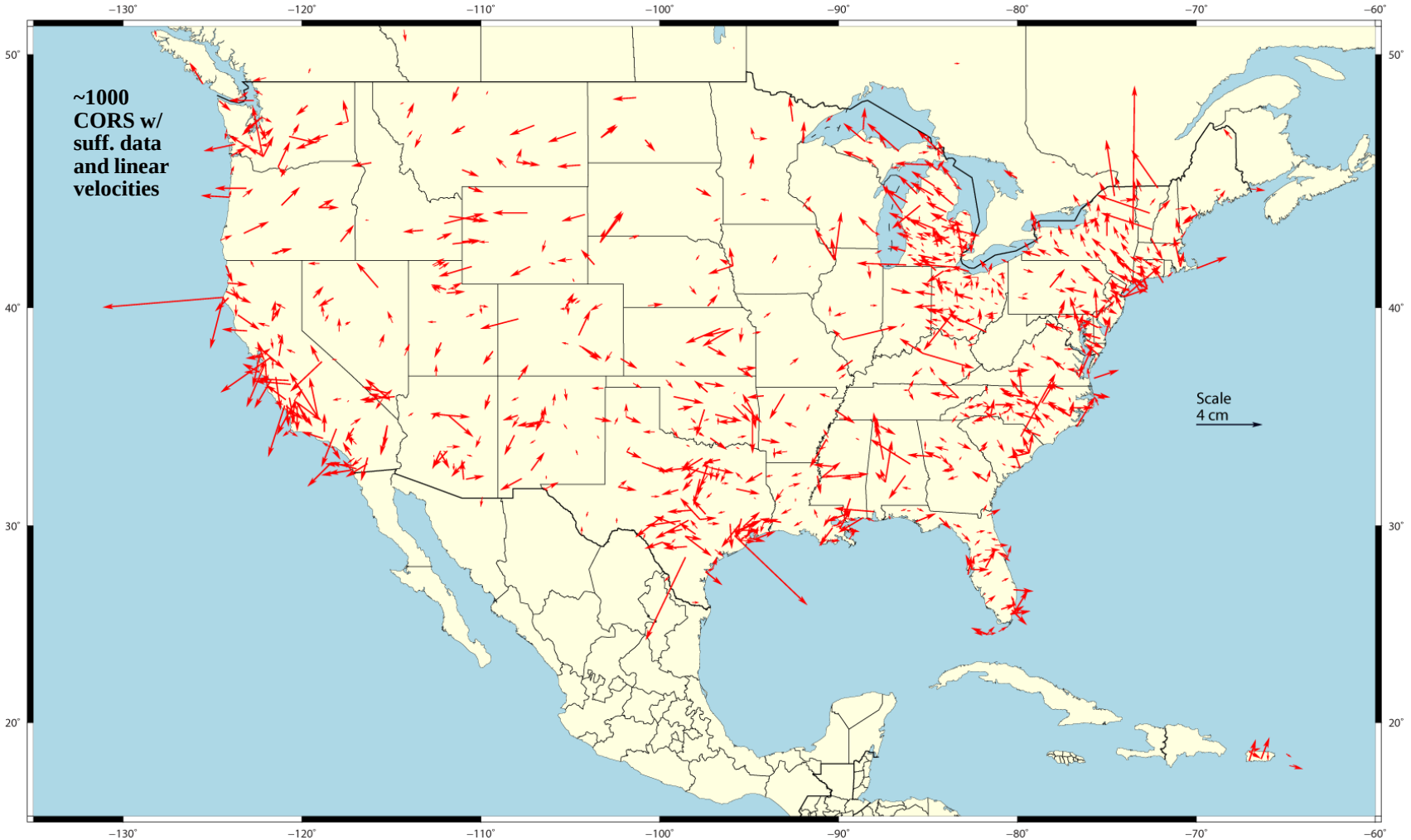
# U.S. CORS Velocity Field



# Changes in *Horizontal* NAD 83 Positions

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

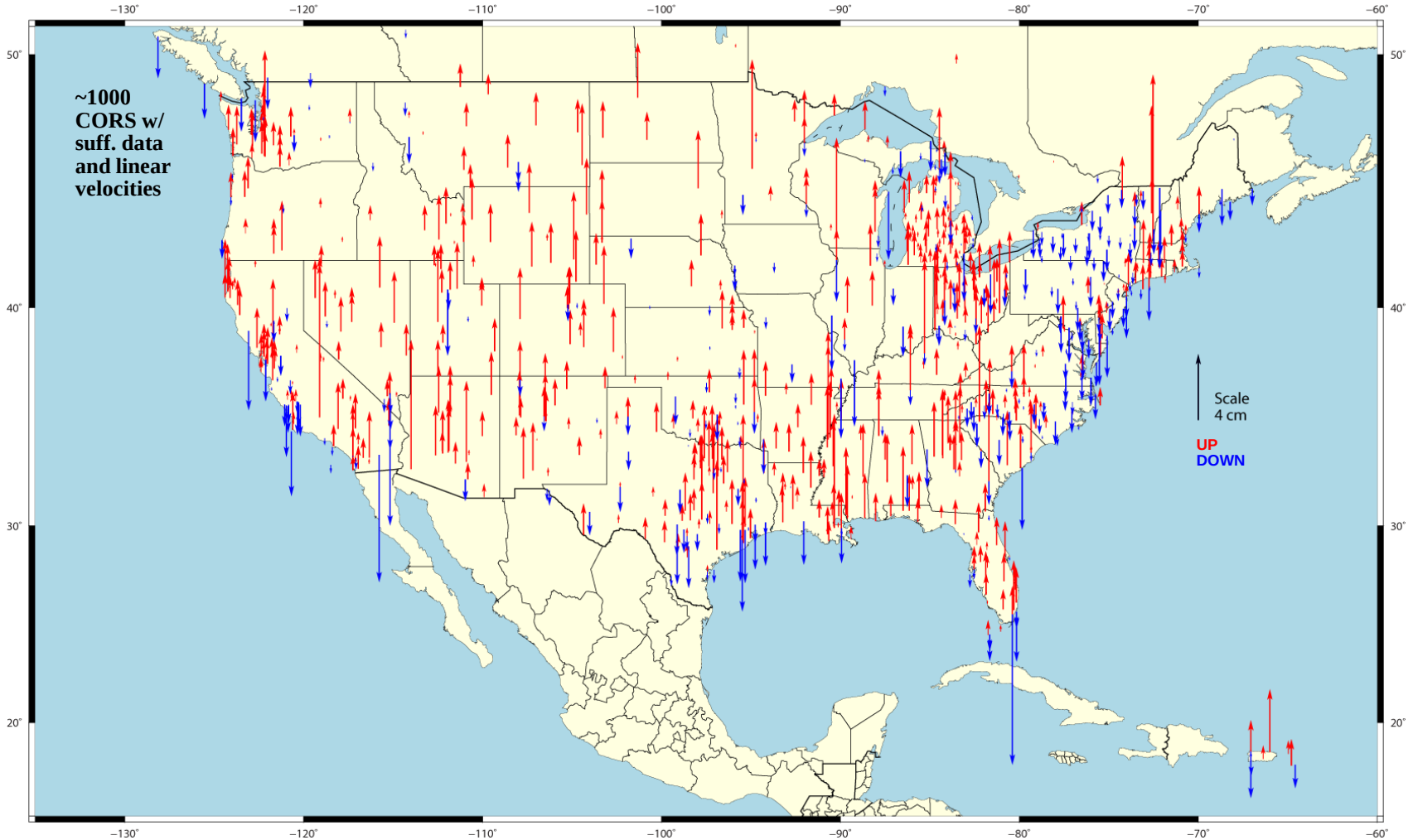
- approx. 2 cm error expected @ 2005.0 (based on σ in old solution)
- avg. horizontal shifts: $\Delta E = -0.17 (\pm 1.86)$ cm  $\Delta N = 0.20 (\pm 2.31)$ cm
  - prescribing velocities using numerical models (i.e. HTDP)
  - smaller random part probably caused by change to absolute antenna calibrations



# 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 <u>switch to absolute antenna calibrations</u>**
  - **shifts also caused by assuming $V_u = 0$ in NAD 83(CORS96)**



