DEPENDENCE OF IGS PRODUCTS ON THE ITRF DATUM

- IGS use of ITRF datum
  - historic & recent
- Special reliance on ITRF scale
  - fixed TRF scale used to estimate satellite antenna offsets
  - problem is non-linear but hopefully convergent over time
- Recommendations for future ITRF realizations

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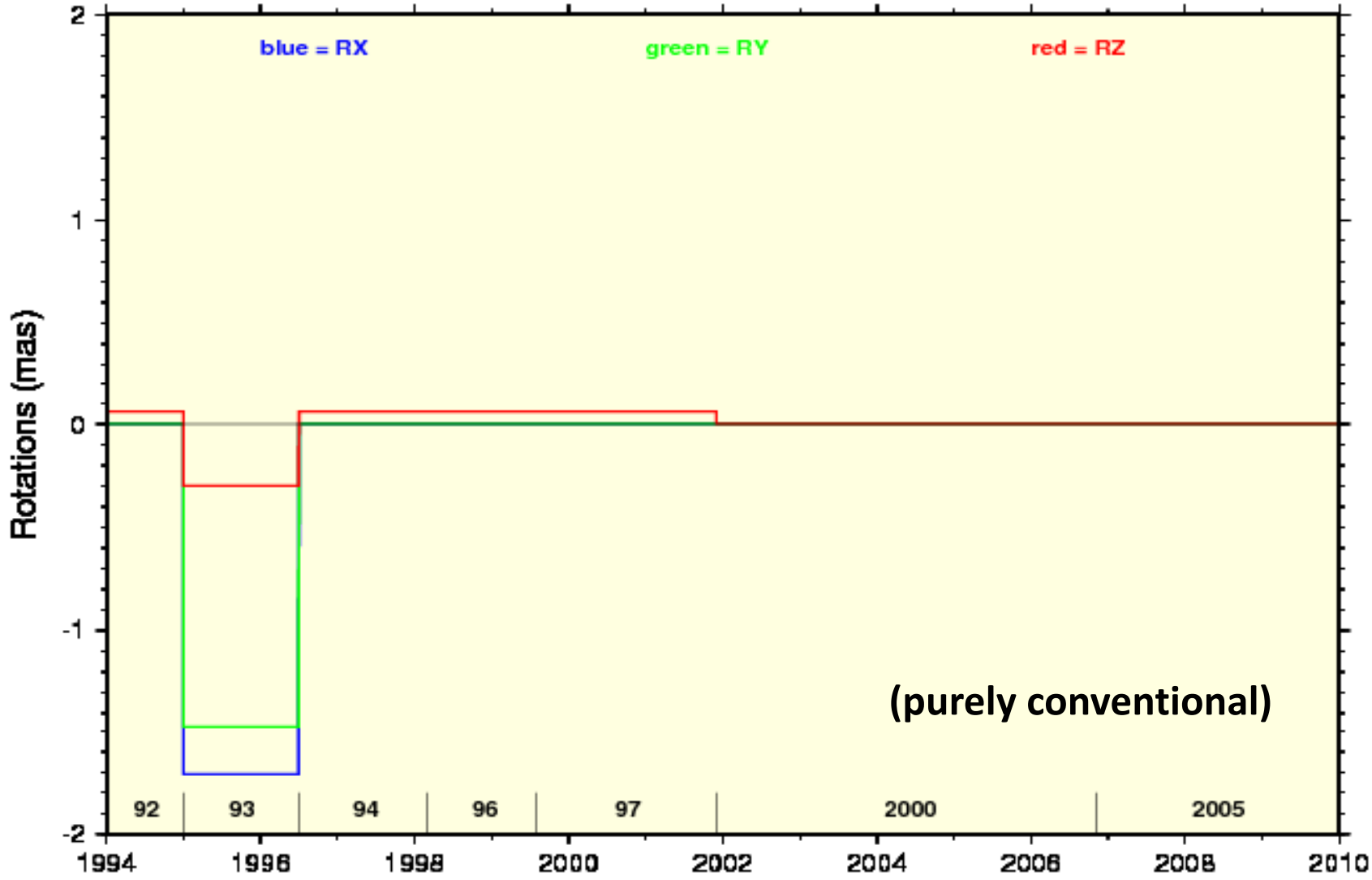
IGS Aligns to IERS Reference Systems

