Assessment of the orbits from the 1st IGS reprocessing campaign

- results from combined reprocessed IGS GPS orbits and EOPs
- assessment of IG1 orbit repeatability
- items to consider for next reprocessing

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2009 AGU Fall Meeting - 14 December 2009 - San Francisco, CA – Paper #G13A-04

Why Reprocess?

- To obtain fully consistent IGS Finals orbits using the latest models & frames
  - IERS 2003 Conventions generally implemented
  - absolute antenna calibrations
    - satellite transmitting and ground receiving antennas
  - updated model for station displacements due to ocean tidal loading
    - FES2004
    - whole-Earth center-of-mass corrections
  - updated models for troposphere propagation delays
  - details at http://acc.igs.org/reprocess.html
  - use IGS05 frame; first attempt to obtain a full history of IGS products in a fully consistent framework

- Existing history of IGS orbits, clocks and station coordinate estimates are inadequate for modern realizations of ITRF

Who is Reprocessing?

- All IGS Final-product Analysis Centers:
  - CODE/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:
  - GFZ TIGA – Potsdam, Germany

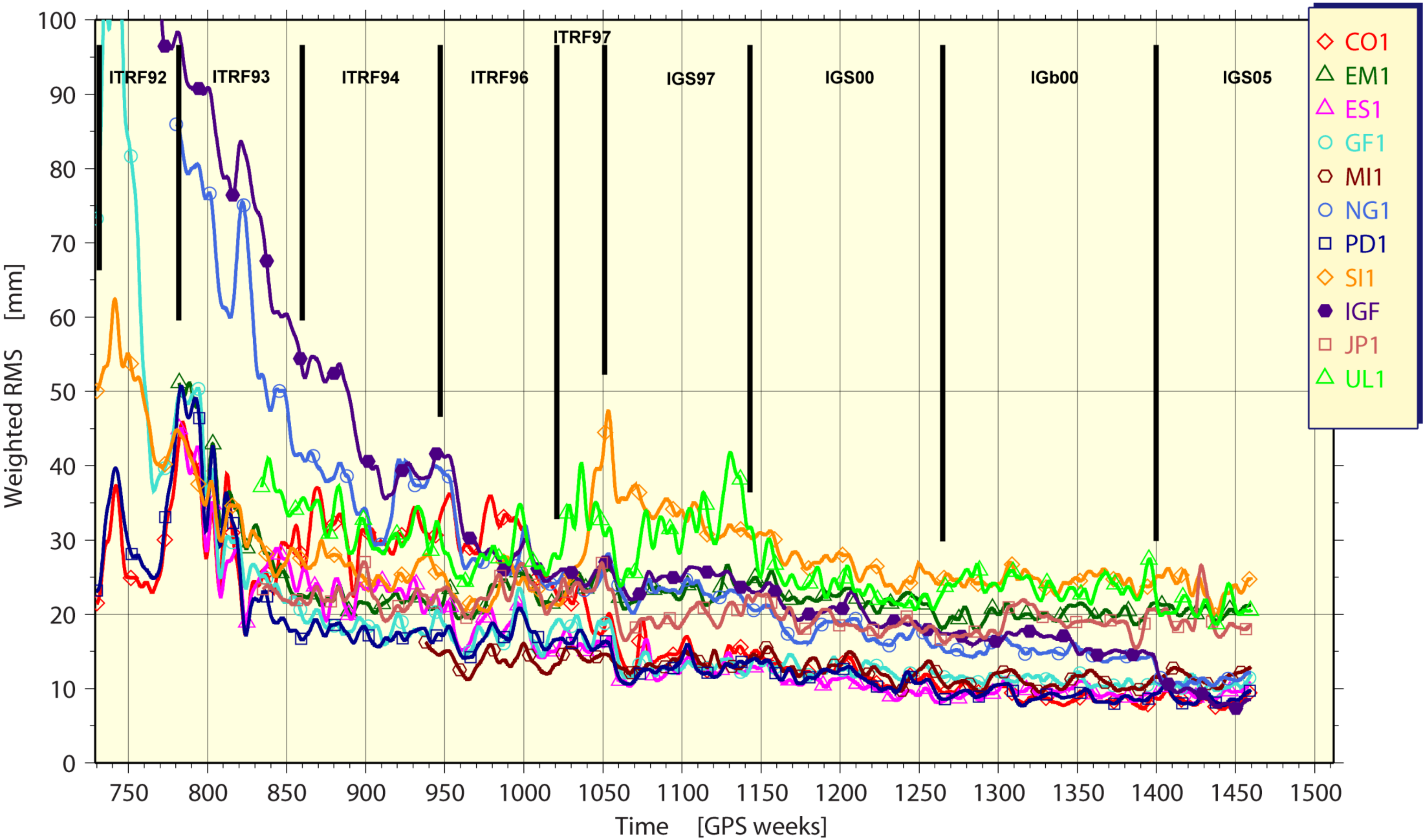
COMPARISON OF AC DATA USAGE

ANALYSIS CENTER	OBS TYPE	ORBIT DATA ARC LENGTH	DATA RATE	ELEVATION CUTOFF	ELEVATION INVERSE WGTS
CODE	DbDiff (weak redundant)	24 + 24 + 24 h	3 min	3 deg	$1/\cos^2(z)$
EMR	UnDiff	24 h	5 min	10 deg	none
ESA	UnDiff	24 h	5 min	10 deg	$1/\sin^2(e)$
GFZ	UnDiff	24 + 24 + 24 h	5 min	7 deg	1/2sin(e) for e < 30 deg
JPL	UnDiff	3 + 24 + 3 h	5 min	7 deg	none
MIT	DbDiff (weak redundant)	24 h (SRPs over 9d)	2 min	10 deg	$a^2 + (b^2/\sin^2(e))$ a,b from site residuals
NGS	DbDiff (redundant)	24 h	30 s	10 deg	$[5 + (2/\sin(e))\ \text{cm}]^2$
PDR (Repro)	DbDiff (weak redundant)	24 + 24 + 24 h	3 min	3 deg	$1/\cos^2(z)$
SIO	DbDiff (weak redundant)	24 h	2 min	10 deg	$a^2 + (b^2/\sin^2(e))$ a,b from site residuals
ULR (Repro)	DbDiff (weak redundant)	24 h	3 min	10 deg	$a^2 + (b^2/\sin^2(e))$ a,b from site residuals