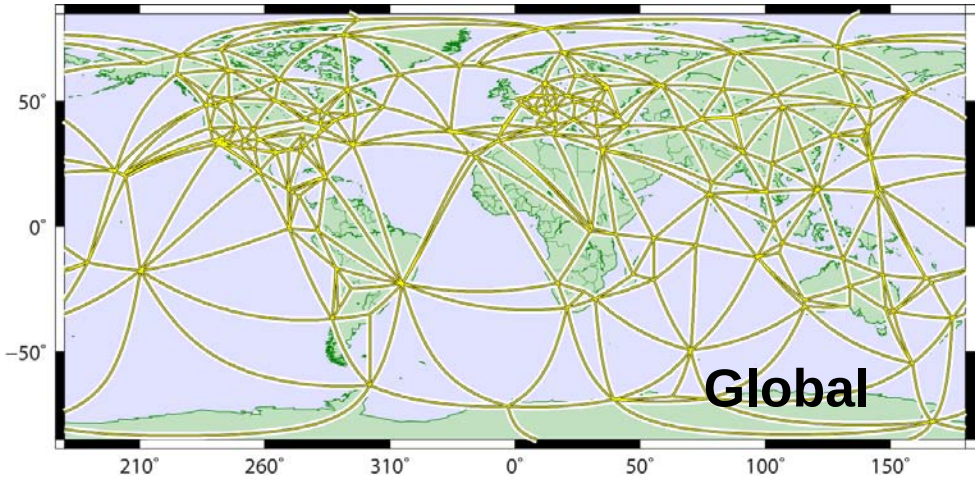
# Conclusions

- 1st reprocessing at NGS of global and U.S. CORS GPS data collected since 1994 is complete
- provisional solution is complete
- new NAD 83 positions and velocities result in coordinate changes:
  - $\Delta E = -0.17 (\pm 1.86)$ cm
  - $\Delta N = 0.20 (\pm 2.31)$ cm
  - $\Delta U = 0.65$ cm $(\pm 2.08)$ cm
- updated, more accurate 3D velocity field for crustal motion models and other tectonic studies
- official solution expected to be complete by spring 2011