- Over its history (~17 years) IGS has tried to adopt IERS references
  - IERS Conventions are implemented (mostly)
  - successive ITRFxx datums have been adopted
  - but in recent years, GPS-based realizations of ITRF (e.g., IGS05) preferred for highest internal consistency
  - UT1 reference is fixed (but propagated to EOP epoch via IGS LODs)

- But there have been difficulties
  - datum shifts in ITRFxx updates have been disruptive for users
  - rotations applied to ITRF93 were a big problem
  - scale variations have become leading problem lately

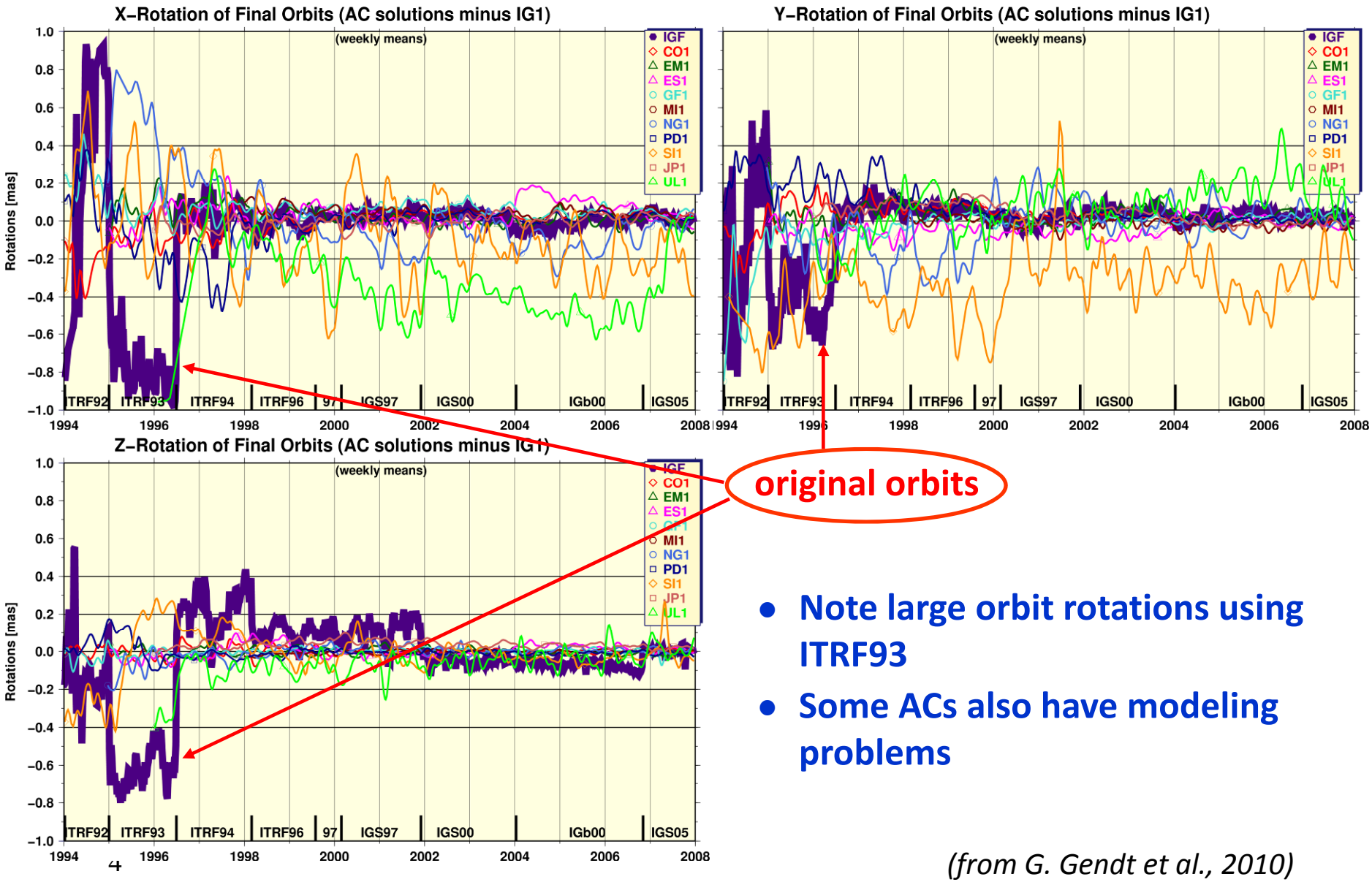
- And IERS EOPs found to be too inaccurate
  - IERS polar motion & UT1 were overly smoothed in mid-1990s
  - current IERS UT1 values are noisy at short periods
  - IGS adopted its own observed pole in 1995

