

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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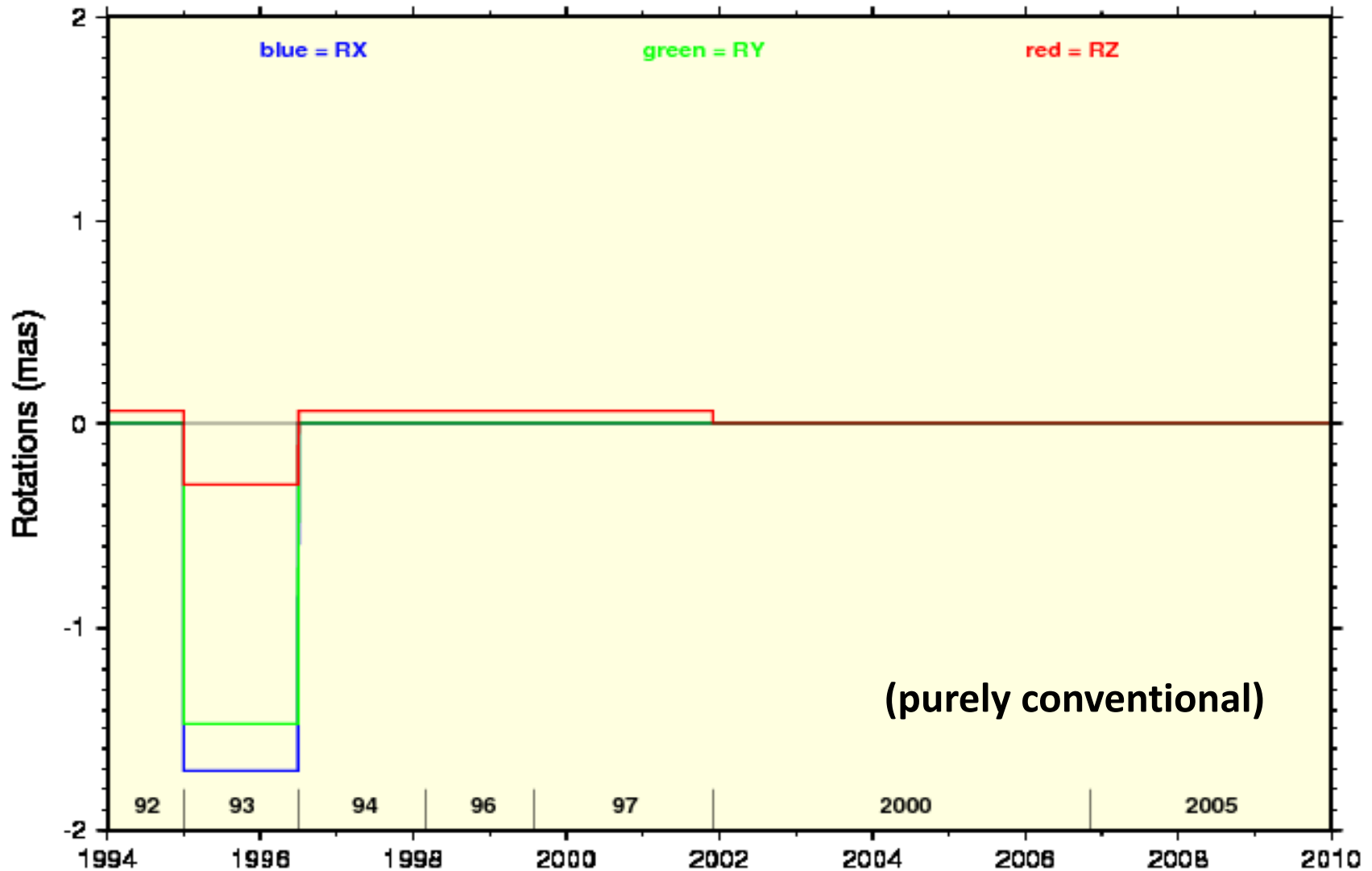
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IGS Aligns to IERS Reference Systems