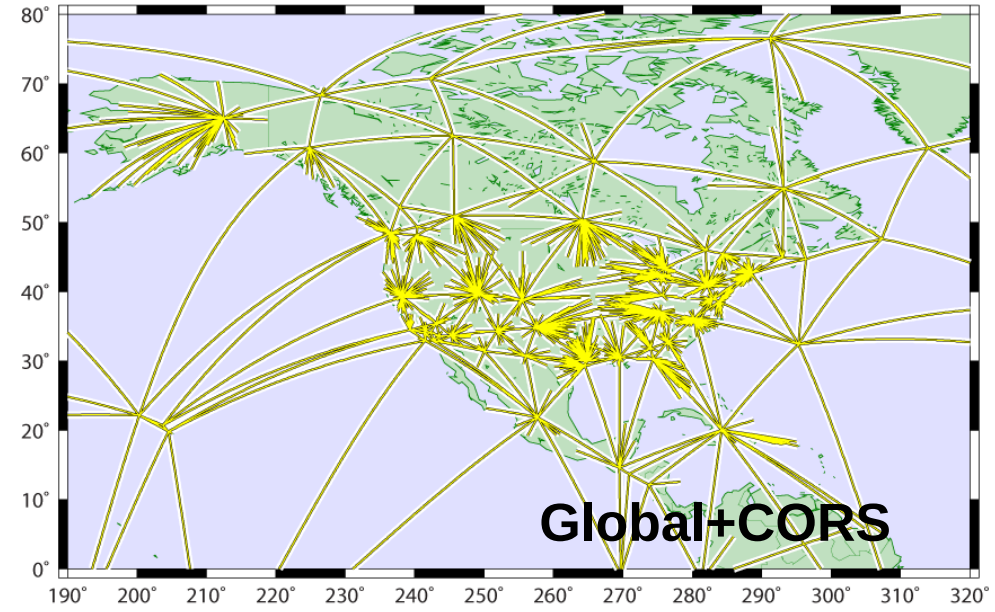
# Backup Slides

# Tying CORS to Global Network

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

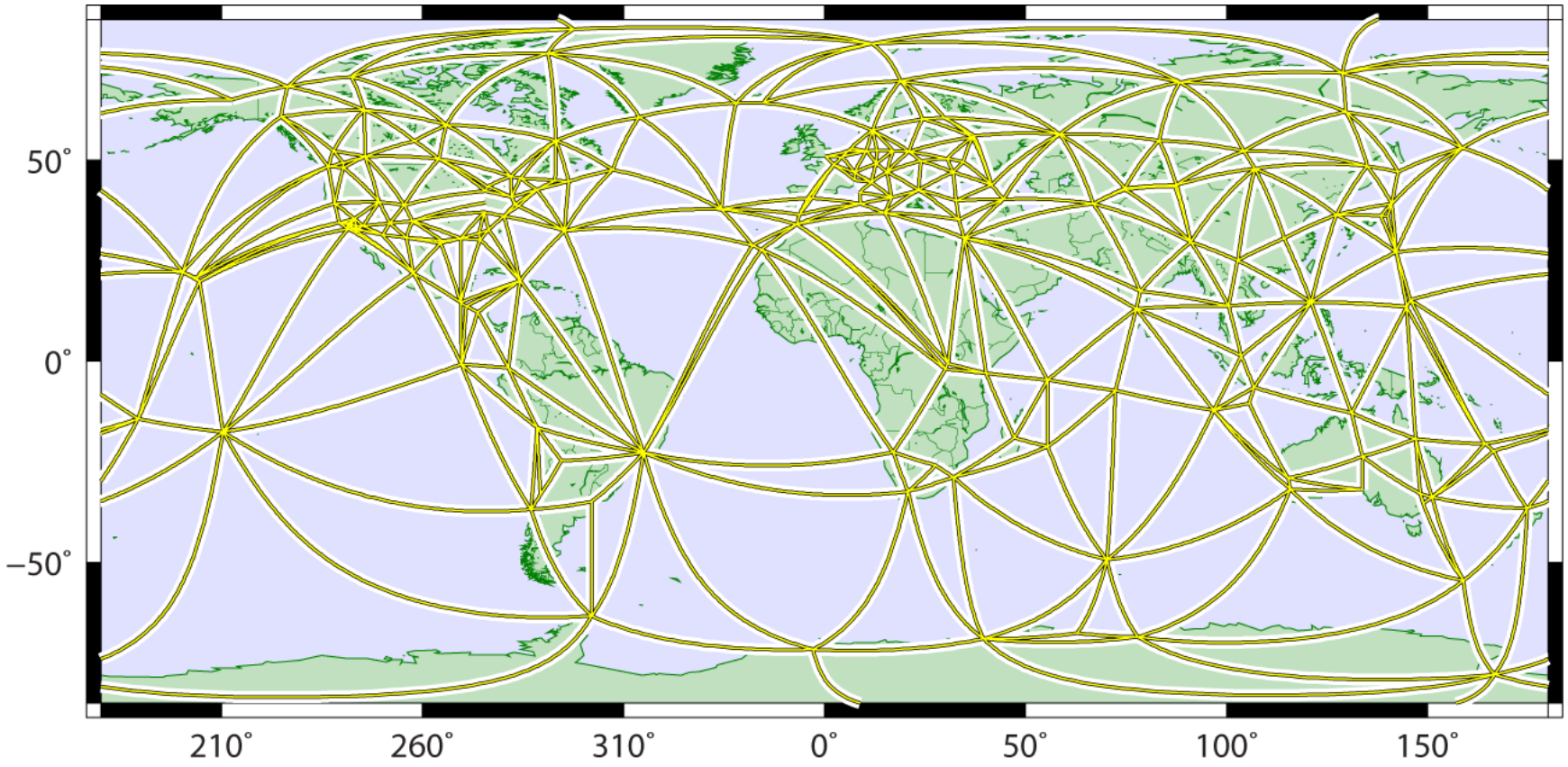



- global tracking network used for estimating:
  - GPS satellite orbits (15-min intervals)
  - terrestrial framework
    - Earth Orientation (EOPs)
    - global station positions (weekly averages)