ITRFxx Rotations wrt ITRF2008 (@ 2000.0)



- ITRF orientation has been stable except during ITRF93
  - caused direct impact on IGS orbits (next slide)

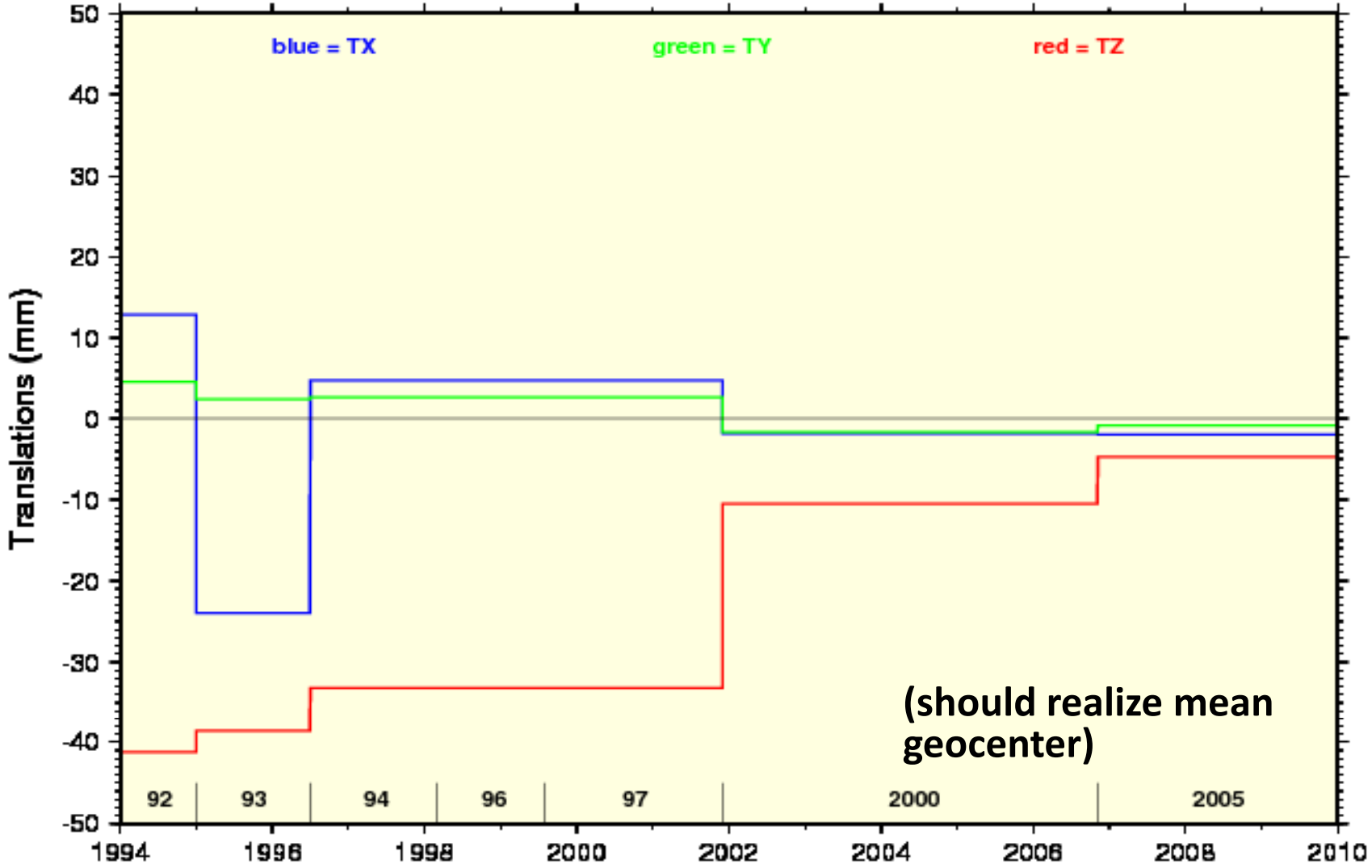