COMPARISON OF AC SATELLITE DYNAMICS

ANALYSIS CENTER	NUTATION & EOPs	SRP PARAMS	VELOCITY BRKs	ATTITUDE	SHADOW ZONES	EARTH ALBEDO
CODE	IAU 2000; BuA ERPs	D,Y,B scales; B 1/rev	every 12 hr + constraints	none	E+M: umbra & penumbra	none
EMR	IAU 1980; BuA ERPs	X,Y,Z scales stochastic	none	yaw rates estimated	E: umbra & penumbra	none
ESA	IAU 2000; BuA ERPs	D,Y,B scales; B 1/rev	none; Along, Along 1/rev accelerations	none	E+M: umbra & penumbra	applied + IR
GFZ	IAU 2000; GFZ ERPs	D,Y scales	@ 12:00 + constraints	yaw rates estimated	E+M: umbra & penumbra	none
JPL	IAU 1980; BuB ERPs → BuA	X,Y,Z scales stochastic	none	nominal yaw rates used	E+M: umbra & penumbra	applied
MIT	IAU 2000; BuA ERPs	D,Y,B scales; B(D,Y) 1/rev	none; 1/rev constraints	nominal yaw rates used	E+M: umbra & penumbra	none
NGS	IAU 2000; IGS PM; BuA UT1	D,Y,B scales; B 1/rev	@ 12:00 + constraints	none; delete eclipse data	E+M: umbra & penumbra	none
PDR (Repro)	IAU 2000; BuA ERPs	D,Y,B scales; B 1/rev	every 12 hr + constraints	none	E+M: umbra & penumbra	none
SIO	IAU 2000; BuA ERPs	D,Y,B scales; D,Y,B 1/rev	none; 1/rev constraints	nominal yaw rates used	E+M: umbra & penumbra	none
ULR (Repro)	IAU 2000; BuB ERPs	D,Y,B scales; D,Y,B 1/rev	none	nominal yaw rates used	E+M: umbra & penumbra	none

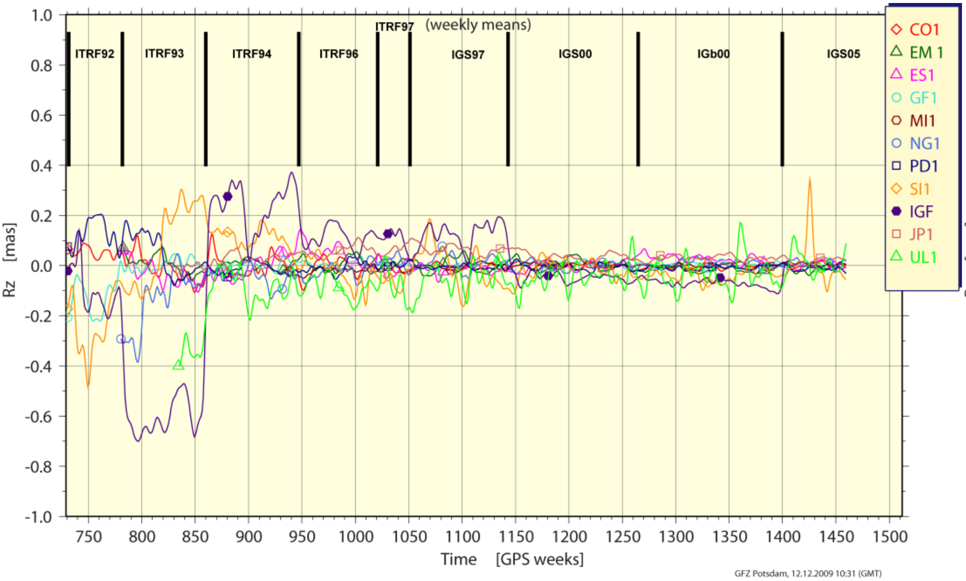
Weighted RMS of AC Orbits w.r.t. IG1



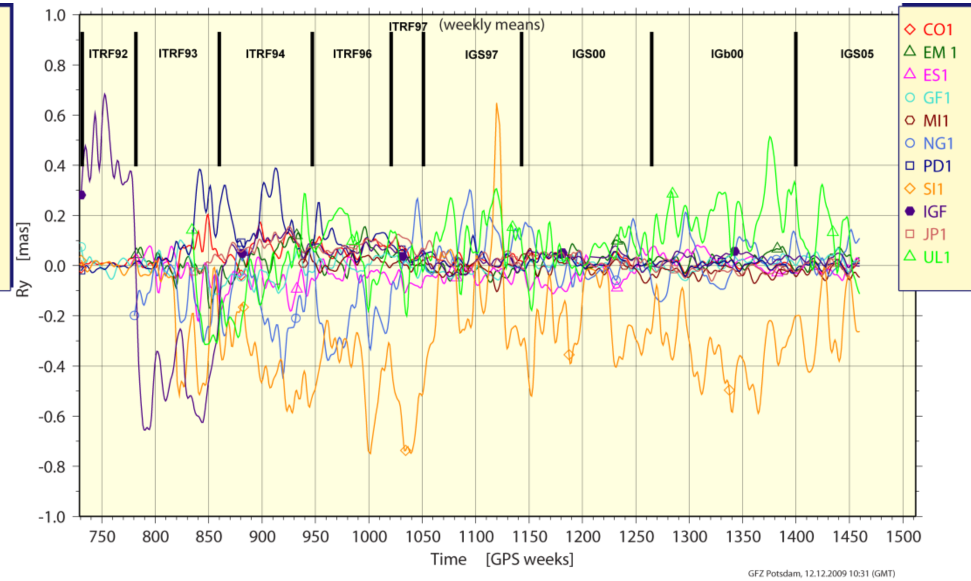
GFZ Potsdam, 12.12.2009 10:31 (GMT)