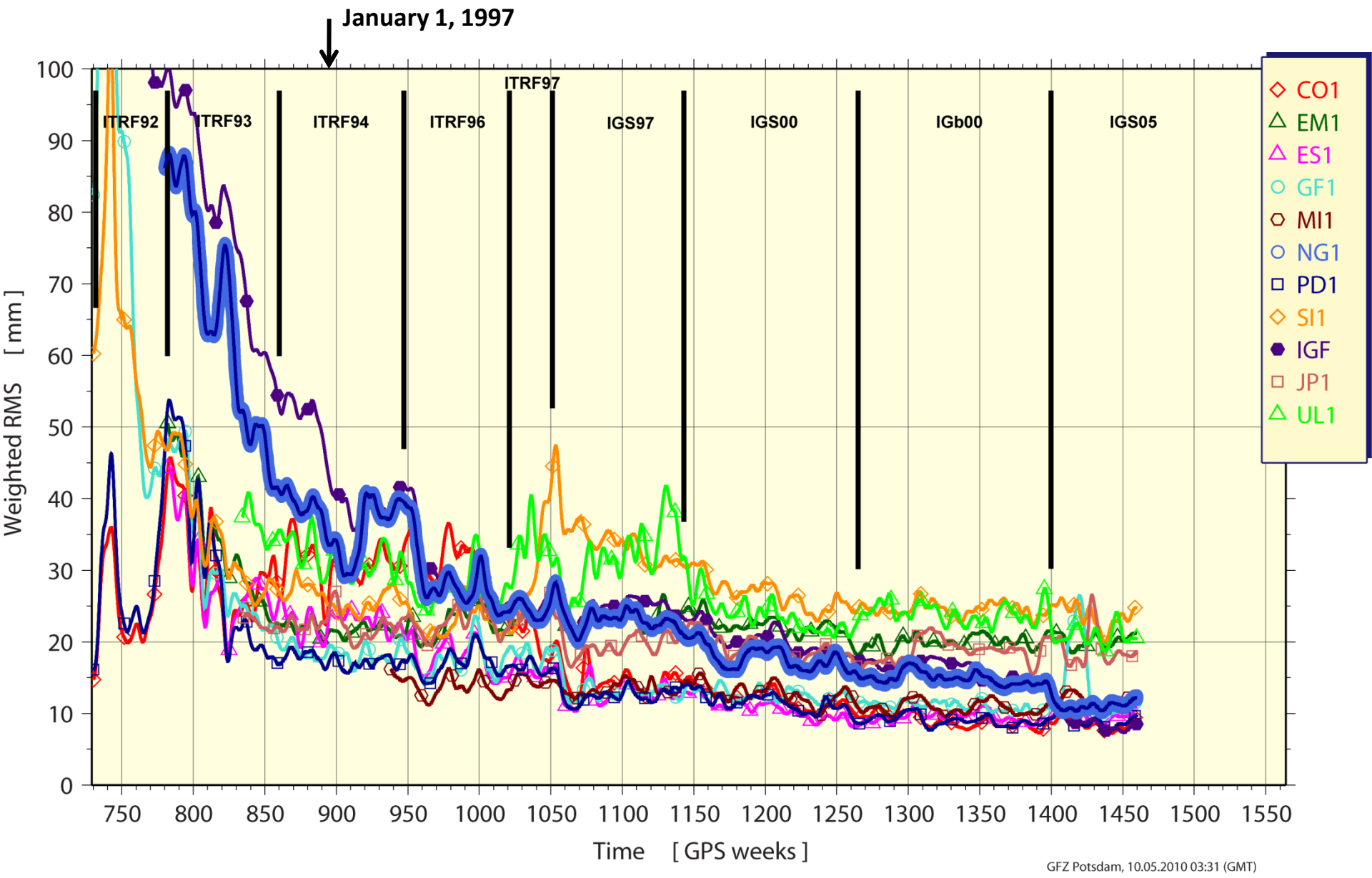



- U.S. CORS tied to global framework via single baselines radiating from global stations
  - minimizes frame distortions from local effects in dense regional networks