Orbit Rotations wrt IGS Reprocessed



- Note large orbit rotations using ITRF93
- Some ACs also have modeling problems

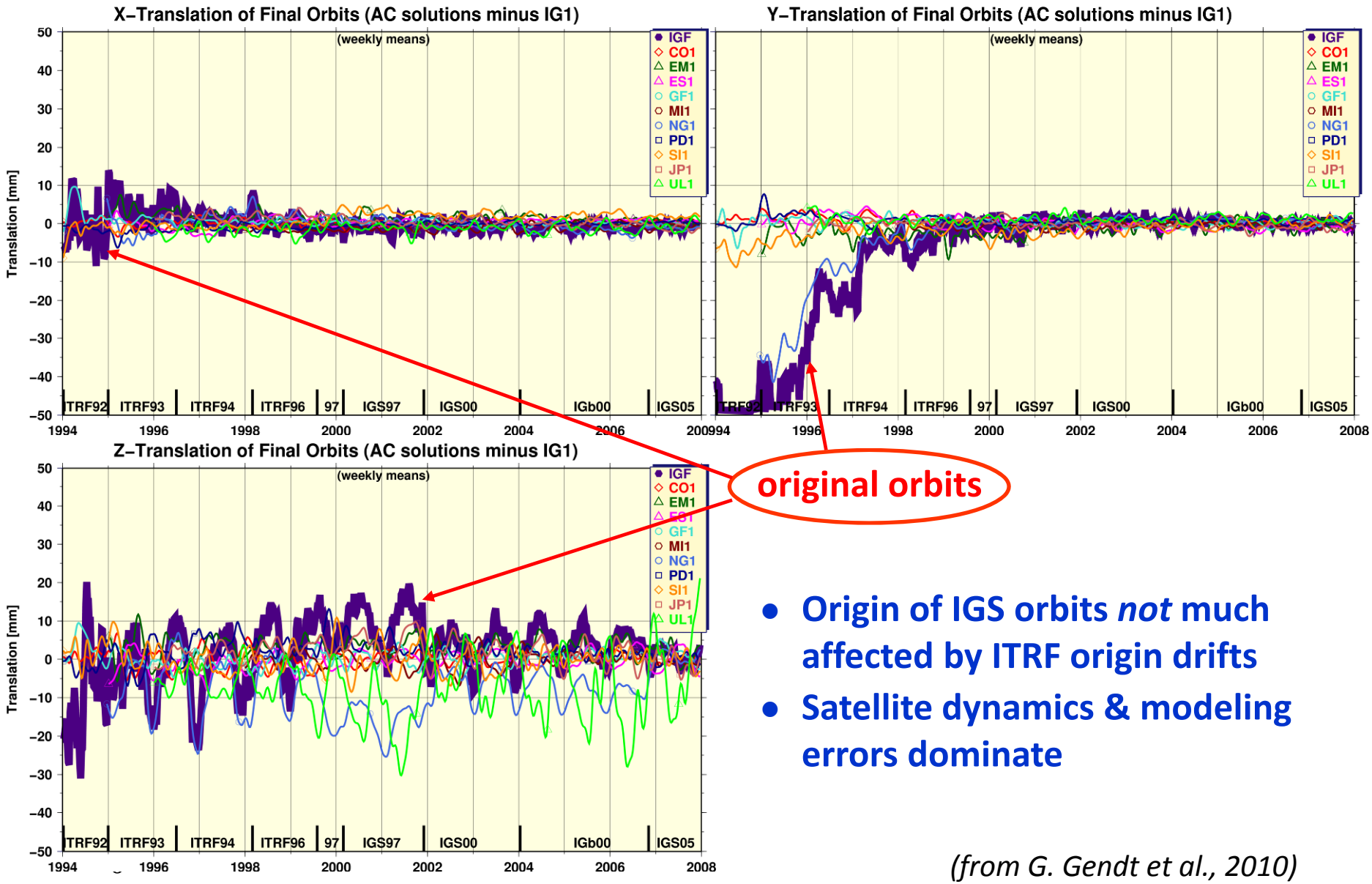
(from G. Gendt et al., 2010)

