Status of the Current Multi-year CORS Solution (MYCS)

- why reprocess?
- quality of reprocessed NGS orbits and TRF
- obtaining MYCS_P—where P is for “provisional”
- quality assessment of MYCS_P
- estimated impact on users of CORS in switch to NAD 83 (CORS96A)

by

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with contributions from MYCS team:

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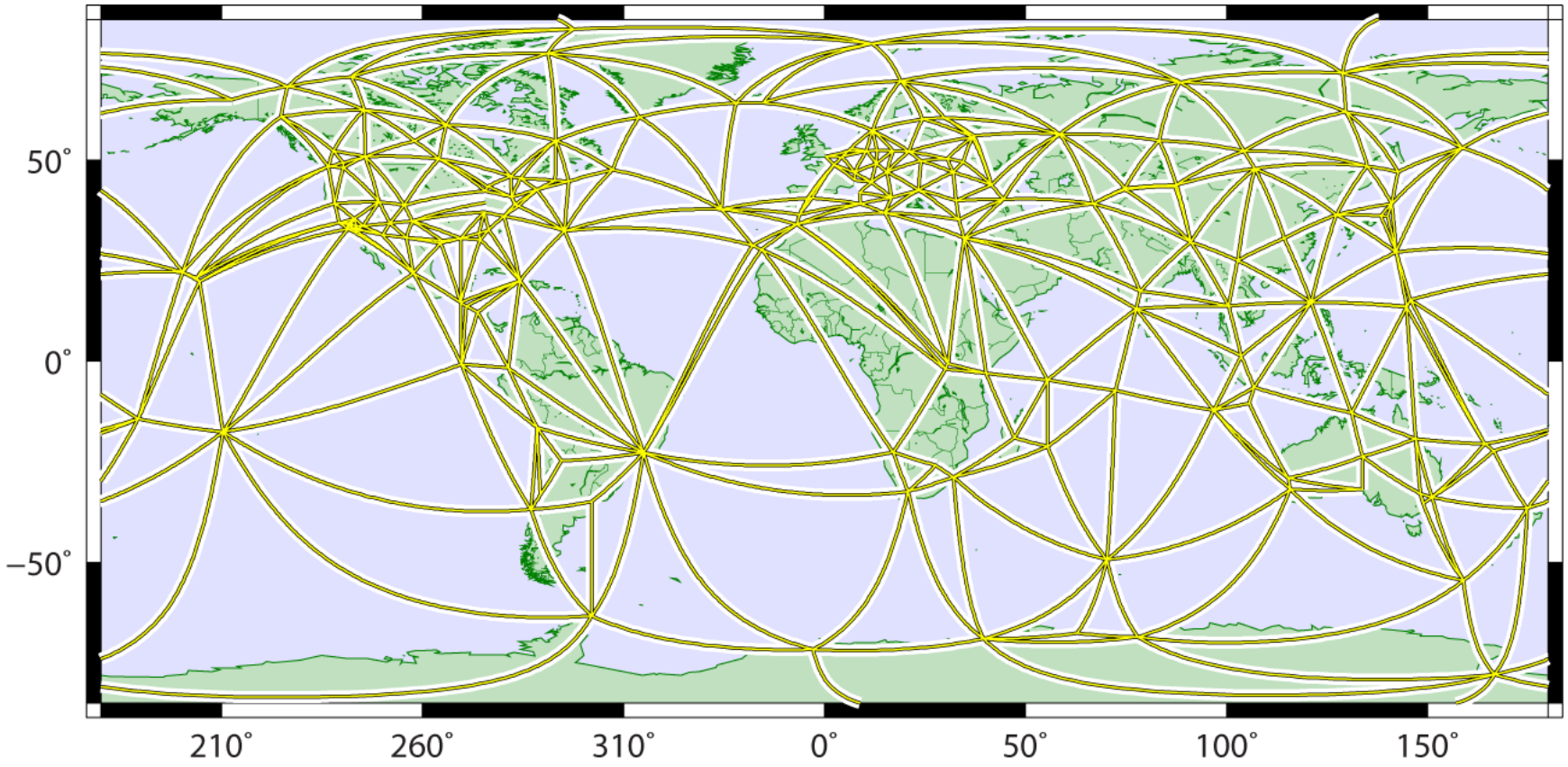
Why Reprocess?

- 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
    - 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
- 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

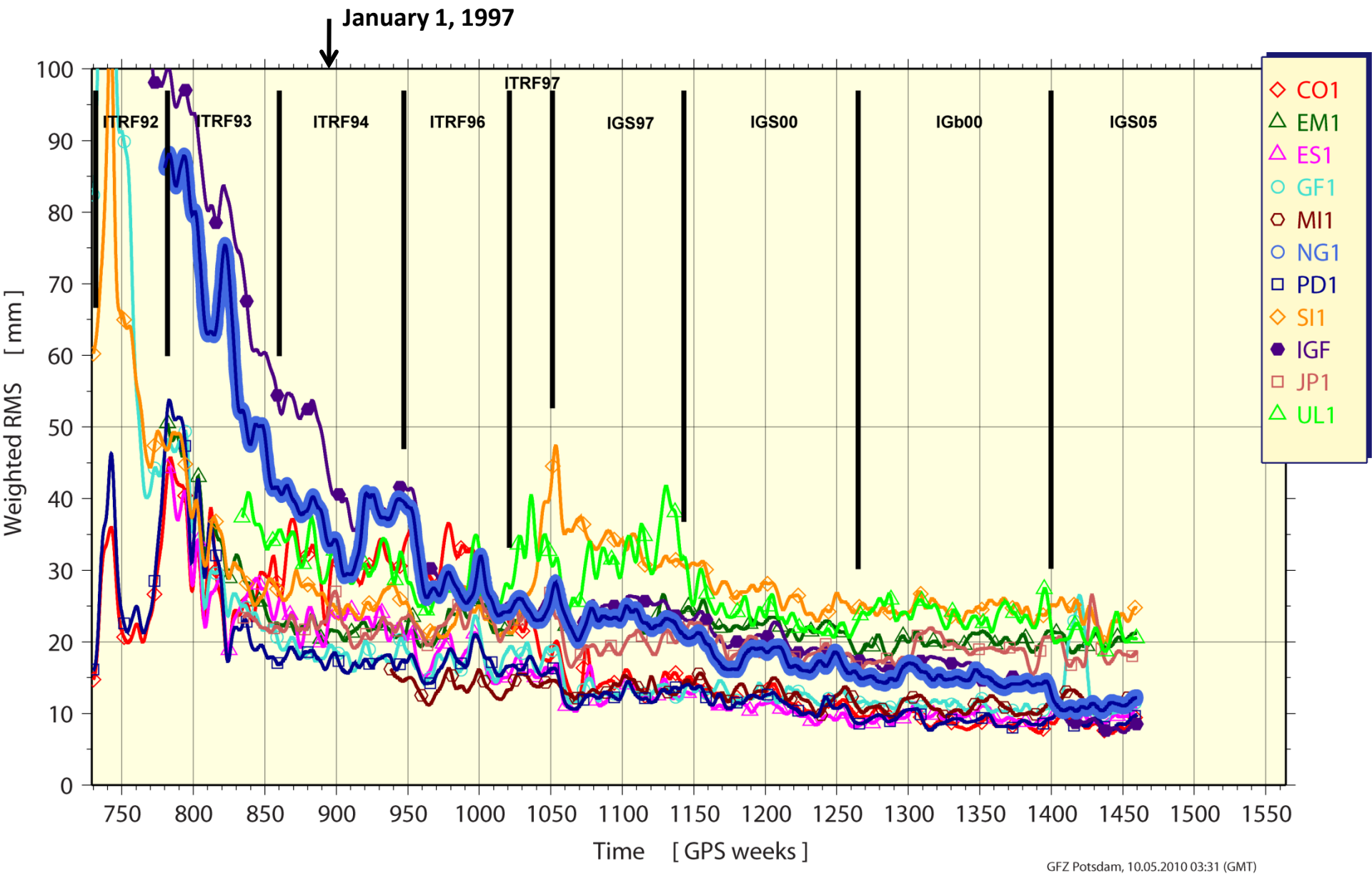
Contributors to IGS repro1 Campaign

- all IGS Final-product Analysis Centers:
  - COD/AIUB – Switzerland
  - EMR/NRCan – Canada
  - ESA/ESOC – Germany
  - GFZ – Potsdam, Germany
  - JPL – USA
  - MIT – USA
  - NGS/NOAA – USA
  - SIO – USA
- plus 2 reprocessing Centers
  - PDR – Potsdam/Dresden Reprocessing, Germany
  - ULR – University of La Rochelle TIGA (tide gauges), France
- plus 1 Center contributing to TRF only:
  - GTZ/GFZ TIGA – Potsdam, Germany
- IGS repro1 SINEX files submitted to IERS for ITRF2008