# Design of Global Tracking Network

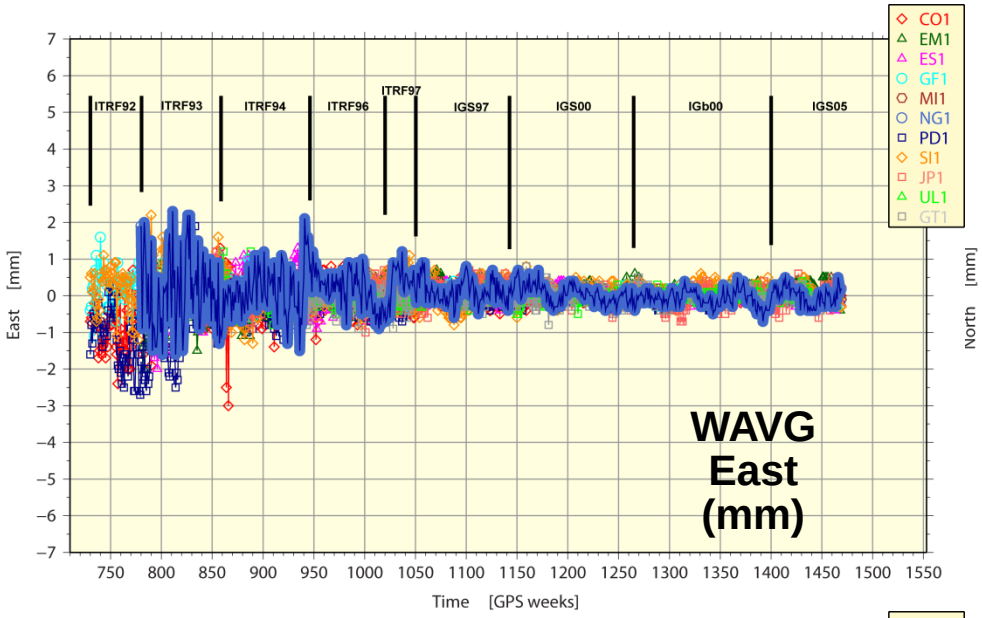


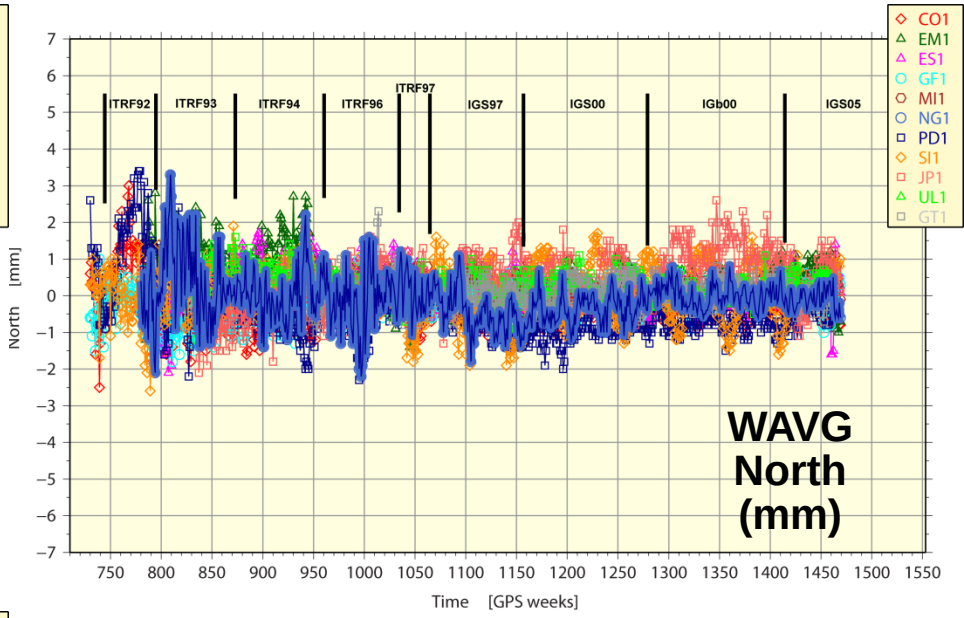
# Quality of NG1 Orbits: WRMS of AC Orbits (w.r.t. IG1)

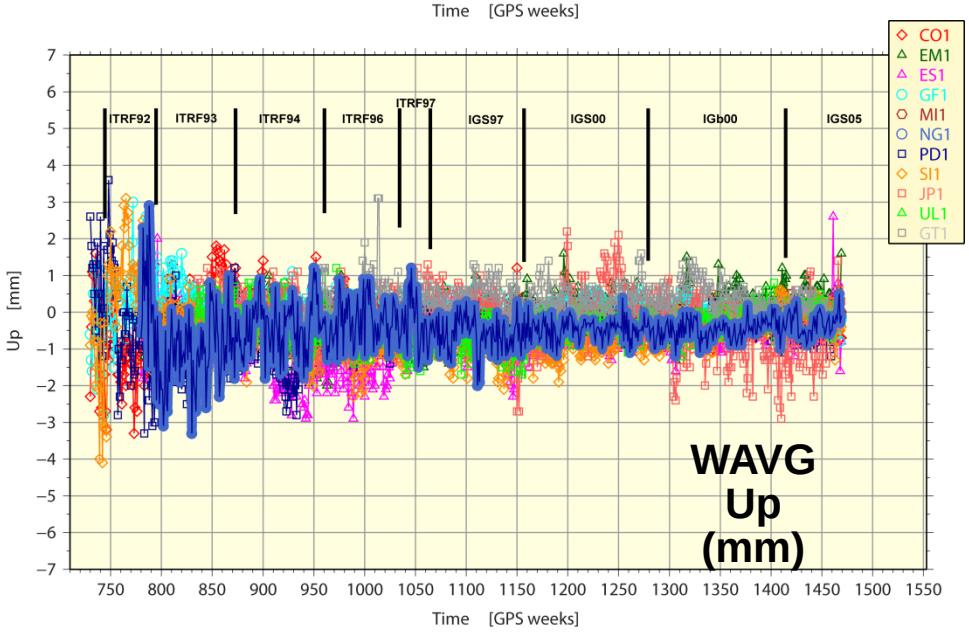



**Courtesy: IGS Analysis Center Coordinator [2010]**

# 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

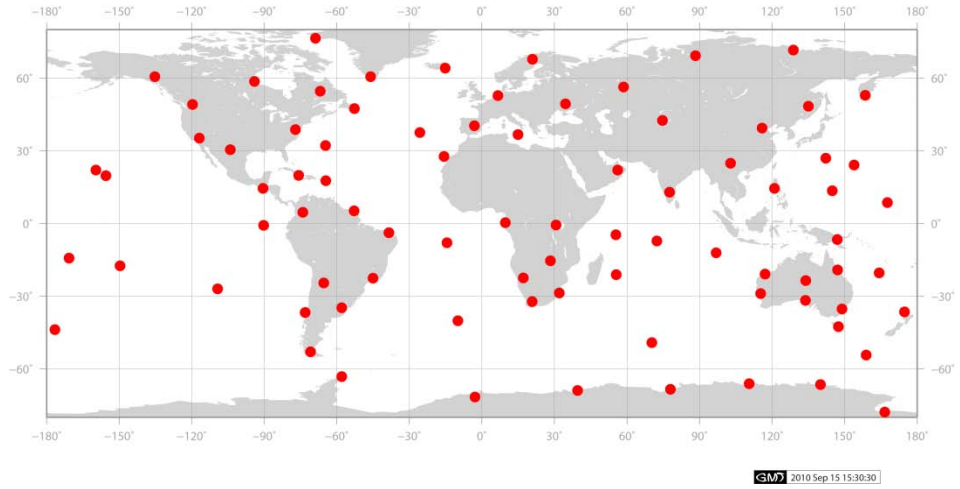
- CORS RINEX observations reduced in global framework
  - tie remaining CORS to backbone sites via single baselines
  - hold fixed NGS reprocessed orbits & EOPs
  - adjust CORS+global station coordinates (NNR over IGS05 sites)
- full history of consistent weekly CORS+global SINEX files
- use CATREF software (from Institut Géographique National, France) 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/