Orbit Frame Differences: Rotations & Scale

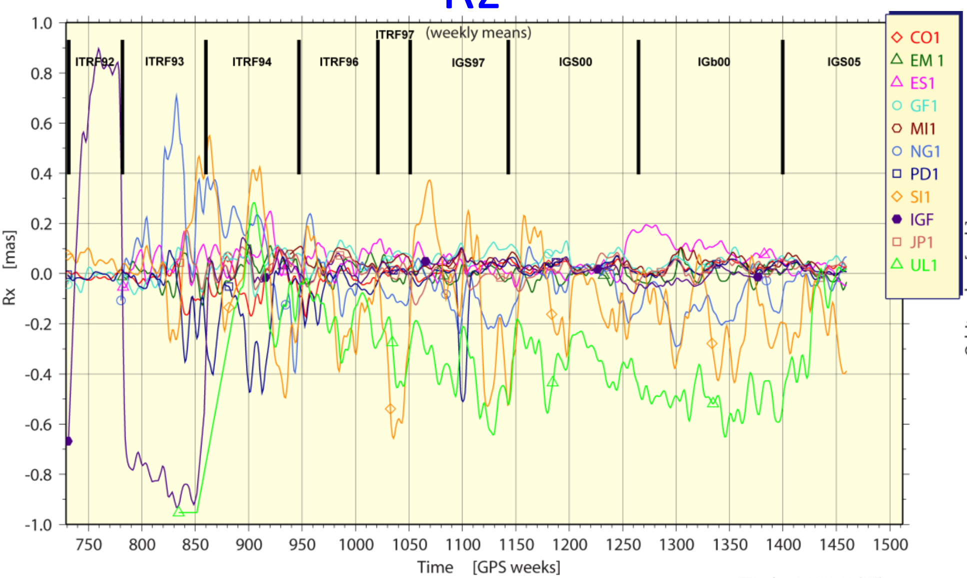
Rx



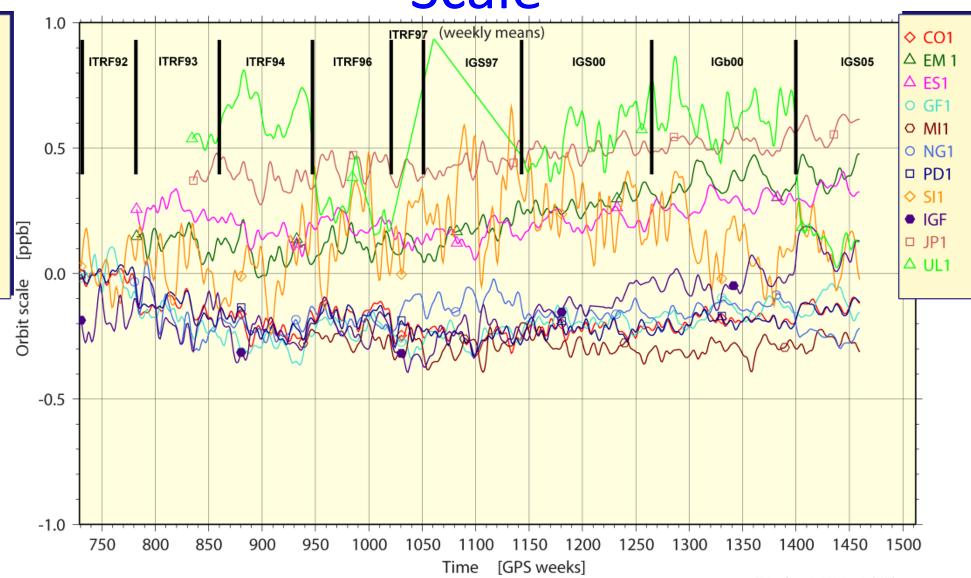
Ry



Rz

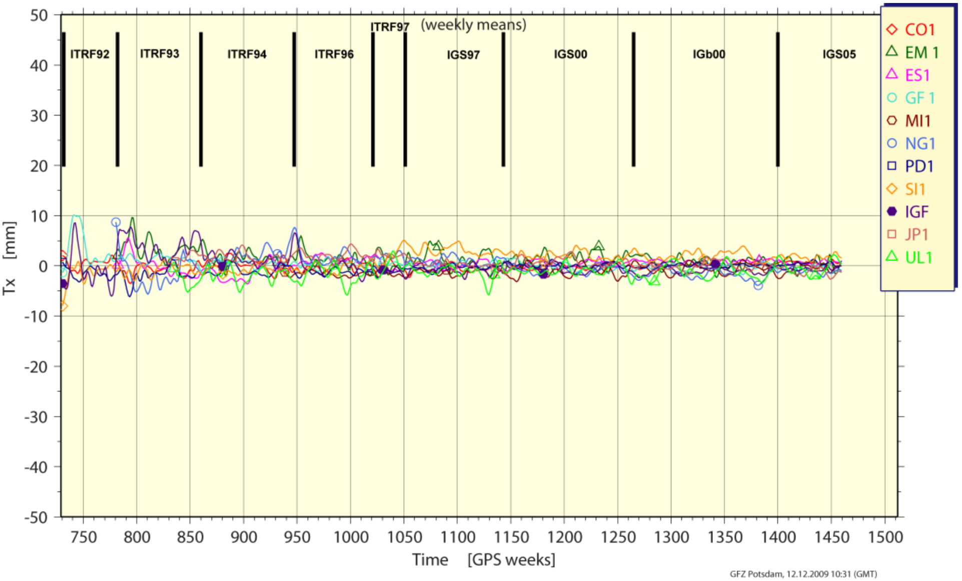


Scale

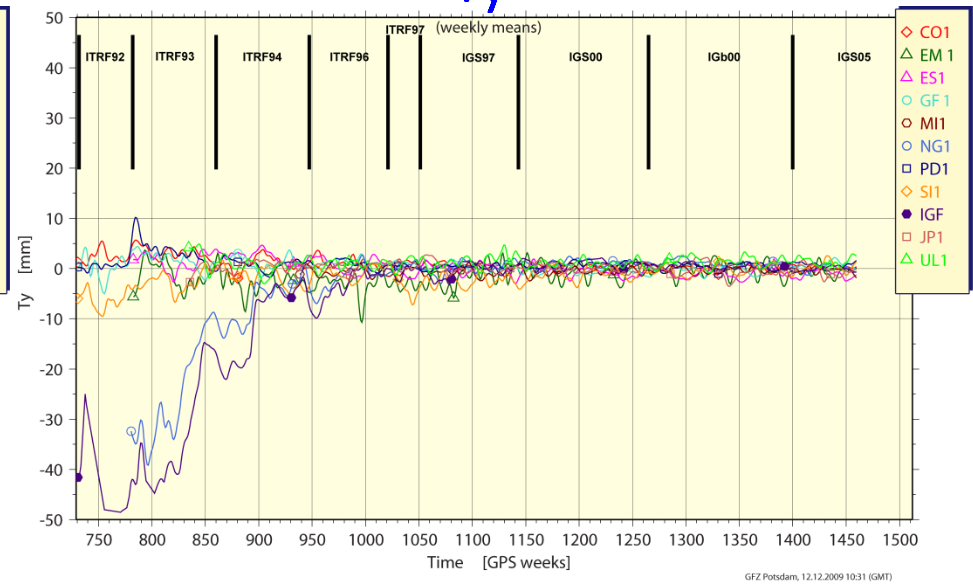


Orbit Frame Differences: Origin Translations

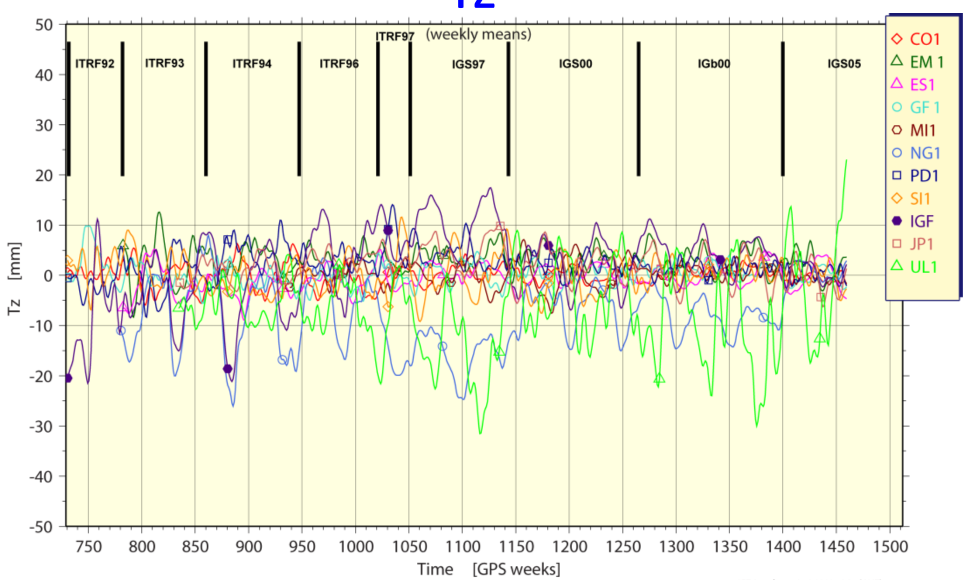
Tx



Ty



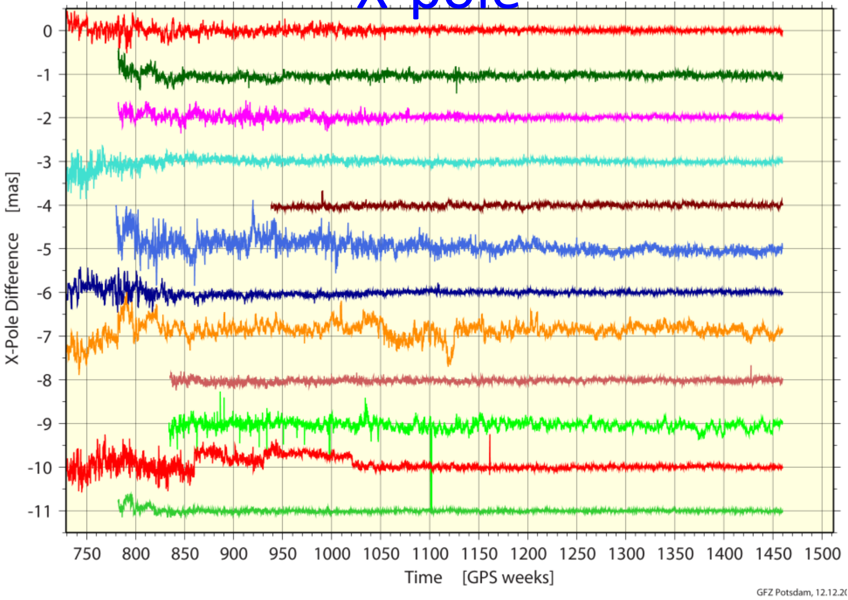