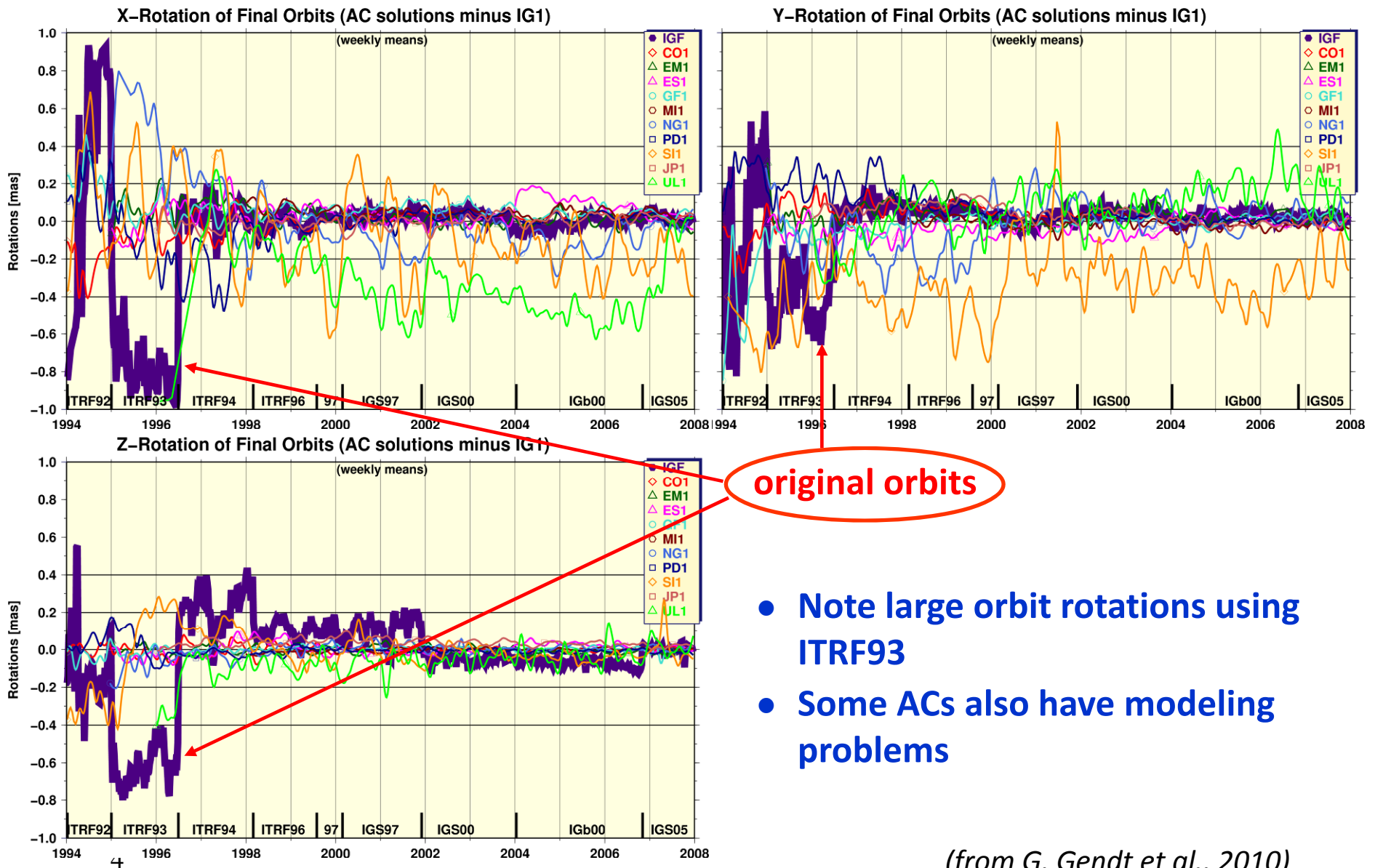
- Over its history (~17 years) IGS has tried to adopt IERS references
 - IERS Conventions are implemented (mostly)
 - successive ITRFxx datums have been adopted
 - but in recent years, GPS-based realizations of ITRF (e.g., IGS05) preferred for highest internal consistency
 - UT1 reference is fixed (but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