ITRFxx Translations wrt ITRF2008 (@ 2000.0)



- **Large drifts in ITRF origin, esp along Z axis**
  - **but these have not impacted IGS orbits much (next slide)**

Orbit Translations wrt IGS Reprocessed



- Origin of IGS orbits *not* much affected by ITRF origin drifts
- Satellite dynamics & modeling errors dominate

(from G. Gendt et al., 2010)

ITRF Scale Especially Important for IGS

- **Since 2006 IGS estimates satellite antenna phase center offsets (PCOs)**
  - **but GPS data only weakly sensitive to PCO errors:**

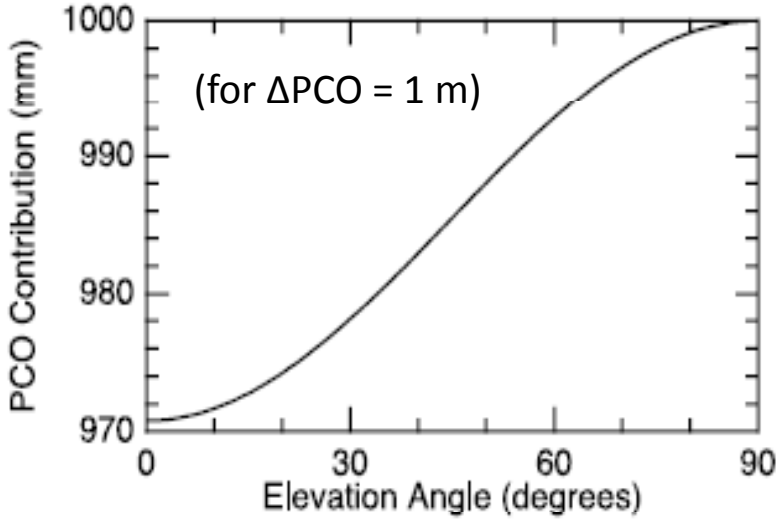
    $\Delta\rho = -\Delta PCO\,(0.94 + 0.06 \sin^2 e)^{1/2}$