Design of Global Tracking Network used by NGS

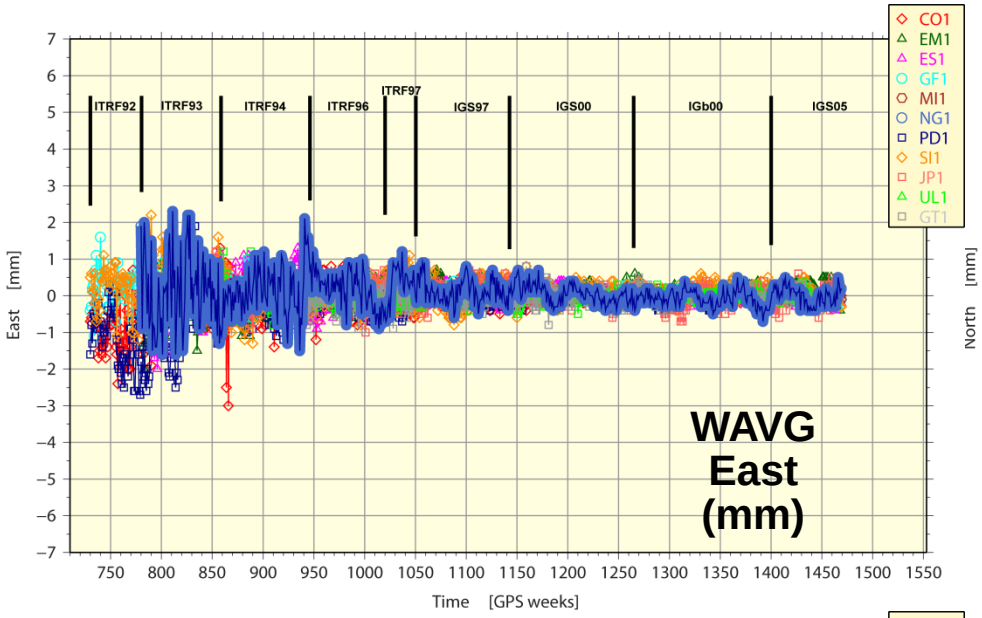


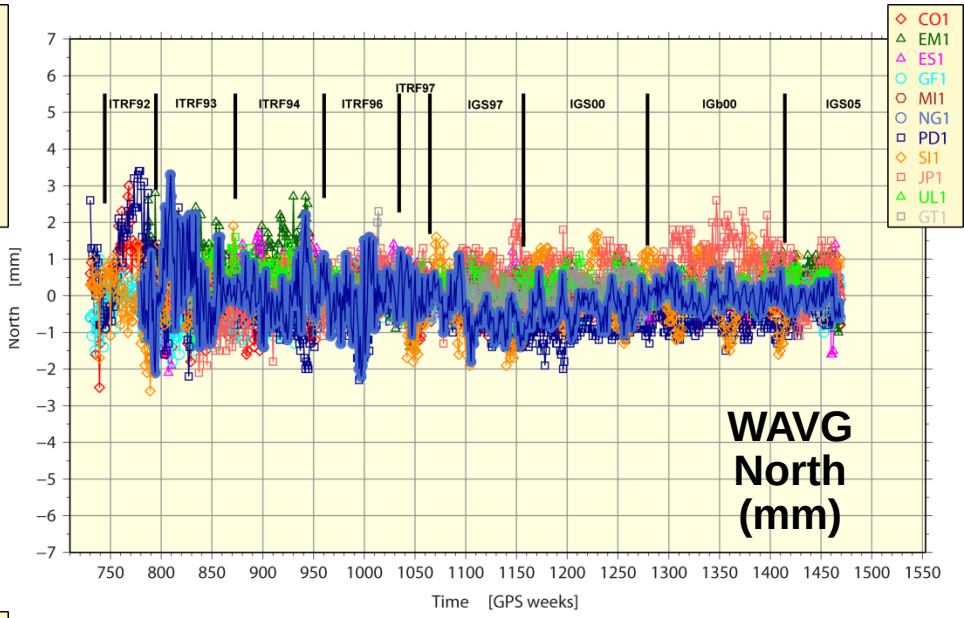
Quality of Orbits: WRMS of AC Orbits (w.r.t. IG1)

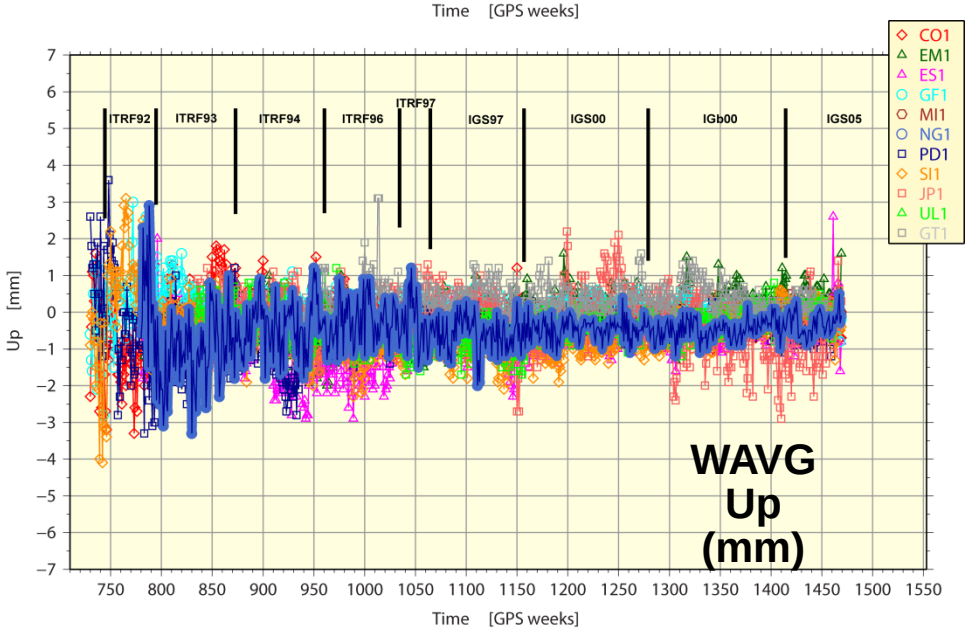


Courtesy: IGS Analysis Center Coordinator [2010]

Performance of NG1 w.r.t. IG1 Weekly Combination







- 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 necessary for aligning to ITRF in downstream processing
  - recall, GNSS part of ITRF2008 is the IG1 contribution