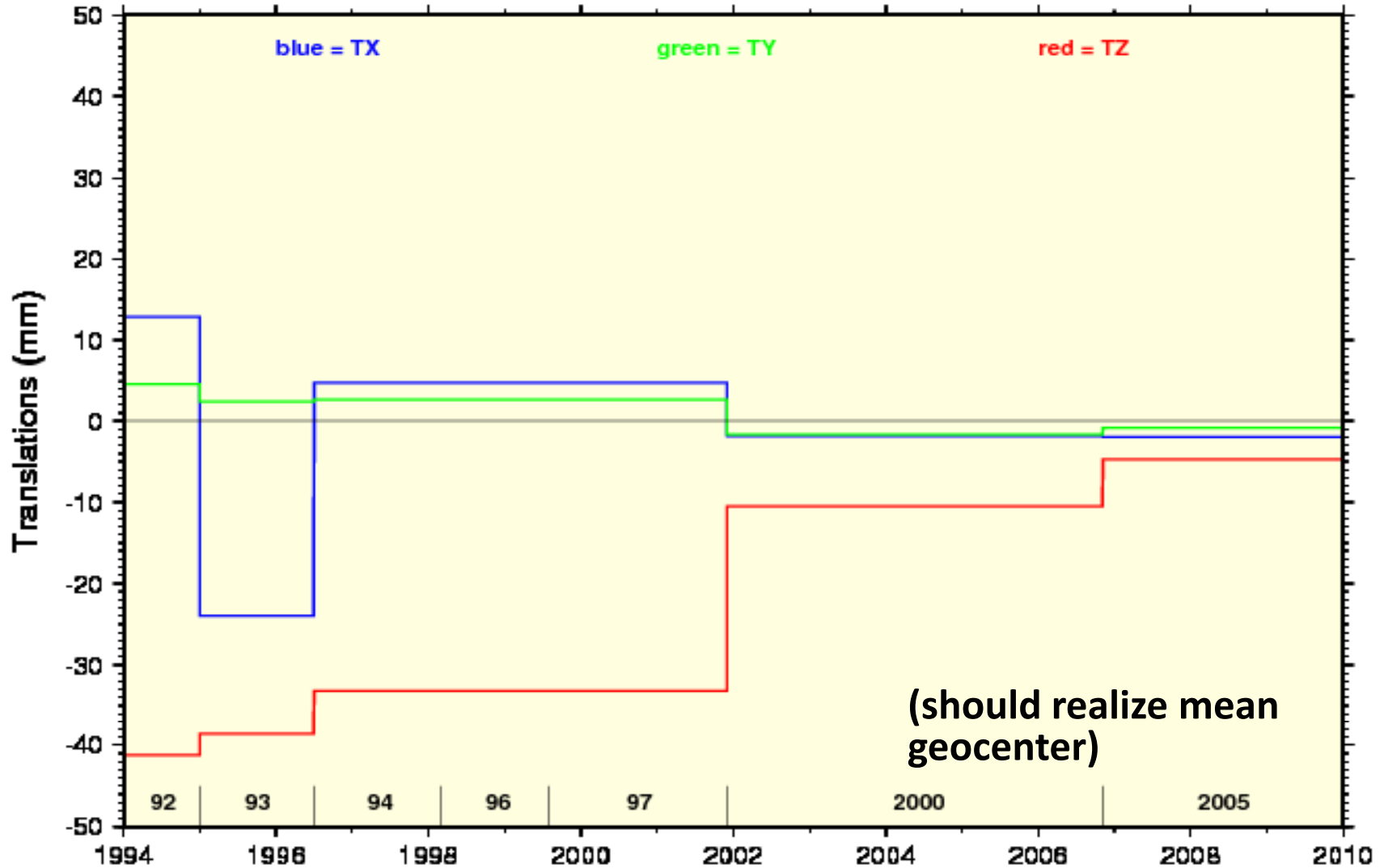
- ITRF orientation has been stable except during ITRF93
 - caused direct impact on IGS orbits (next slide)