  - **and highly correlated with station heights:**

    $\Delta H \sim \sin e$

  - **as well as with zenith troposphere delays:**

    $\Delta ZTD \sim 1/\sin e$ where e = elevation angle

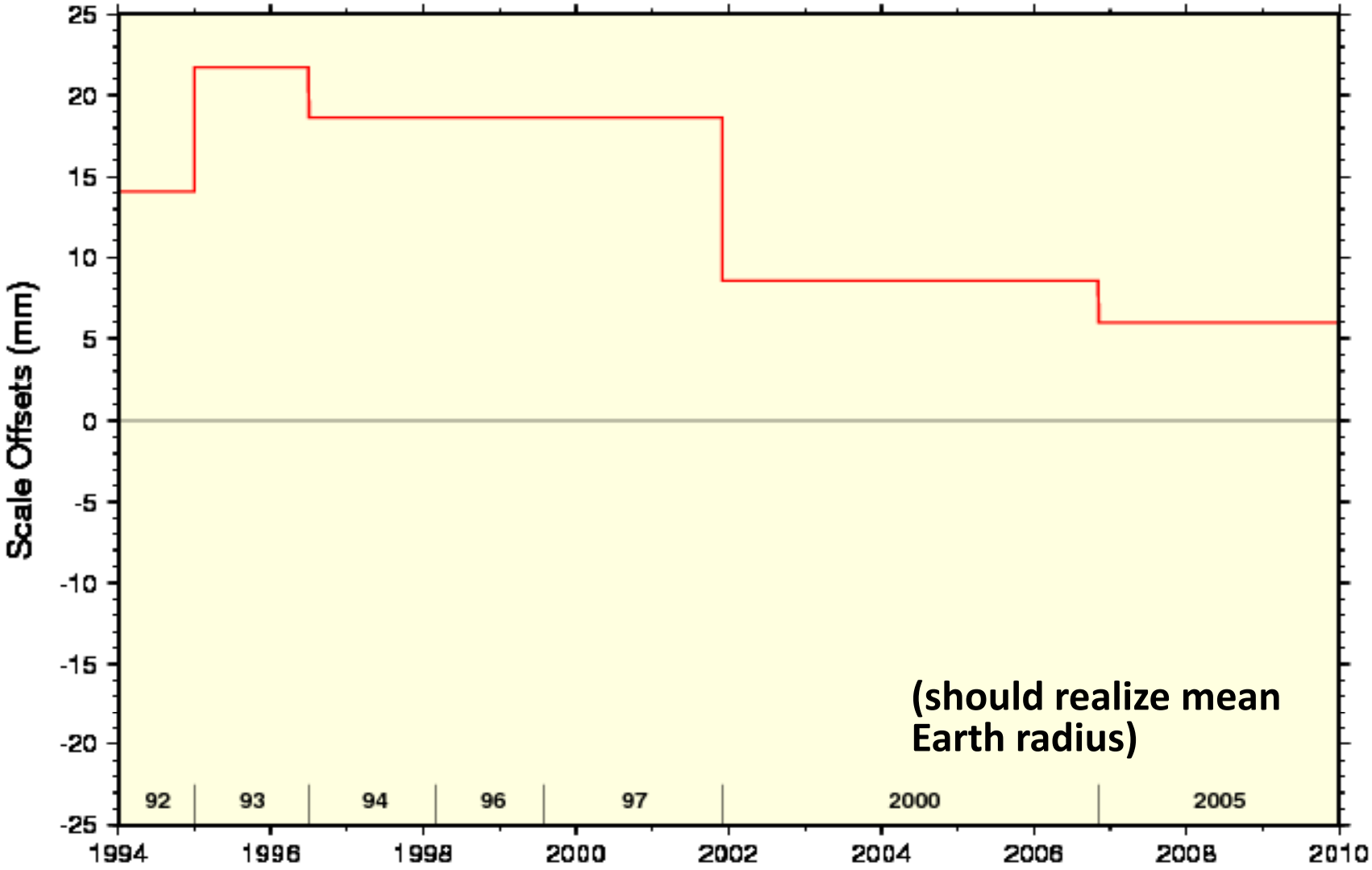


(from E. Cardellach et al., 2007)

- **So it is necessary to fix the ITRF scale (i.e., net station heights) to solve for satellite PCOs**

  $\langle \Delta PCO \rangle\,[mm] = -20 \cdot \Delta s\,[mm]$

ITRFxx Scales wrt ITRF2008 (@ 2000.0)



- **ITRF scale has drifted significantly over time**
  - **current uncertainty ~8 mm (1.2 ppb) ⇒ PCO uncertainty ~16 cm**

Maintenance of PCOs is Iterative Process

- IGSxx frame + igsxx.atx (PCOs + PCVs) ⇒ inputs for next ITRFyy
  - IGSxx frame & igsxx.atx calibrations must be self-consistent
  - applied in reprocessing of old data for IGS inputs to next ITRFyy