Tz



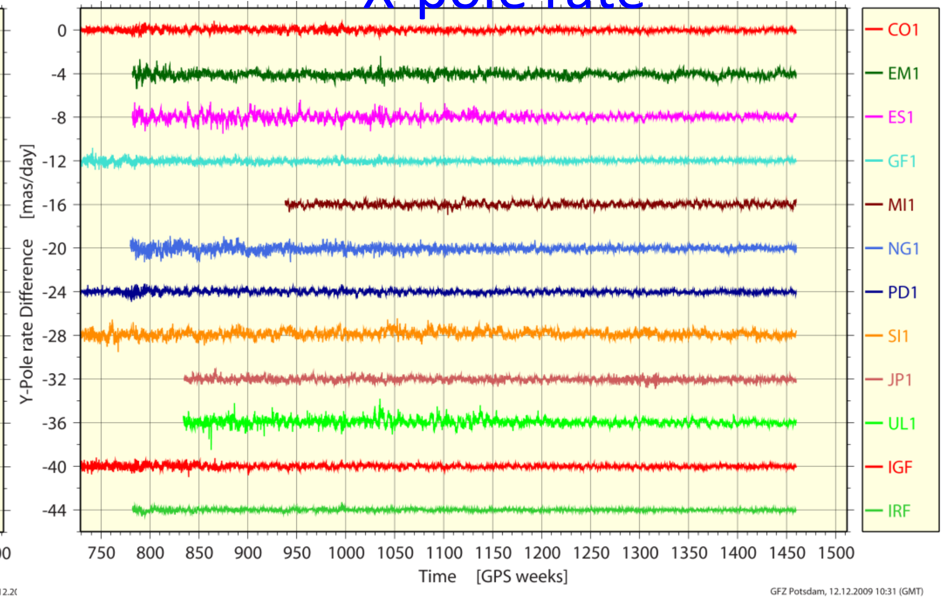
- **Synopsis**
  - good consistency among most ACs
  - UL1 & SI1 show large Rx & Ry rotations
  - original IGS orbits (IGF) had large rotations before July 1996 (due to ITRF93)
  - NG1 & UL1 have large origin motions
  - original IGS orbit origin drifted in Y & oscillated in Z annually