Orbit Rotations wrt IGS Reprocessed



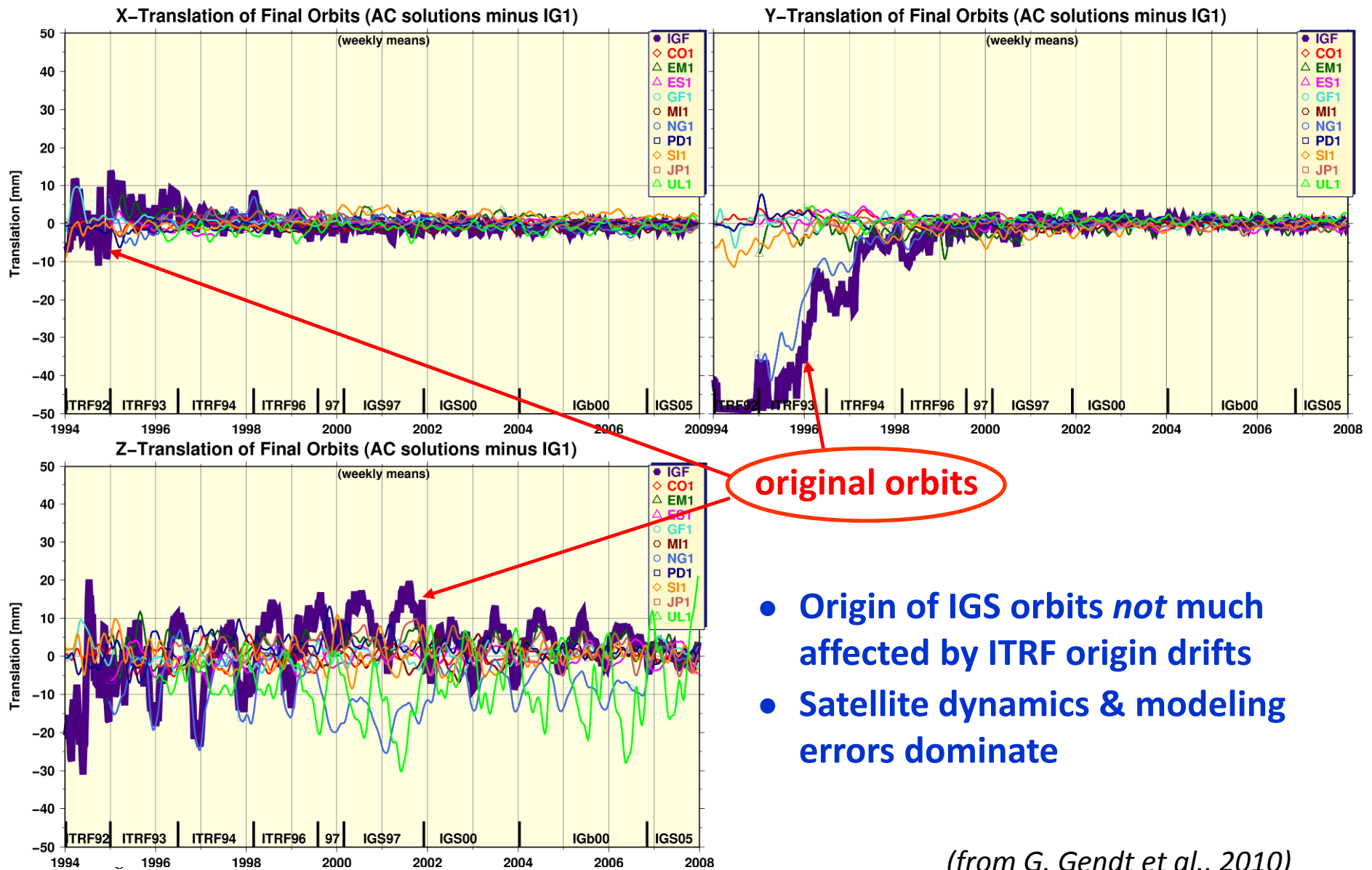
(from G. Gendt et al., 2010)

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



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:

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

- and highly correlated with station heights:

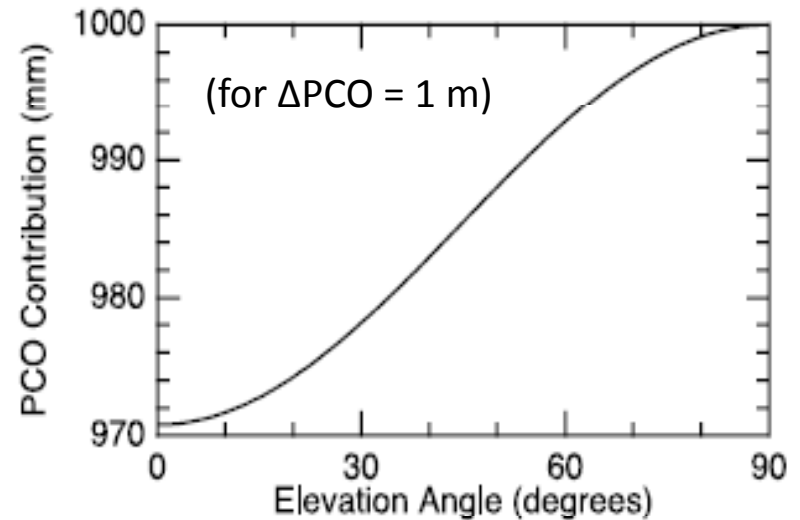
$$\Delta H \sim \sin e$$

- as well as with zenith troposphere delays:

$$\Delta\text{ZTD} \sim \frac{1}{\sin e} \quad \text{where } e = \text{elevation angle}$$