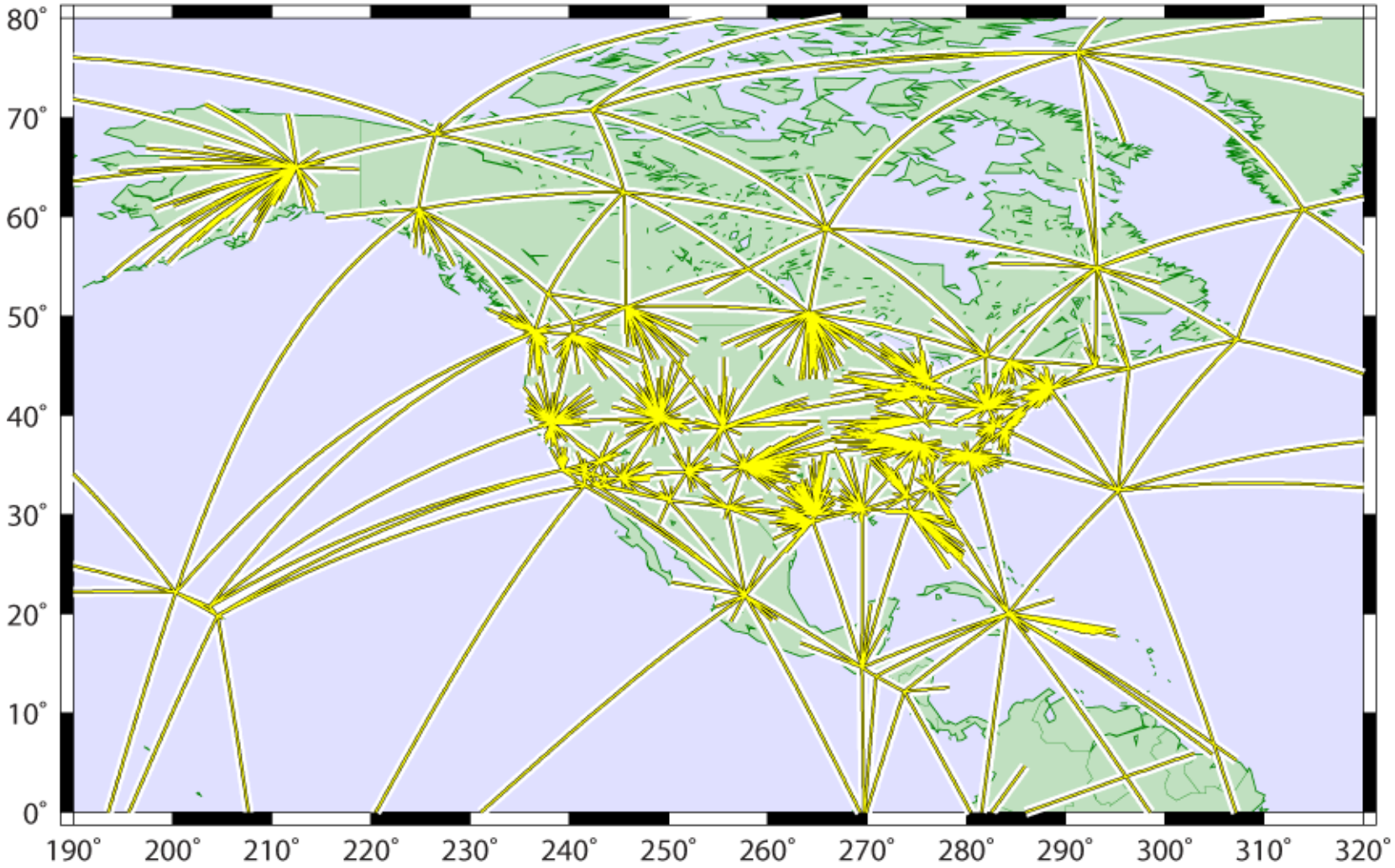
Courtesy: IGS Reference Frame Coordinator [2010]

How is Multi-year CORS Solution Obtained?

- CORS RINEX observations processed in global framework using NGS reprocessed orbits, EOPs and global station coordinates
- 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: attenuate aliasing effects caused by local non-linear motions
    - sub-network of ~90 sites chosen—optimal global distribution and long data span
    - 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: obtain MYCS—i.e., align "unbiased" stacked TRF to ITRF2008 via GPS sites common to both SNXs
    - scale is inherited from ITRF
  - overall stacking strategy follows one developed by X. Collilieux (IGN); more details of procedure at http://beta.ngs.noaa.gov/myear/
- in stacking, undocumented positional discontinuities are detected using SIGSEG [Vitti, 2009] and Change-point Analysis [Taylor, 2000]

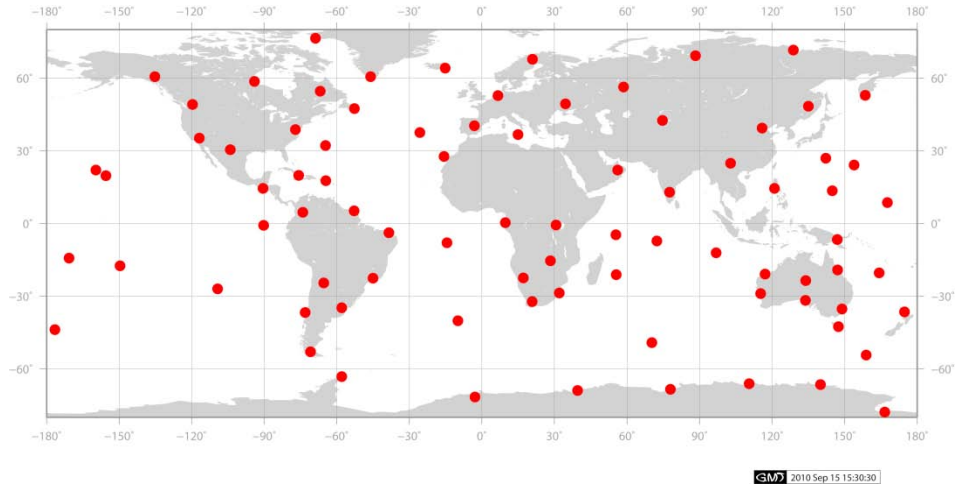
Design for tying CORS to Global Network

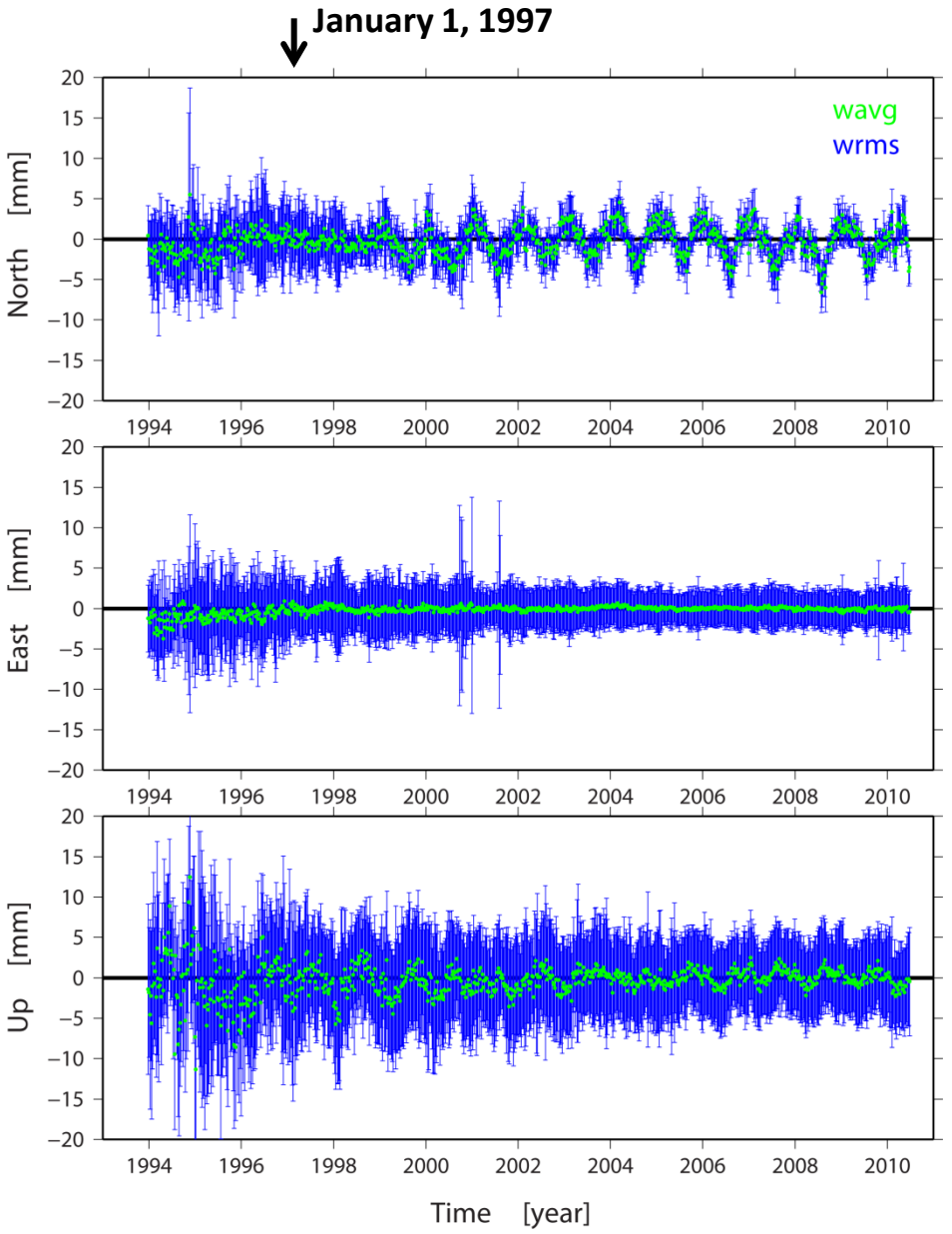
(>2200 sites in CORS+global network)



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 is less than optimal
  - signal in U may be masked by noise/error
- early years scattered
- long-term stability is quite good