- Any shift in ITRFyy scale ⇒ new satellite PCOs & igsyy.atx
  - back-solve reprocessed IGS solutions for new consistent satellite PCOs
  - updated ground calibrations only allowed with major *.atx revisions
  - but new igsyy.atx then no longer fully consistent with ITRFyy

- Consistency is restored by computing ITRFyy station position corrections due to revised *.atx values
  - ITRFyy + atx corrections ⇒ IGSyy frame (aligned to ITRFyy)

- IGS then adopts IGSyy frame + igsyy.atx
  - but no longer consistent with last reprocessing

- *Process will converge only if ITRF datum gets more stable*

Competing ITRF Combination Strategies

- **Differences between IGN & DGFI strategies should be resolved**
  - **ITRF2005 dilemma repeated 5 years later with no clear progress**
  - **reflects badly on all contributing organizations & undermines confidence in ITRF as an international standard**

- **IGN procedure:**
  - **stack each technique independently in time ⇒ TRFs(X, V) + EOPs(t)**
  - **combine 4 technique solutions with local ties ⇒ ITRF**

- **DGFI procedure:**
  - **solve all technique normal eqns with ties simultaneously**
  - **assume VLBI & SLR have same intrinsic scales**

- **Both assume linear site motions & least squares**

- **Relative performance differences depend on actual VLBI/SLR scale equality & linearity of long-term site motions wrt PM, local ties & reweighting errors**

Polar Motion Correlations wrt AAM+OAM

- Compare combination PM excitation with *independent* AAM+OAM (over 27 Feb. 1997 – 26 Dec. 2008)
  - following results from J. Kouba (2010)
  - provides very sensitive test of relative performance
  - differences of ~0.006 are significant at 95% level

- IGN & IGS results very similar & correlate better with AAM+OAM
  - high-frequency correlations significantly lower for DGFI

(from J. Kouba, 2010)

PM Excitation Correlations wrt AAM+OAM

Intervals	Chi_2 (PM-xrate)			Chi_1 (PM-yrate)		
	IG1	IGN	DGFI	IG1	IGN	DGFI
all	0.904	0.904	0.902	0.769	0.769	0.765
30 d	0.892	0.892	0.888	0.858	0.858	0.852
5 d	0.785	0.785	0.775	0.732	0.732	0.719
3 d	0.703	0.700	0.687	0.634	0.634	0.616

Polar Motion Residuals wrt AAM+OAM

- PM excitation residuals wrt AAM+OAM smallest for IG1 & IGN solutions
  - larger DGFI residuals correspond to 37 µas/d more high-frequency noise

- Probable weaknesses in DGFI approach are:
  - assumption of equivalent VLBI & SLR scales
  - sub-optimal relative weighting of techniques over time
  - sub-optimal weighting of local ties
  - greater sensitivity to poorer geometry of VLBI & SLR networks over time

(from J. Kouba, 2010)

(PM Excitation - AAM+OAM) Residuals

(mas/d)	Chi_2 (PM-xrate)			Chi_1 (PM-yrate)		
	IG1	IGN	DGFI	IG1	IGN	DGFI
all	0.270	0.270	0.273	0.255	0.254	0.257
<6 d	0.162	0.162	0.173	0.139	0.139	0.148
<3 d	0.111	0.111	0.122	0.106	0.106	0.112

Recommendations

- **Stability of ITRF datum critical for IGS**
  - orientation & scale are most important for product continuity
- **Considering ~1 ppb accuracy of present scale, IGS asks that future ITRF scale be conventionally fixed to ITRF2008**
  - neither VLBI or SLR scales likely to improve much in near term
  - therefore no benefit for users to see scale jumps with each update
  - if not, IGS will adopt ITRF2008 scale internally
- **IERS procedures for handling ITRF updates must be improved**
  - clear, respected schedules should be agreed
  - combination methodologies must be objectively & efficiently evaluated
  - aim for next ITRF realization in ~2013
- **Improvements in ITRF datum stability needed**
  - focussed research efforts should be organized by techniques & IERS