EOPs: PM-x & PM-y

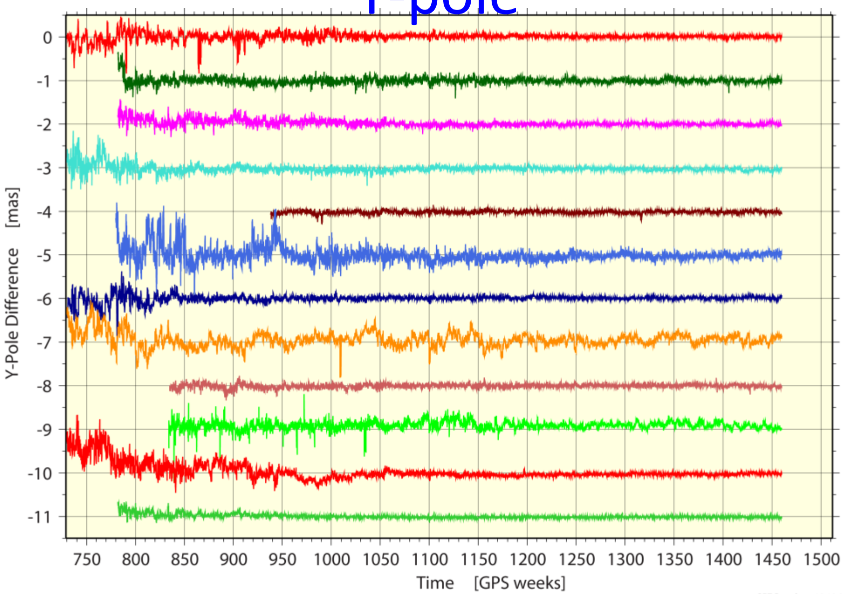
X-pole



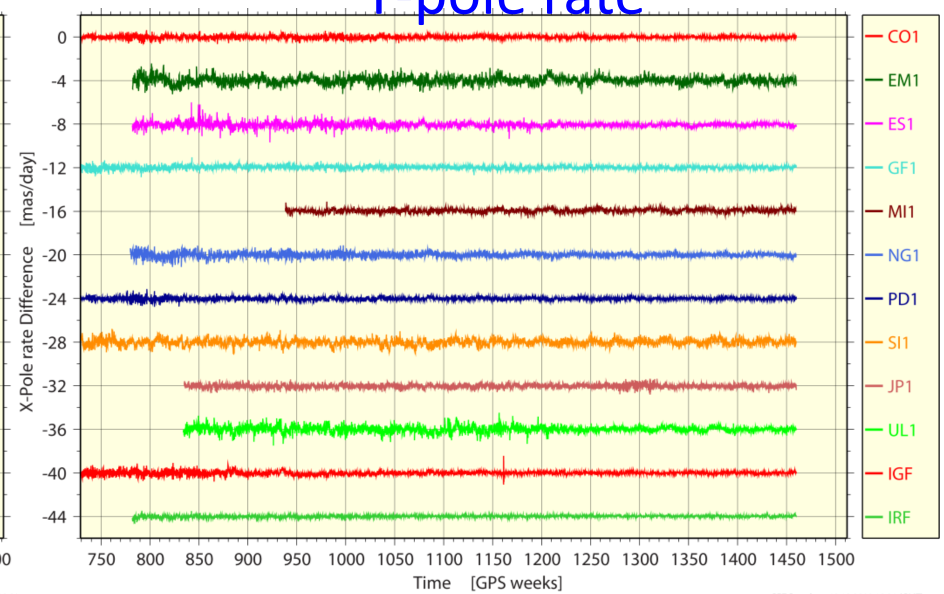
X-pole rate



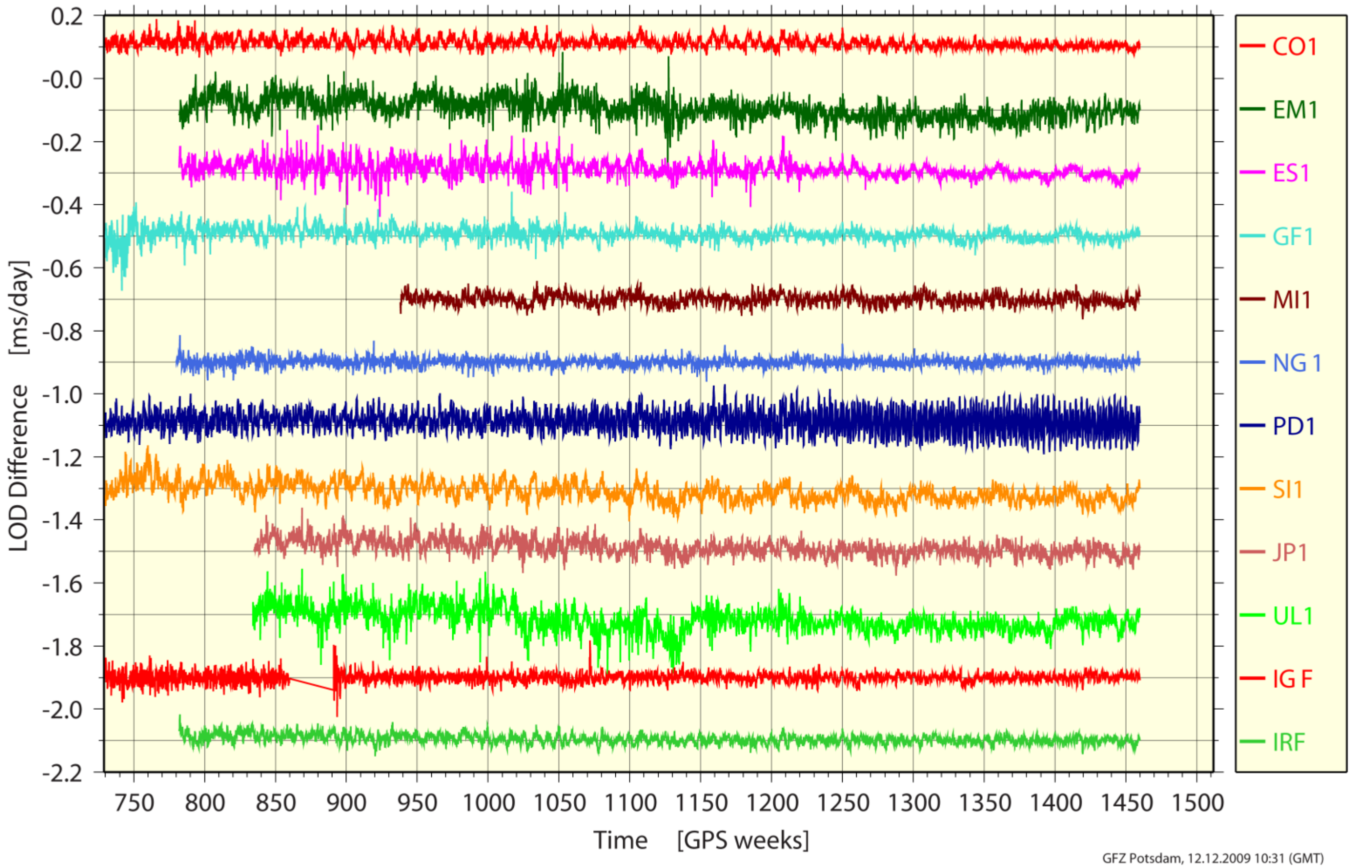
Y-pole



Y-pole rate



EOPs: LOD

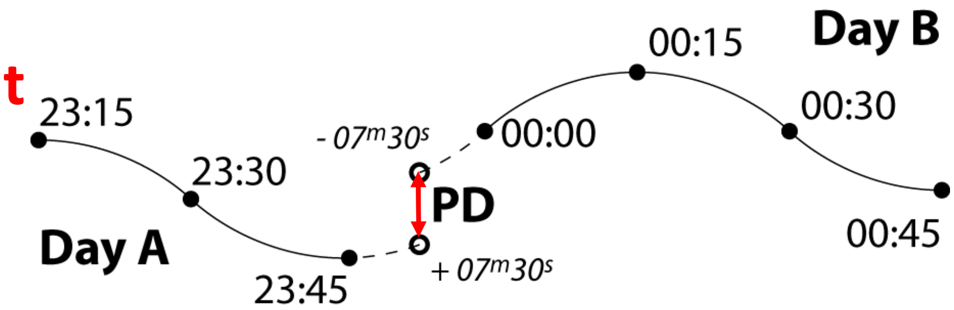


- **Synopsis**
  - reasonable EOP consistency among most ACs
  - IG1 removes frame change effects from IGF PM in early years
  - UL1 and EM1 LODs have near annual period prior to Jan. 2002 (~GPS Wk 1150)
  - PD1 LODs have tide error problem, approximately fortnightly