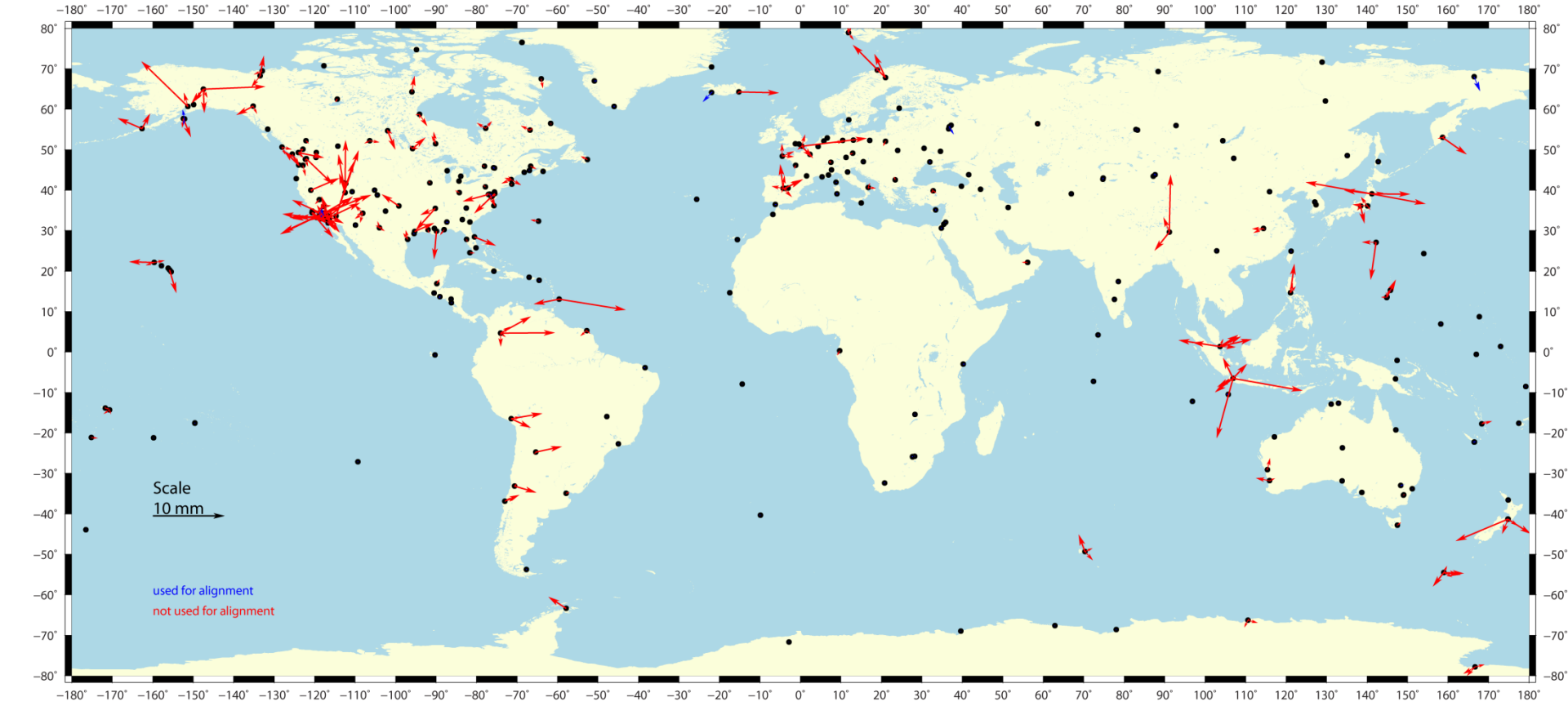


Alignment to ITRF2008: *Horizontal* Position Differences

ITRF2008 – MYCS_P @ 2005.0

- diffs due to additional discontinuities (incl. eqs) & longer data spans in MYCS_P
- diffs <1 cm shown below (all are insignificant at 2σ)
- sites not used in alignment (red arrows) have largest diffs
  - avg. diffs for sites used in alignment:

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



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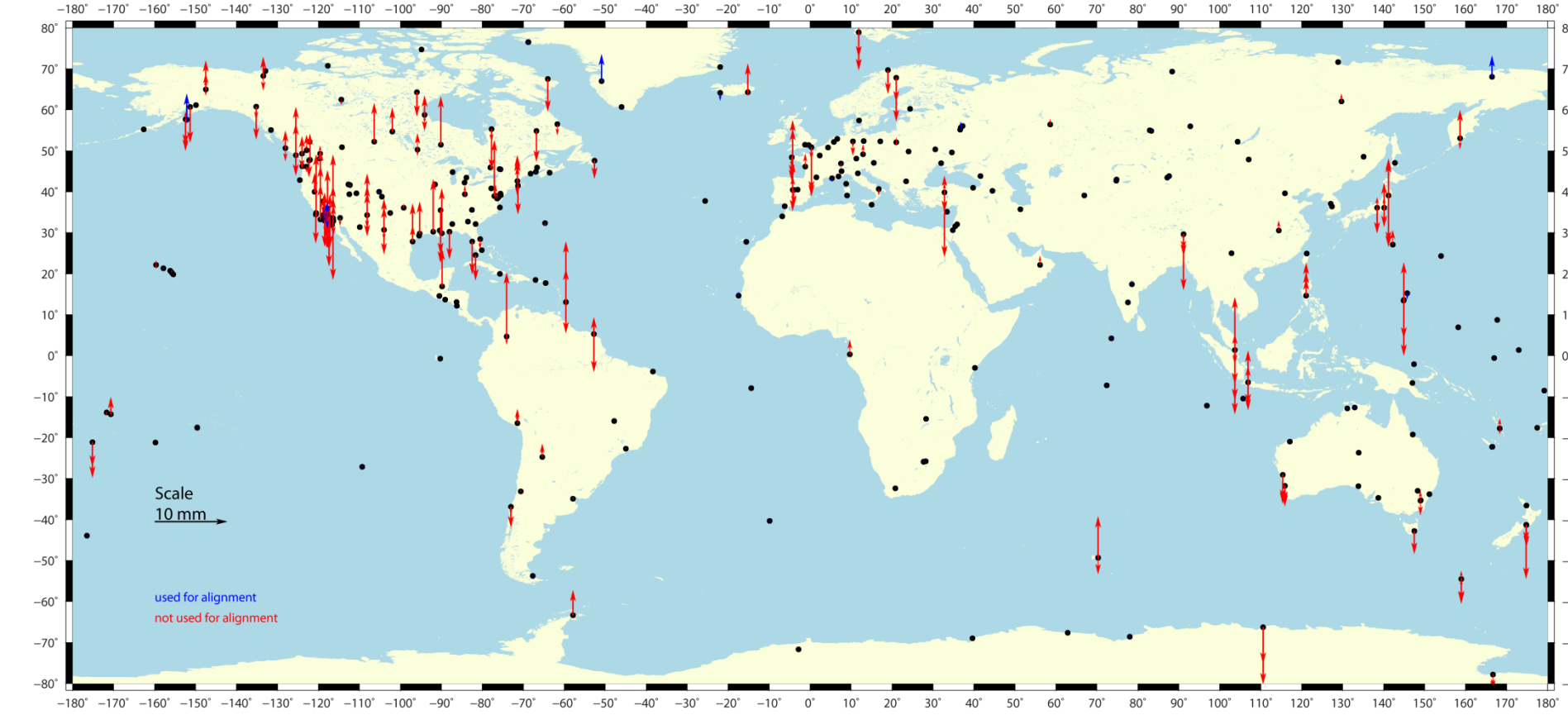
Alignment to ITRF2008: *Vertical* Position Differences