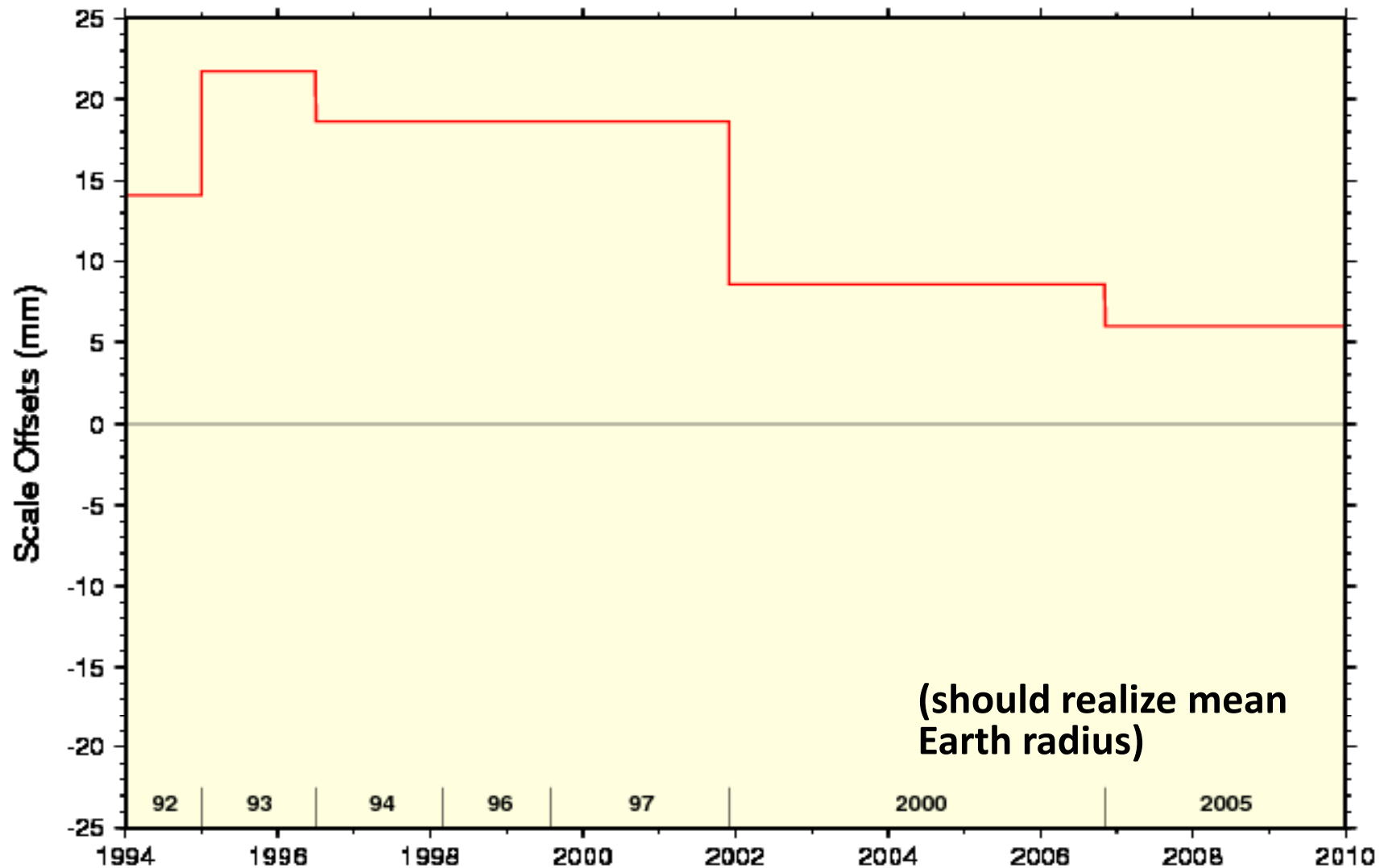
- So it is necessary to fix the ITRF scale (i.e., net station heights) to solve for satellite PCOs

$$\langle\Delta\text{PCO}\rangle [\text{mm}] = -20 \cdot \Delta s [\text{mm}]$$



(from E. Cardellach et al., 2007)

ITRFxx Scales wrt ITRF2008 (@ 2000.0)



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

Maintenance of PCOs is Iterative Process

- IGSxx frame + igsxx.atx (PCOs + PCVs) \Rightarrow 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 \Rightarrow 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 \Rightarrow 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 \Rightarrow TRFs(X, V) + EOPs(t)
 - combine 4 technique solutions with local ties \Rightarrow 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 $\mu\text{s}/\text{d}$ 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