Compute Orbit Discontinuities

- **Fit orbits for each day with BERNE (6+9) orbit model**
  - fit 96 SP3 orbit positions for each SV as pseudo-observations for Day A
  - parameterize fit as $X, Y, Z, \dot{X}, \dot{Y}, \dot{Z}$ plus 3 SRPs per SV component
  - propagate fit forward to 23:52:30 for Day A
  - repeat for Day B & propagate backwards to 23:52:30 of day before

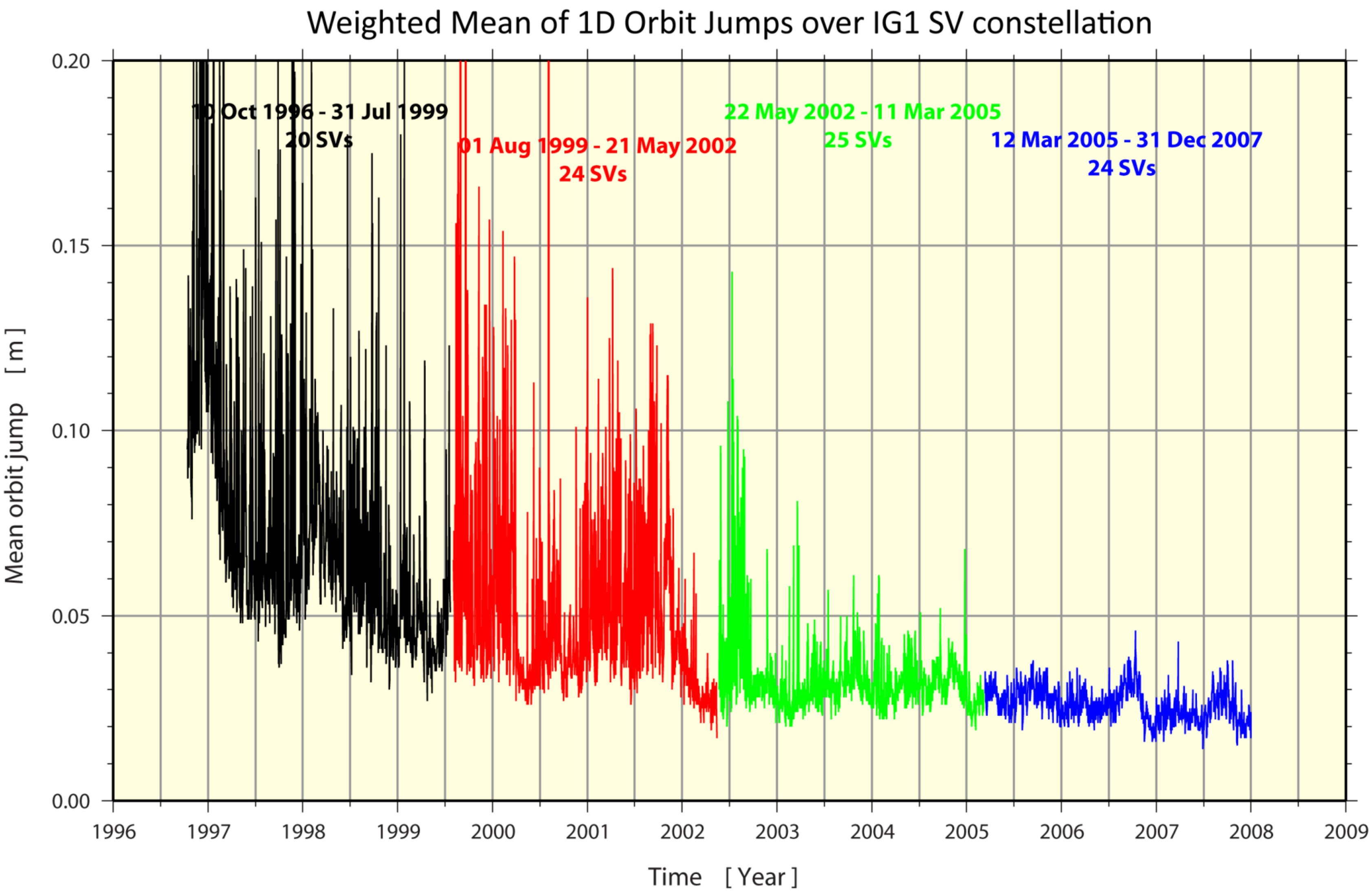
- **Compute 1D magnitude of orbit 3D differences at 23:52:30**