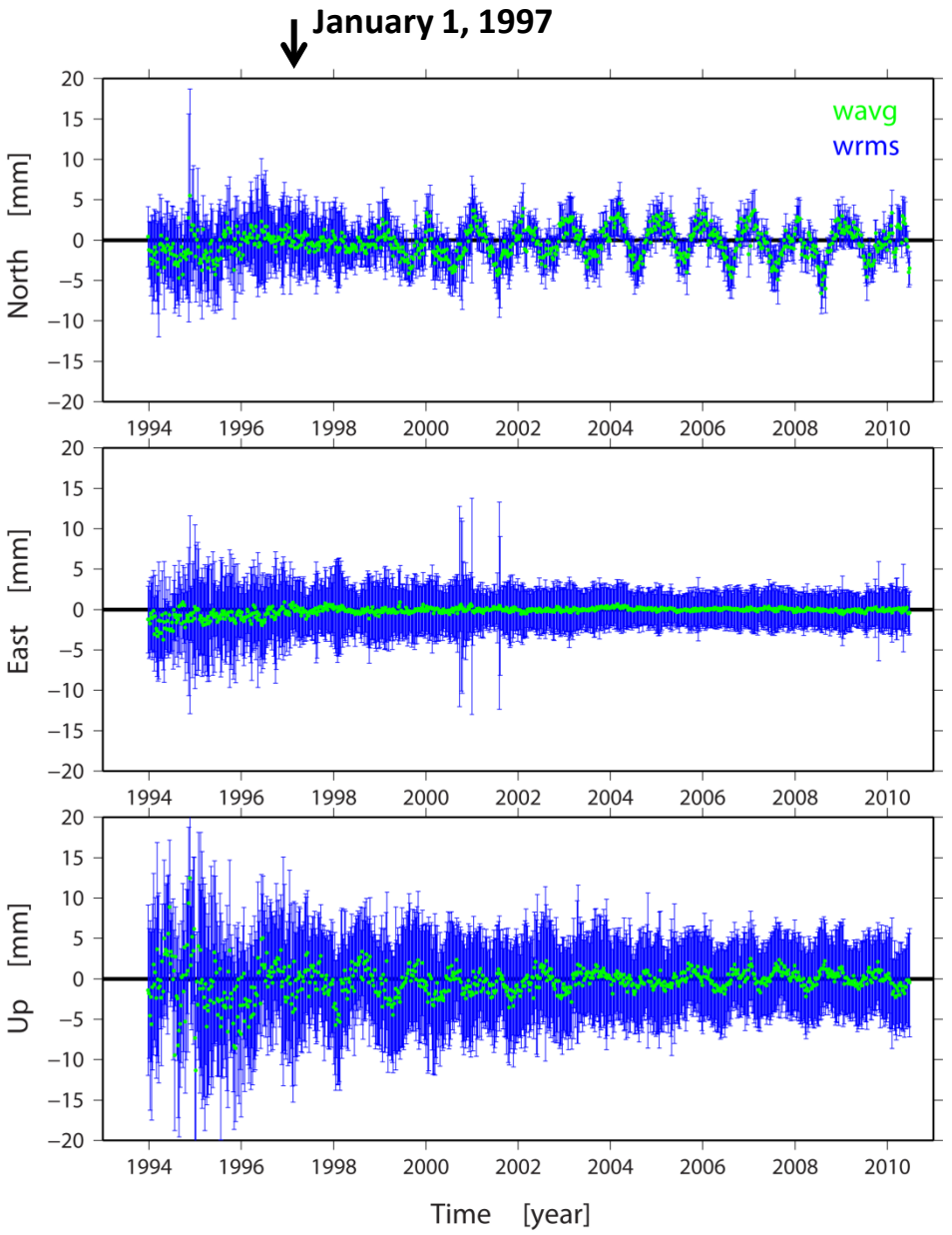
# Discontinuities

- 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



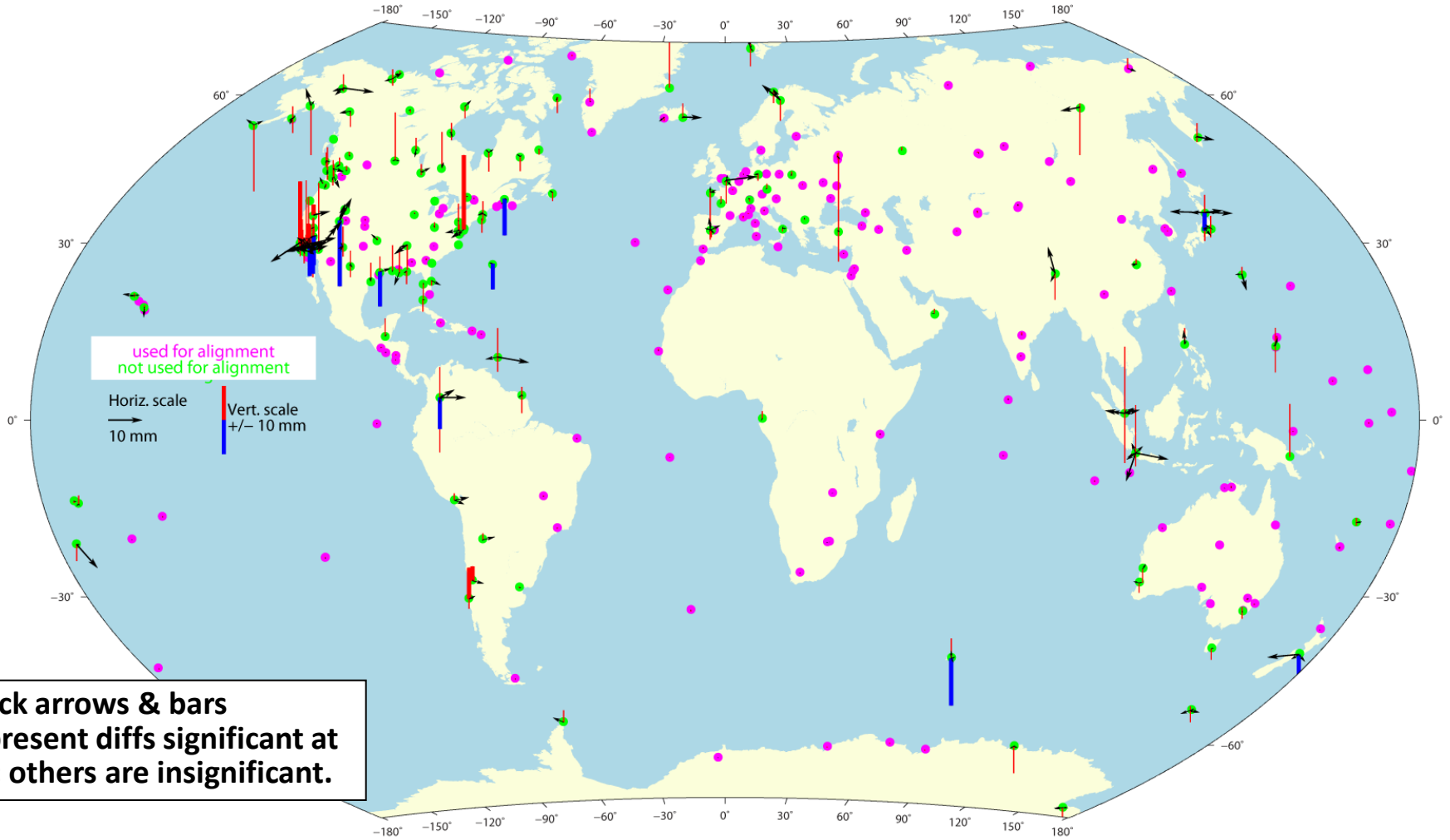


# Alignment to ITRF2008: Position Differences

