IGS Reprocessing – Summary of Orbit/Clock Combination and First Quality Assessment

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- General information about the Repro1 activity
- Combination results and consistency of products
- Assessment of the product accuracy
  - PPP with combined products
  - Orbit overlaps

IGS Workshop - 30 June 2010 - Newcastle

Why Reprocessing

- To obtain a full history of IGS Final products using the latest models
  - Absolute antenna model (igs05.atx)
  - P1-C1 satellite code biases were updated
  - IERS 2003 Conventions generally implemented
    - Updated model for station displacements due to ocean tidal loading (FES2004; whole-Earth center-of-mass corrections)
    - Updated models for troposphere propagation delays
    - No 2nd order ionospheric effects

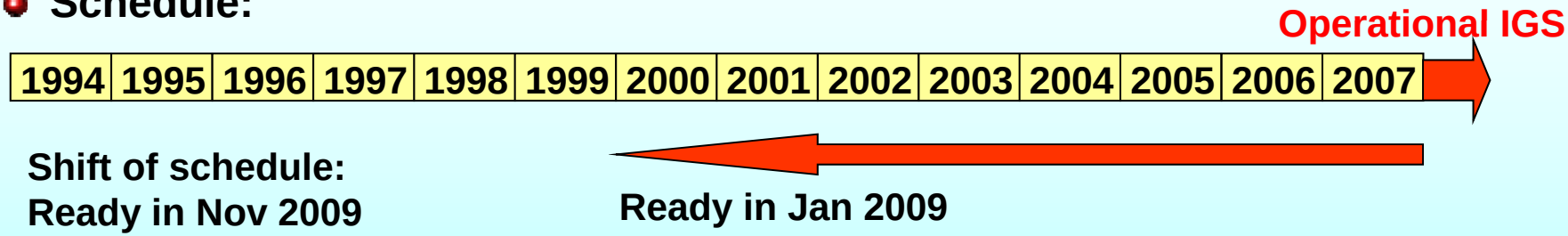
(for details, see http://acc.igs.org/reprocess.html)

- Remove inconsistencies over time due to frame changes
  - Use of IGS05 frame
  - first attempt to obtain a full history of IGS products in a fully consistent framework

→ IGS contribution with homogenous products to ITRF2008

History

- 2007: Year-2000 (Jan-Apr) test campaign
- Feb 2008: begin of full reprocessing
- Jun 2008: IGS workshop, evaluation of year 2000-test and 2007 products
- Schedule:



- Nov 2009:
  - Test combination were performed to check the quality and to identify problems; 1996-2007
  - Some corrected resubmissions followed
- Mar/Apr 2010
  - combination finished (not yet clock alignment to IGS time frame; affects no other products)

AC Products /Combination Centers

- **Products:**
  - Daily orbits - 15min sampling
  - Daily satellite and station clocks - 5 min sampling (no 30s for repro1)
  - Daily ERP (x&y and rates; LOD)
  - Weekly SINEX files with station coordinates, ERP
  - Weekly satellite antenna offsets (4 ACs: CO1, EM1, GF1, MIT)
- **Aligned to the IGS05 reference frame, absolute antenna model**

- **Combination Centers**
  - NRCan: SINEX combination
  - GFZ: Orbit & clock combination
  - NRL: IGS Time Scale based on combined clocks

Contributing ACs

AC		Code	Software	From 19..	(yrs)	Clk
CODE/AIUB	Switzerland	CO1	Bernese 5.0	94	(14)	
EMR/NRCan	Canada	EM1	GIPSY	95	(13)	clk
ESA/ESOC	Germany	ES1	NAPEOS	95	(13)	clk
GFZ	Germany	GF1	EPOS	94	(14)	clk
		GT1		98	(10)	
JPL	USA	JP1	GIPSY	96	(12)	clk
MIT	USA	MI1	GAMIT	98	(10)	clk
NGS/NOAA	USA	NG1	PAGES	95	(13)	
SIO	USA	SI1	GAMIT	94	(14)	
PDR (Pdm/Dresden)	Germany	PD1	Bernese 5.0	94	(14)	
ULR (La Rochelle)	France	UL1	GAMIT	96	(12)	