ITRF2008 – MYCS_P @ 2005.0

- similar story as for horizontal diffs
  - avg. diff for sites used in alignment:

$$\Delta U = 0.05\ (\pm 0.41)\ \text{mm}$$

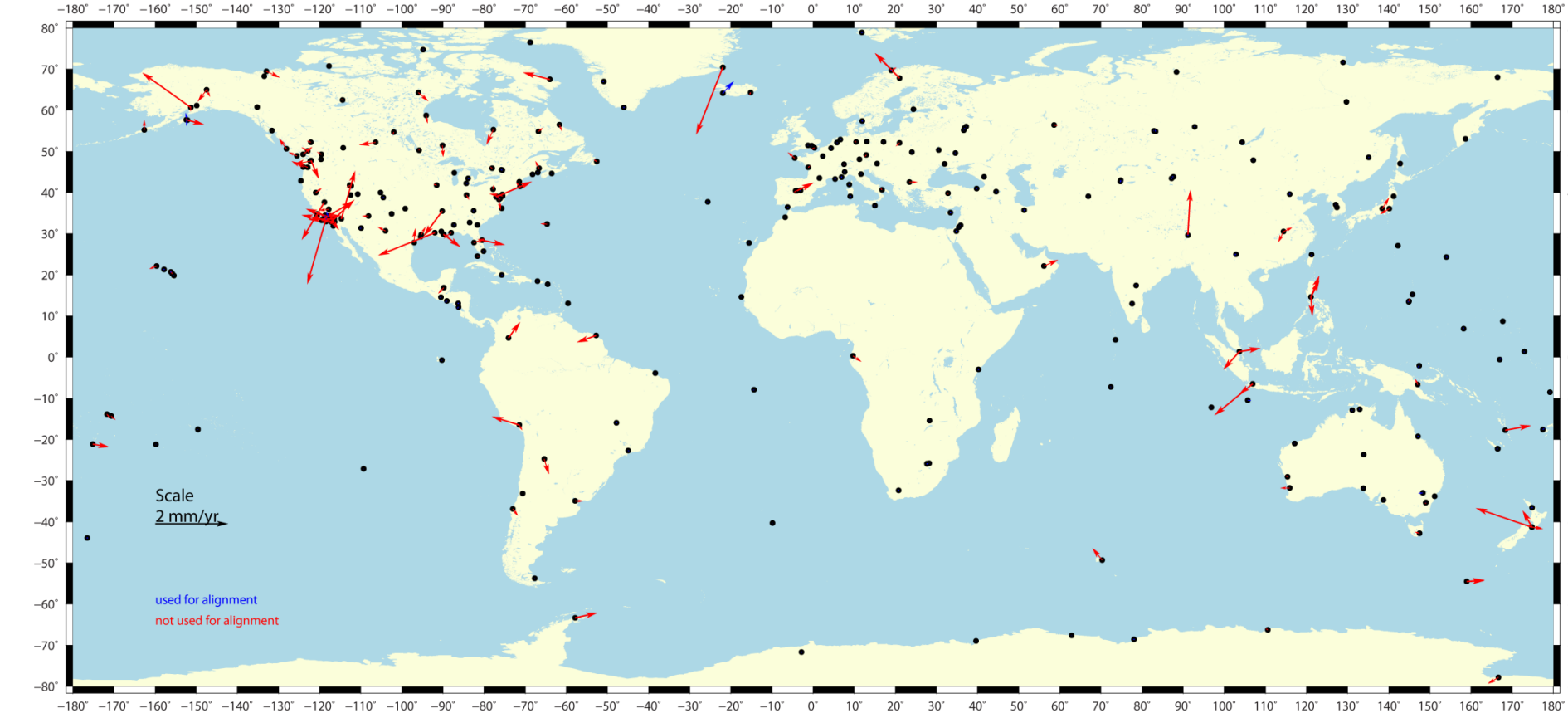


Alignment to ITRF2008: *Horizontal* Velocity Differences

ITRF2008 – MYCS_P @ 2005.0

- diffs < 2 mm/yr shown below
  - diffs < 2σ; alignment sites have small diffs
- diffs here from same effects as for position diffs
  - avg. diffs for sites used in alignment:

$\Delta Vn = 0.00 (\pm 0.03)$ mm/yr $\Delta Ve = 0.00 (\pm 0.03)$ mm/yr

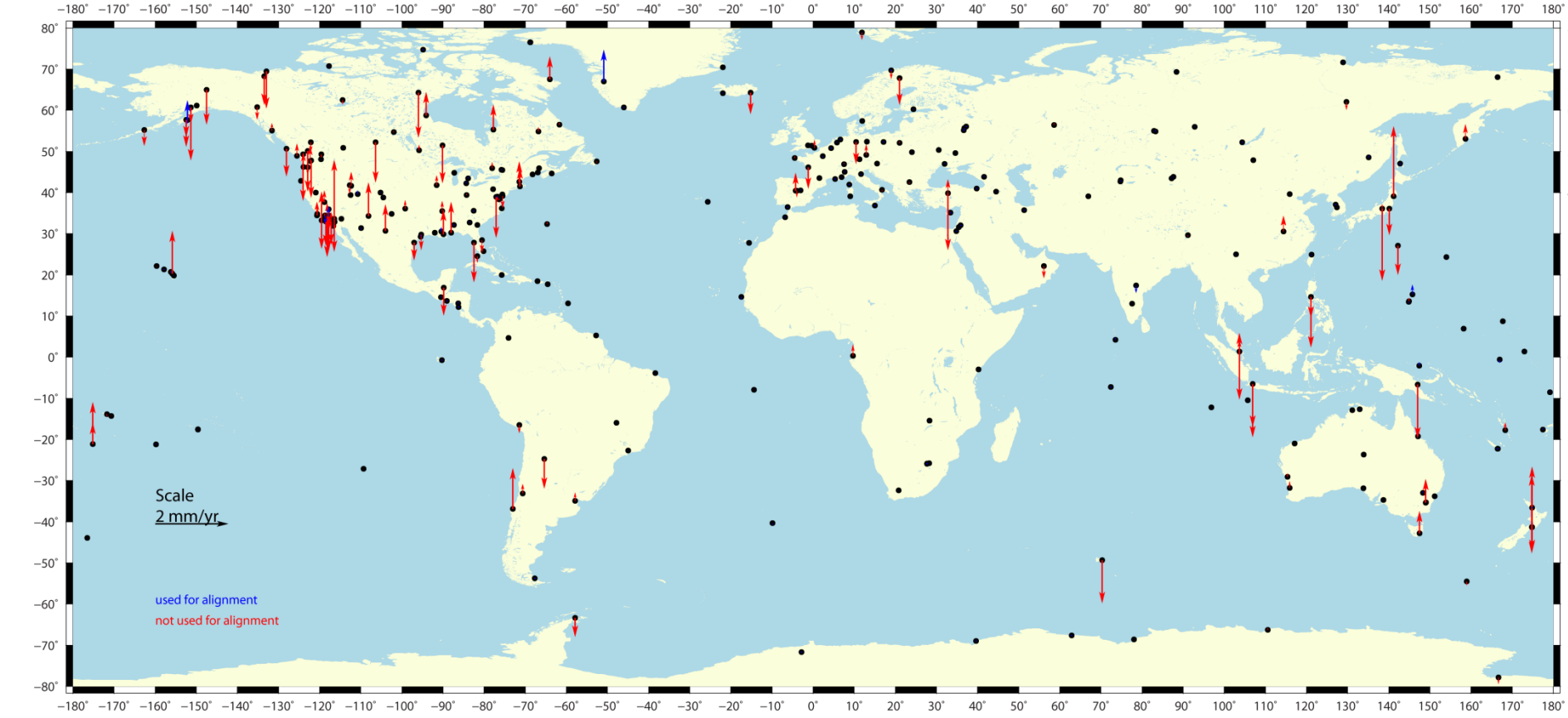


Alignment to ITRF2008: *Vertical* Velocity Differences

ITRF2008 – MYCS_P @ 2005.0

- similar story to horizontal diffs
  - avg. diff for sites used in alignment:

$$\Delta Vu = 0.01 (\pm 0.08) \text{ mm/yr}$$



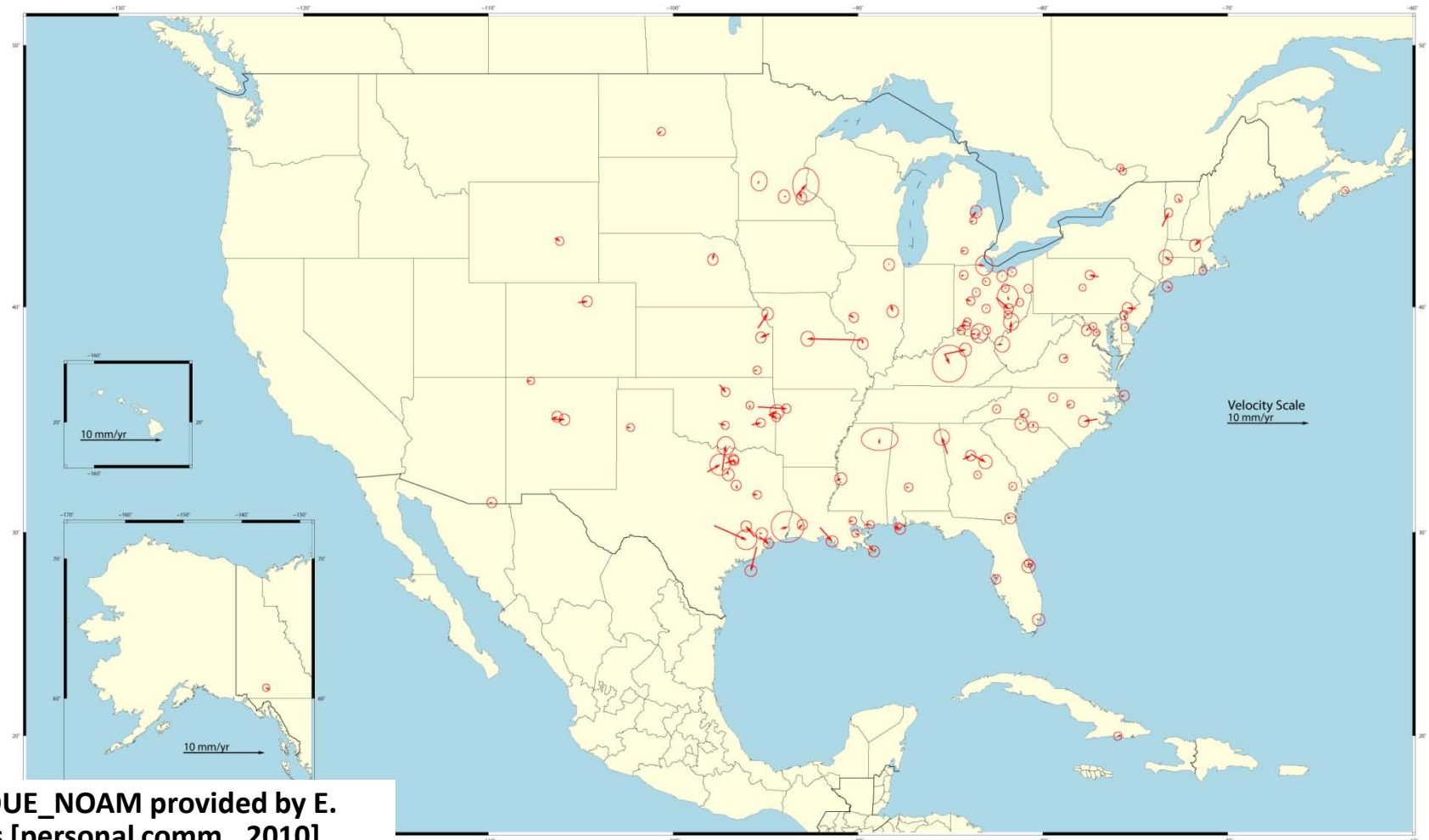
Summary of Alignment to ITRF

- approach used to attenuate aliasing effects in Helmerts works well
  - slight residual bias in N
  - may try to remove residual bias by de-weighting heights
  - overall stability is good
- small coordinate and velocity differences, esp. for alignment sites, show excellent agreement with ITRF2008
  - critical to accurately determining positions and velocities for CORS w.r.t. ITRF
- let us now examine what this means for CORS
  - example of how CORS are tied to global network
  - comparison w/ external estimates of velocities for selection of CORS
  - examine changes in NAD 83 positions

Comparison of MYCS_P *Horizontal* Velos w/ Others

MYCS_P – [PURDUE_NOAM]$_{\text{aligned to ITRF2008}}$ @ 2005.00

- most differences in horizontal << 5 mm/yr
- few sites have significant diffs—caused by different data spans

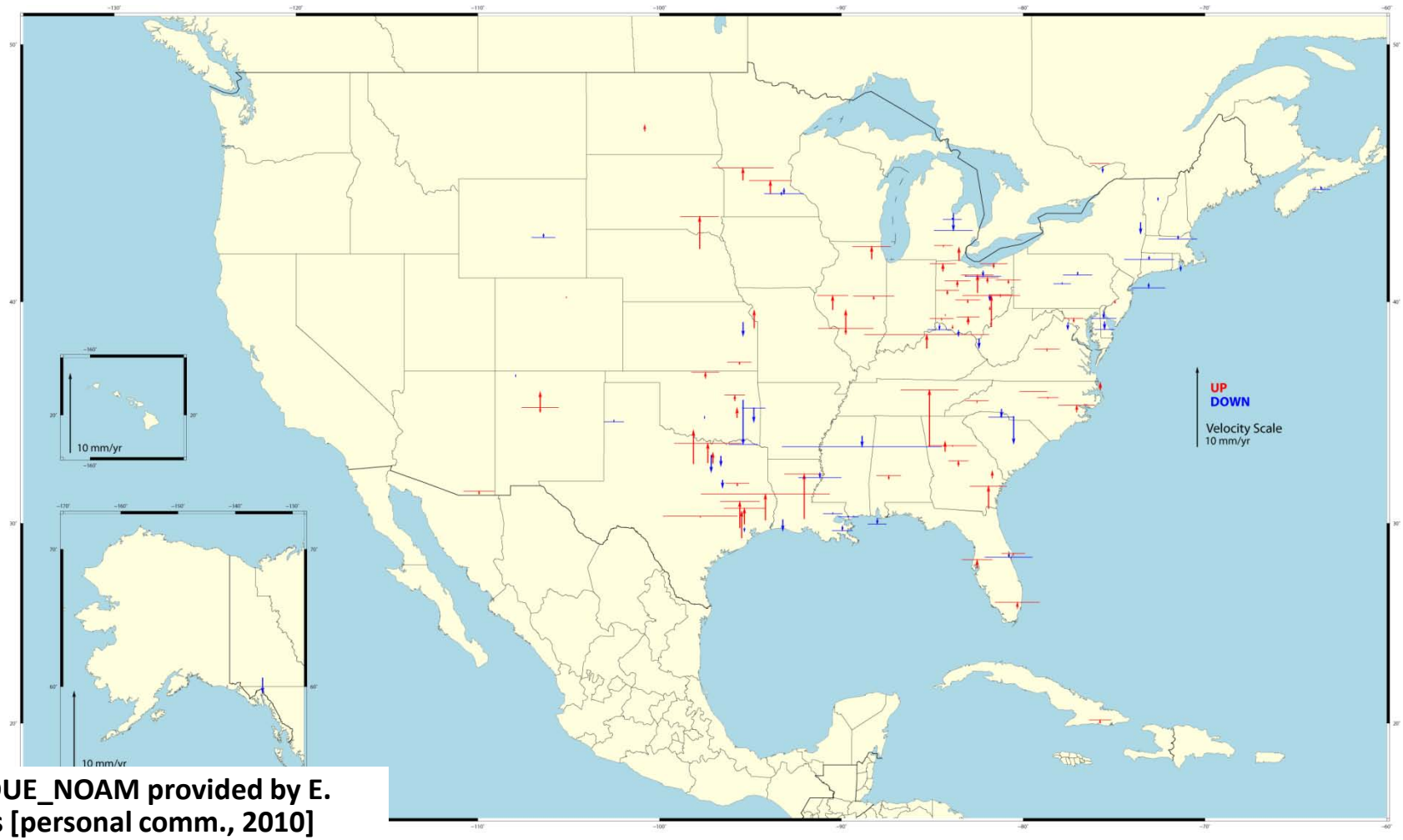


PURDUE_NOAM provided by E. Calais [personal comm., 2010]

Comparison of MYCS_P *Vertical* Velos w/ Others

MYCS_P – [PURDUE_NOAM]$_{\text{aligned to ITRF2008}}$ @ 2005.00

- most differences in vertical << 10 mm/yr
- NOTE: comparison with NRCan solution [M. Craymer] in Great Lakes region also shows small diffs