- **Use 4 equal 1025 d segments from 10 Oct 1996 thru 31 Dec 2007**
  - spectra for all SVs stacked for each AC; data gaps linearly interpolated
  - sliding boxcar filter used to smooth across each 3 adjacent frequencies

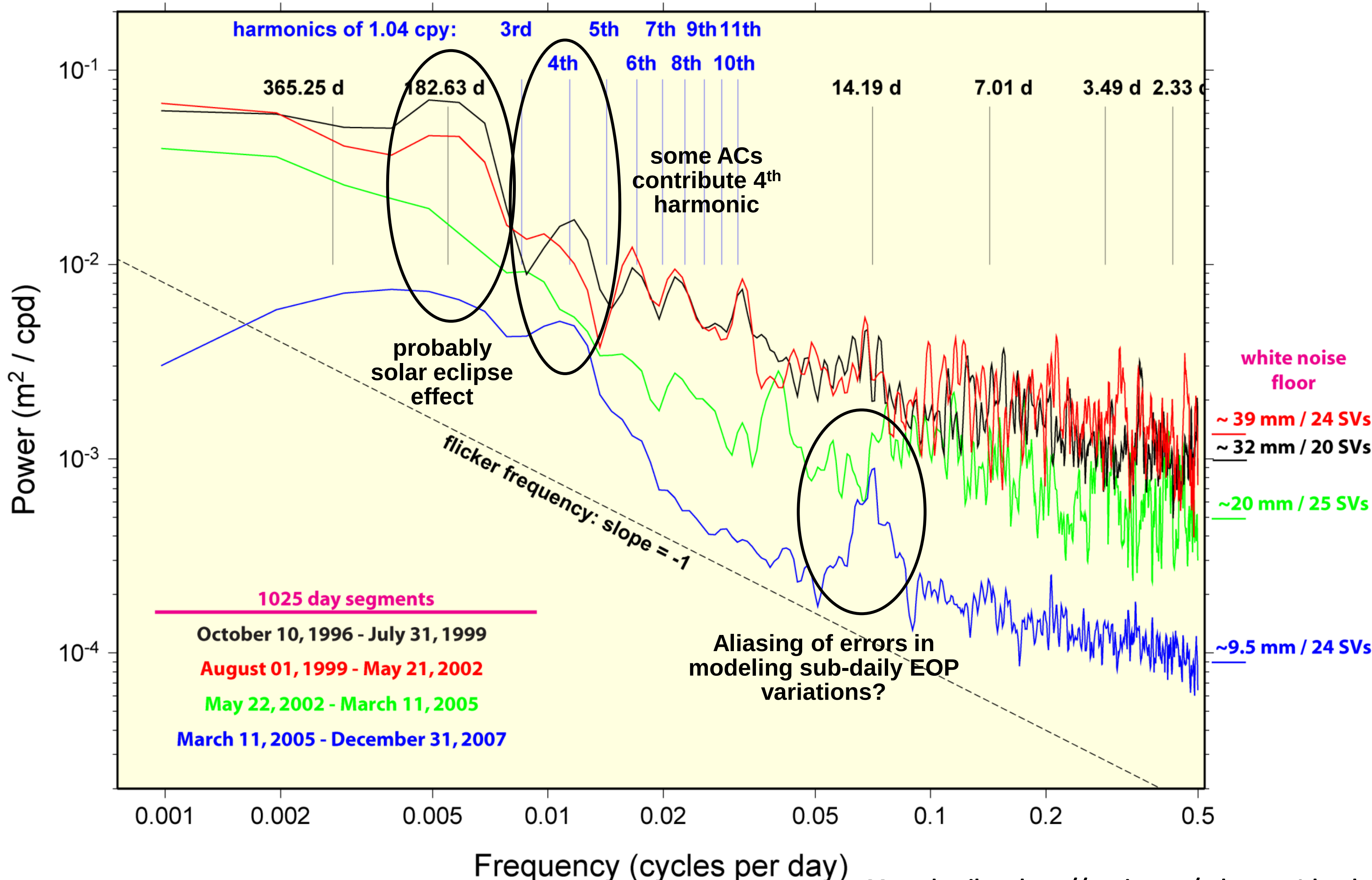
- **Tests indicate fit/extrapolation error ≤ ~4 mm RMS *[e.g., Griffiths and Ray, 2009]***

Time Series of Orbit Discontinuities



Spectra for IG1 1D Orbit Jumps

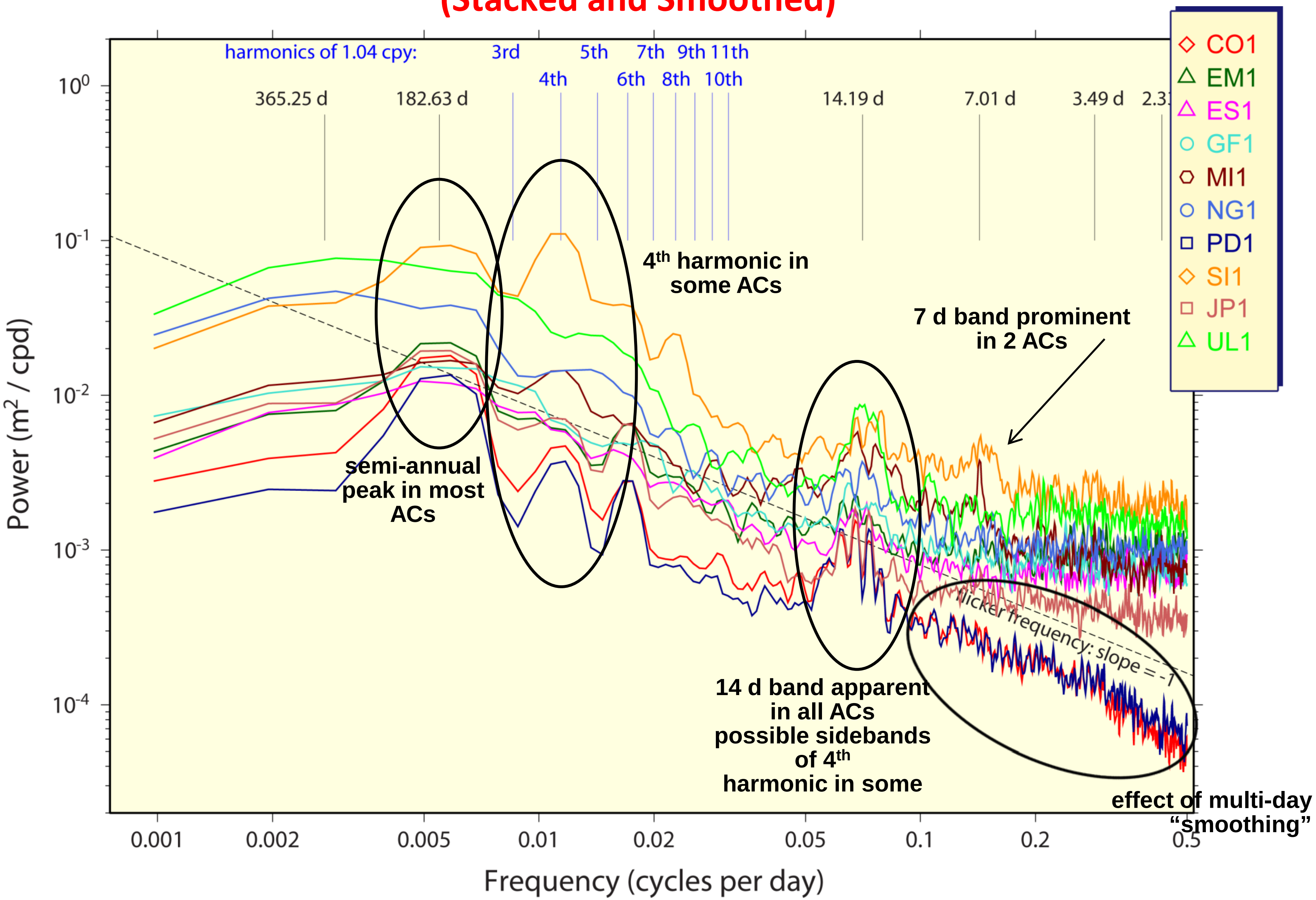
(Stacked and Smoothed)