## 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):

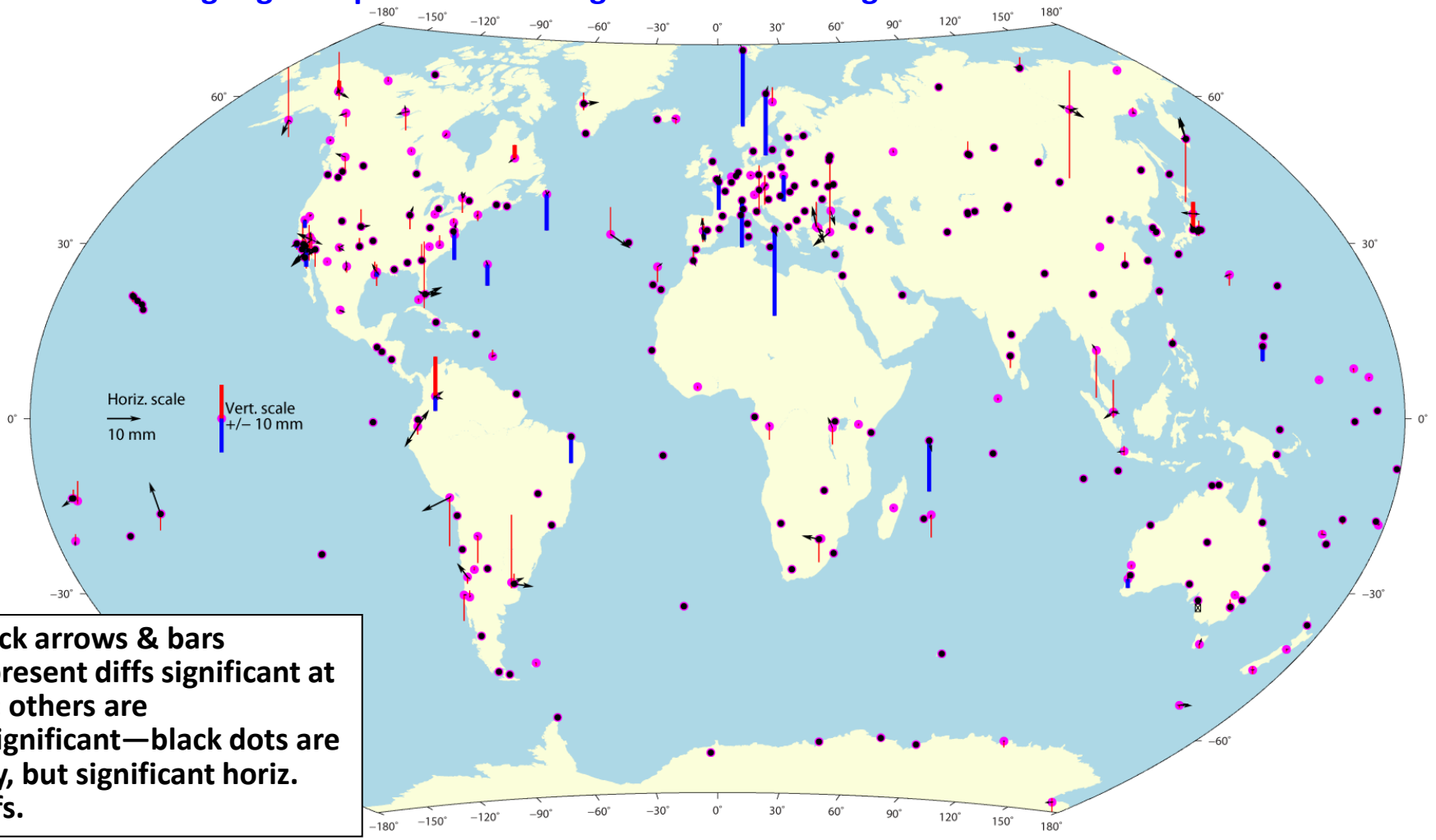
$\Delta E = 0.00 (\pm 0.12)$ mm  $\Delta N = 0.00 (\pm 0.19)$ mm  $\Delta U = 0.05 (\pm 0.41)$ mm