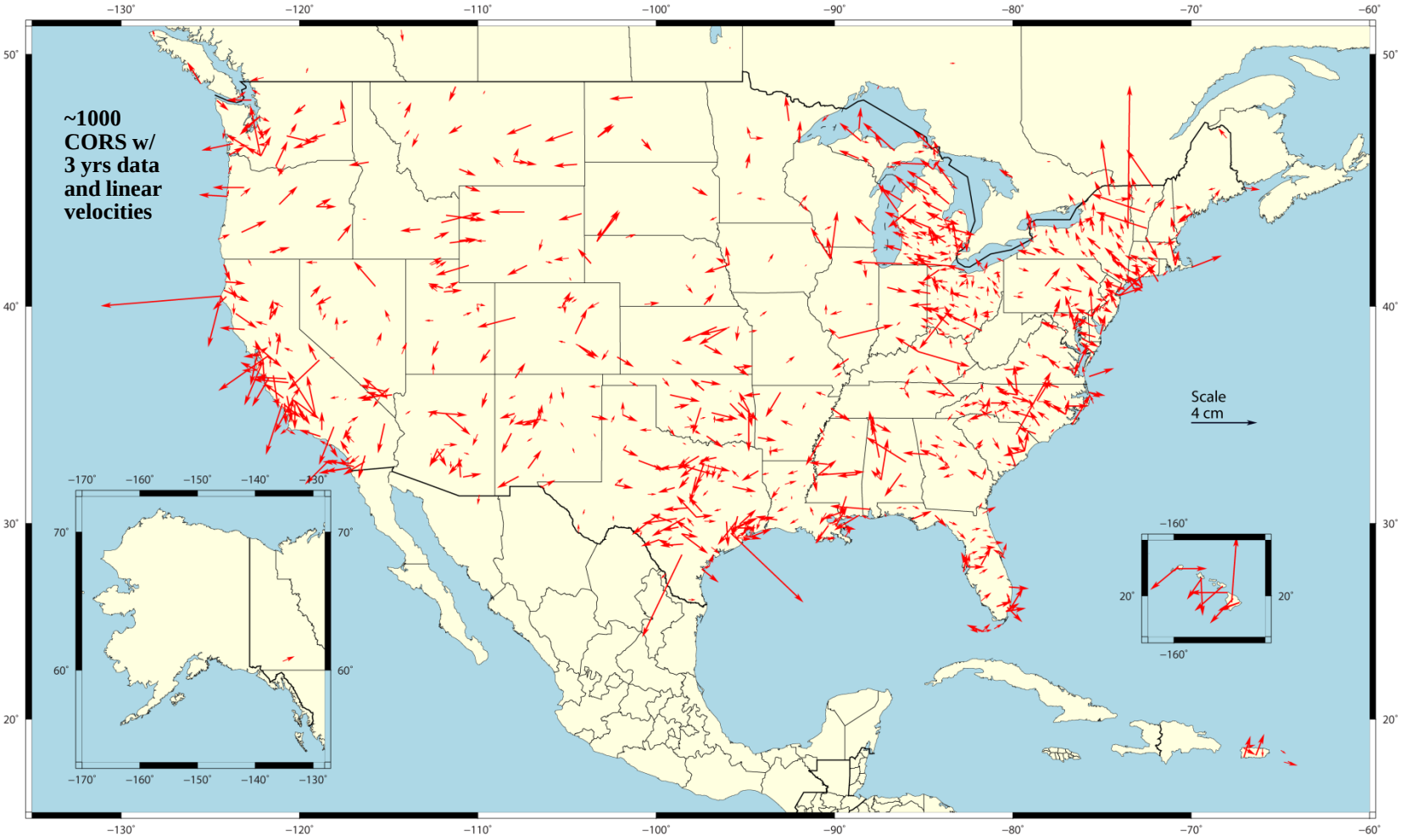


PURDUE_NOAM provided by E. Calais [personal comm., 2010]

Changes in *Horizontal* 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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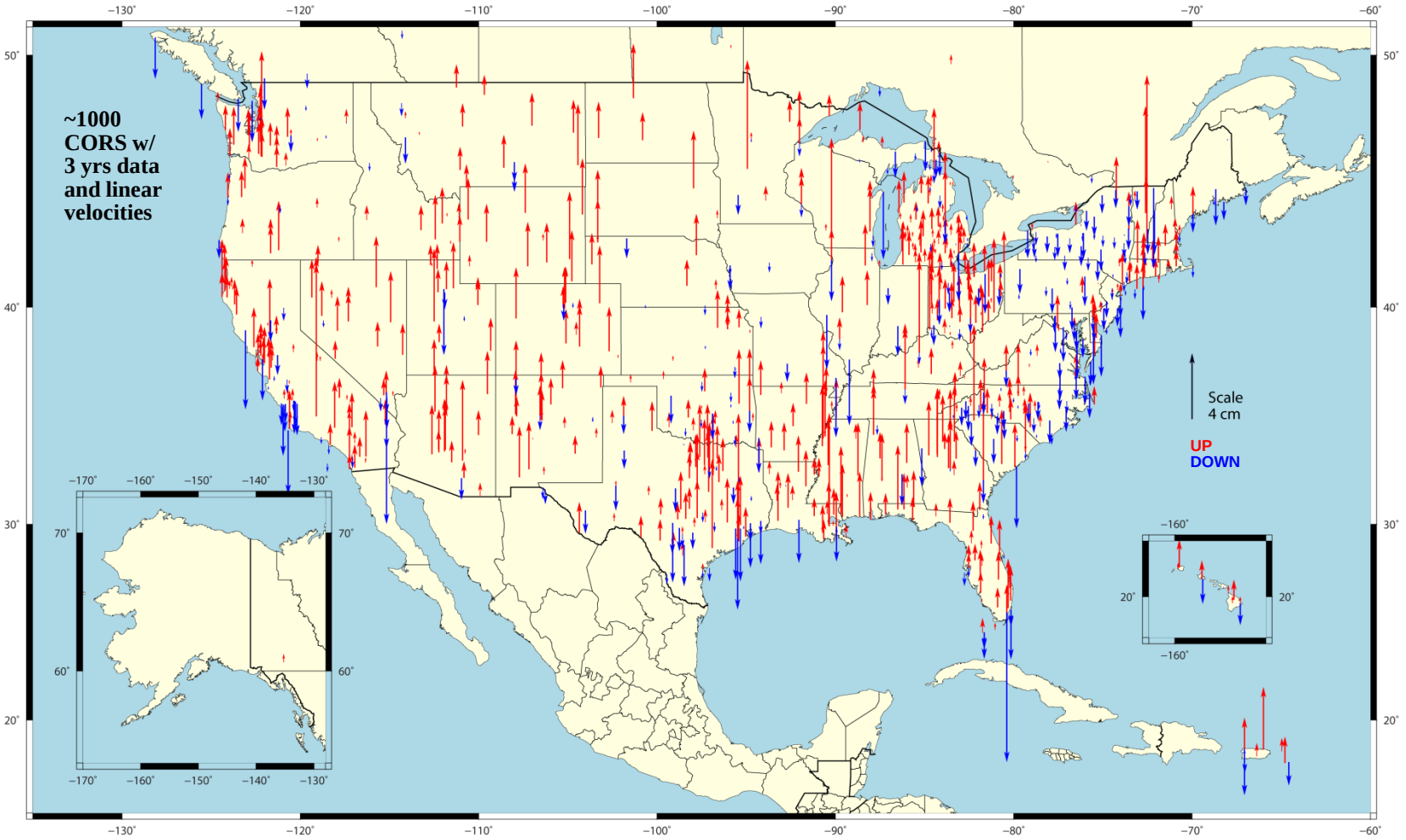
Changes in *Vertical* Positions

NAD 83 (CORS96A @ 2002.0) – NAD 83 (CORS96 @ 2002.0)