More details at http://acc.igs.org/orb-repro1.html

Spectra for AC Jumps in Along-track Direction

(Stacked and Smoothed)



More details at http://acc.igs.org/orb-repro1.html

Conclusions

- 1st reprocessing of IGS GPS data collected since 1994 is complete
- IG1 orbit combinations expected to be released by spring 2010
- Overall quality improvement of IGS Final orbits
  - Historical frame changes appear to be removed in IG1
  - Precision/accuracy of IG1 orbits ranges from ~64/sqrt(2) mm (1996 to 1999) to ~25/sqrt(2) mm (2005 to 2007)
- Semi-annual & 4th draconitic harmonic peaks in spectra for IG1 orbit jumps
  - probably the result of mis-modeling of solar eclipses
  - Low-frequency errors (e.g. solar eclipsing) largest source of inaccuracy
- Prominent 14.19 d band in orbit jumps
  - errors in sub-daily EOP tidal variations aliasing into a broad comb of frequencies centered at ~ 14 d with apparent sidebands
- Begin preparing for 2nd reprocessing campaign
  - study further 14 d band issue
  - consider whether all ACs should process over 24 h arcs, only, to eliminate smoothing effects

Backup Slides

COMPARISON OF AC TIDAL MODELS

ANALYSIS CENTER	SOLID EARTH	EARTH POLE	OCEAN LOAD	OCEAN POLE	OCEAN CMC	SUBDAILY EOPs
CODE	IERS 2003; dehanttideinel.f	eqn 23a/b mean pole	FES2004; hardisp.f	none	sites & SP3	IERS 2003; subd nutation
EMR	IERS 2003	eqn 23a/b mean pole	FES2004; gipsy	none	sites & SP3	IERS 1996; no subd nutation
ESA	IERS 2003; dehanttideinel.f	eqn 23a/b mean pole	FES2004; hardisp.f	none	sites & SP3	IERS 2003 & PMsdnut.for
GFZ	IERS 1992	eqn 23a/b mean pole	FES2004; hardisp.f	none	sites & SP3	IERS 2003; subd nutation
JPL	IERS 2003	eqn 23a/b mean pole	FES2002; gipsy	none	none → sites & SP3	IERS 1996 → IERS 2003
MIT	IERS 2003	eqn 23a/b mean pole	FES2004	none	sites & SP3	IERS 2003 & PMsdnut.for
NGS	IERS 2003; dehanttideinel.f	eqn 23a/b mean pole	FES2004; hardisp.f	none	sites & SP3	IERS 2003 & PMsdnut.for
PDR (Repro)	IERS 2003; dehanttideinel.f	fixed mean pole	GOT00.2 w/ 11 terms	none	none	IERS 2003; no subd nutation
SIO	IERS 2003	eqn 23a/b mean pole	FES2004	none	sites & SP3	IERS 2003 & PMsdnut.for
ULR (Repro)	IERS 2003	eqn 23a/b mean pole	FES2004	none	sites & SP3	IERS 2003 & PMsdnut.for

COMPARISON OF AC GRAVITY FORCE MODELS

ANALYSIS CENTER	GRAVITY FIELD	EARTH TIDES	EARTH POLE	OCEAN TIDES	OCEAN POLE	RELATIVITY EFFECTS
CODE	JGM3; C21/S21 due to PM	IERS 2003	IERS 2003	CSR 3.0	none	dynamic corr & bending applied
EMR	JGM3; C21/S21 due to PM	freq-depend. Love #	IERS 2003	CSR	none	no dynamic corr; bending applied
ESA	EIGEN; C21/S21 due to PM	IERS 2003	IERS 2003	IERS 2003	none	dynamic corr & bending applied
GFZ	JGM2; C21/S21 due to PM	Wahr Love #	GFZ model	CSR 3.0	none	dynamic corr & bending applied
JPL	JGM3; C21/S21 due to PM	IERS 2003	IERS 2003	CSR → FES2004	none	dynamic corr & bending applied
MIT	EGM96; C21/S21 due to PM	IERS 1992; Eanes Love #	none	none	none	no dynamic corr; bending applied
NGS	EGM92; C21/S21 due to PM	IERS 1992; Eanes Love #	none	none	none	no dynamic corr; bending applied
PDR (Repro)	JGM3; constant C21/S21	IERS 2003 except step 2	IERS96; fixed pole	CSR 3.0	none	dynamic corr & bending applied
SIO	EGM96; C21/S21 due to PM	IERS 1992; Eanes Love #	none	none	none	no dynamic corr; bending applied
ULR (Repro)	EGM96; C21/S21 due to PM	IERS 1992; Eanes Love #	none	FES 2004 ???	none	no dynamic corr; bending applied