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

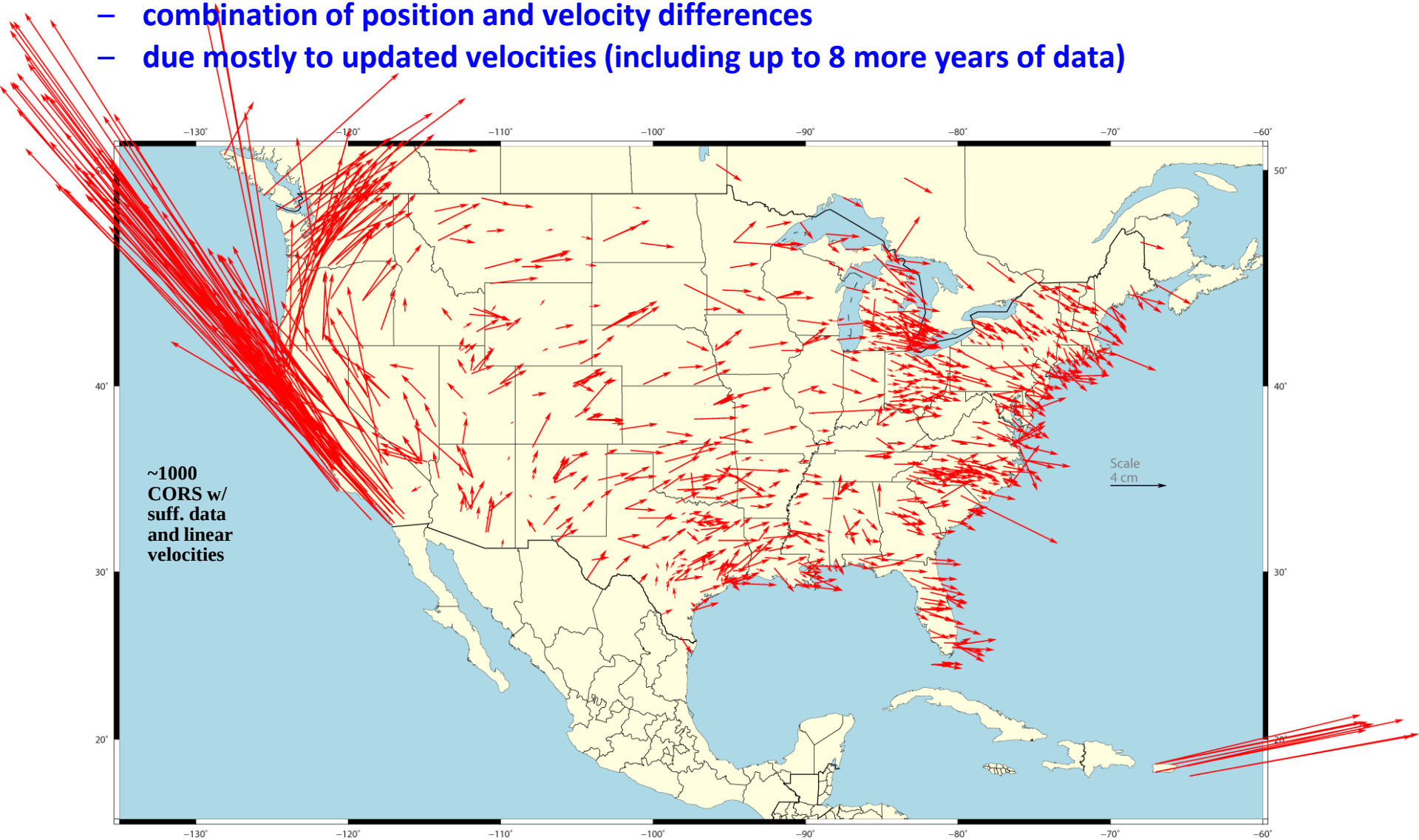



Thick arrows & bars represent diffs significant at 2σ; others are insignificant—black dots are tiny, but significant horiz. diffs.

# Changes in *Horizontal* NAD 83 Positions

## NAD 83(CORS96a @ 2010.0) – NAD 83(CORS96 @ 2002.0)

- approx. 2 cm error expected @ 2005.0 (based on σ in old solution)
- avg. horizontal shifts: $\Delta E = 0.20 (\pm 5.85)$ cm $\Delta N = 1.95 (\pm 6.12)$ 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

## NAD 83(CORS96a @ 2010.0) – NAD 83(CORS96 @ 2002.0)

- **avg. vertical shifts:** $\Delta U = -0.9 (\pm 1.82)$ cm
  - combination of position and velocity differences
  - assuming vertical velocity ≈ 0.00 in NAD 83(CORS96)