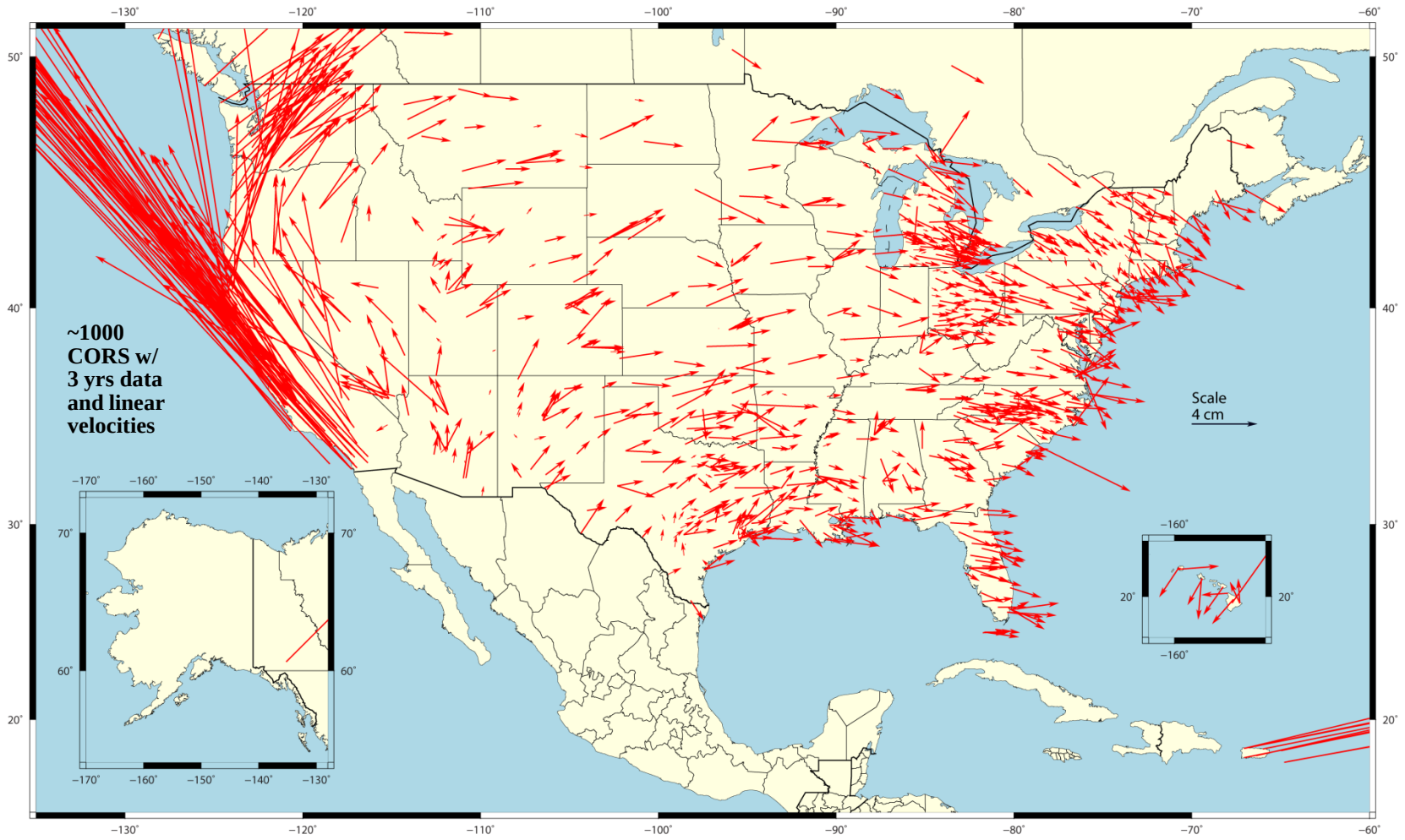
- **avg. vertical shift:** $\Delta U = 0.65$ cm ($\pm$ 2.08) cm
  - random part mostly caused by switch to absolute antenna calibrations
  - shifts also caused by assuming $V_u = 0$ in NAD 83(CORS96)



Shift in *Horizontal* Positions due to Change in Ref Epoch

NAD 83 (CORS96A @ 2010.0) – NAD 83 (CORS96 @ 2002.0)

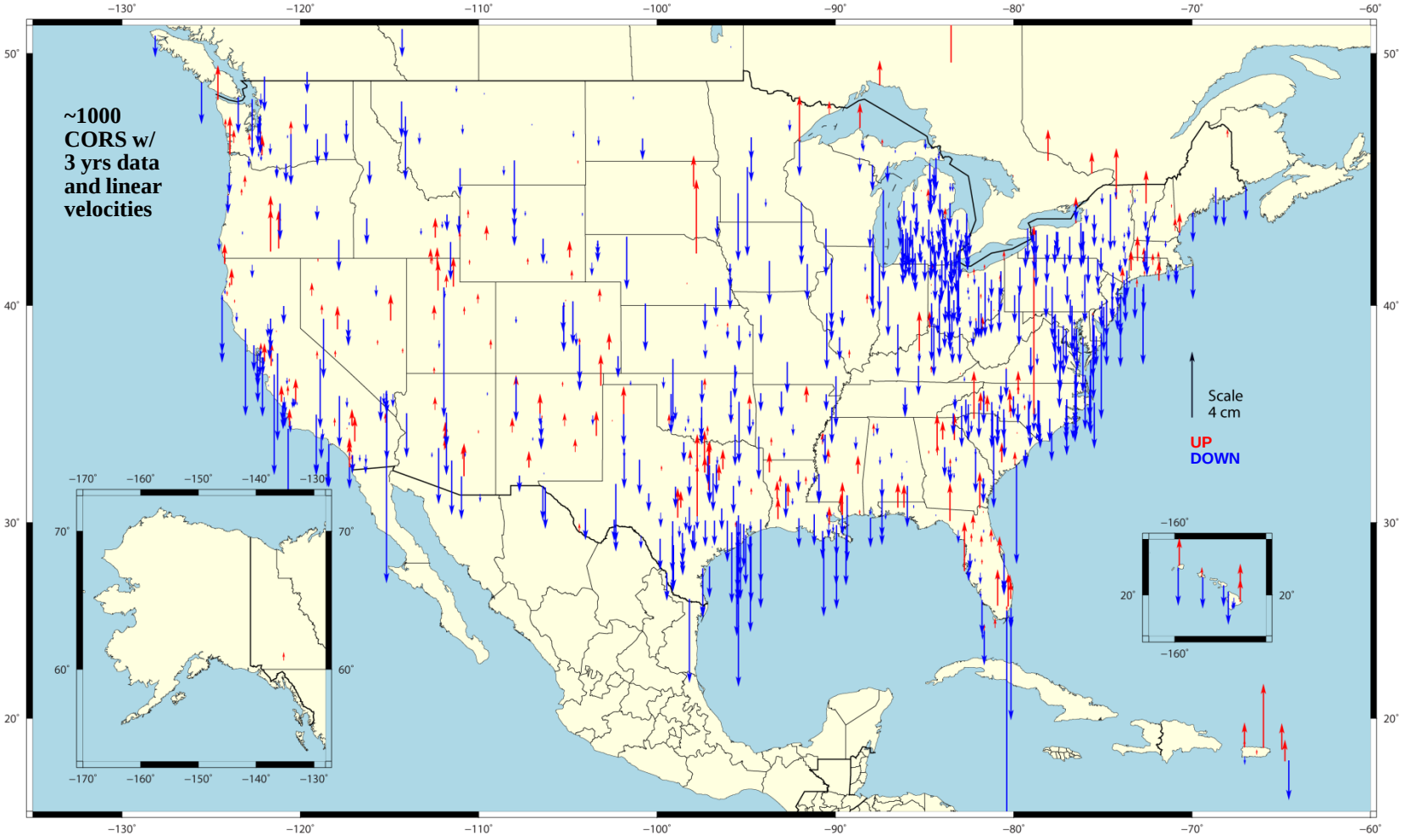
- **avg. shifts:** $\Delta E = 0.20 (\pm 5.85)$ cm; $\Delta N = 1.95 (\pm 6.42)$ cm
  - large shifts in western U.S. due to crustal deformation
  - apparent rotation in "stable" U.S. likely due to errors in NUVEL-1A (used in HTDP)



Shift in *Vertical* Positions due to Change in Ref Epoch

NAD 83 (CORS96A @ 2010.0) – NAD 83 (CORS96 @ 2002.0)

- **avg. shift:** $\Delta U = -0.92$ cm ($\pm$ 2.04) cm
  - switch to absolute antenna calibrations
  - much of eastern U.S. has downward velocities
  - effect of assuming $V_u = 0$ in NAD 83(CORS96), i.e. local vertical motion



Conclusions

- 1st reprocessing of global and CORS GPS data collected since 1994 is complete
- overall excellent alignment to ITRF2008
  - large differences at individual sites caused by earthquakes, longer data spans and different discontinuities
- comparisons for a selection of CORS sites from solutions derived by others show reasonable agreement
  - best effort to help ensure that the MYCS_P is a reasonable solution for CORS
- centimeter-level coordinate changes
  - $\Delta E \approx -0.17 (\pm 1.86)$ cm
  - $\Delta N \approx 0.20 (\pm 2.31)$ cm
  - $\Delta U \approx 0.65$ cm (± 2.08) cm
- Reminder: reference epoch for new realization is 2010.00
  - origin, scale and coordinate axes of NAD 83 (CORS96A) coincide with those of NAD 83 (CORS96)
  - apply CORS96A velocities to compare positions with those of NAD 83 (CORS96)
- users must prepare for change from relative to absolute antenna calibrations, which causes site-specific position changes up to a few cm
- beta testing of MYCS_P expected to begin early October 2010
- NGSTRF08/NAD 83(CORS96A) expected to be complete by early 2011