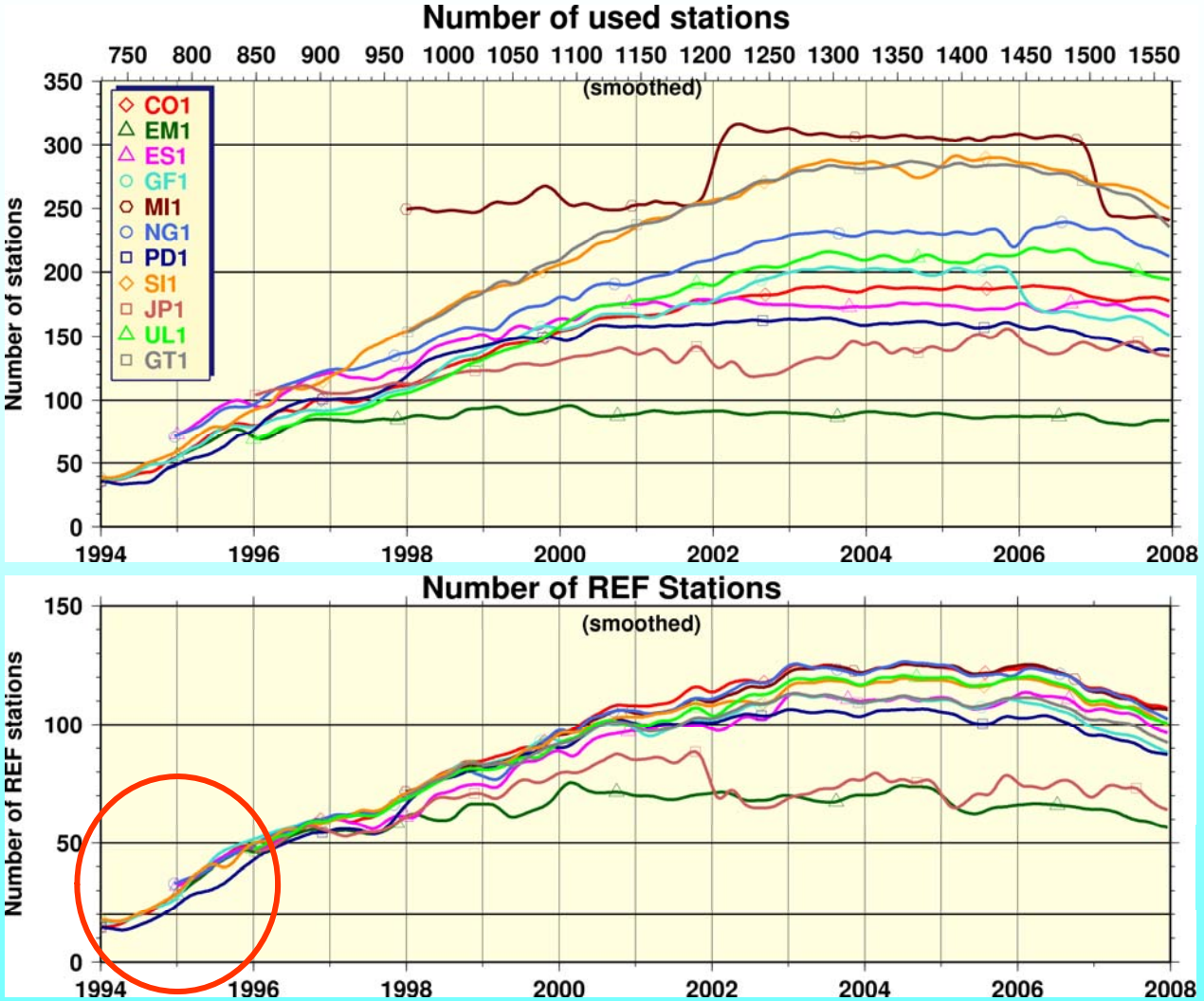
- 10 Analysis Centers (2 from outside the IGS Final ACs)
- 5 different Software Packages
- Only 5 clock solutions (compared to operational product CO1 is missing)

Comparison of AC Parameters & Models

(selection)

AC	Elev-Cutoff	Elev-dep Wei	Arc len.	Velo Brks	Earth Albedo	Ocean tides
CODE	3	yes	3d	every 12h	-	CSR3.0
EMR	10	-	1d	-	-	CSR
ESA	10	yes	1d	none; 1/rev	yes&IR	IERS2003
GFZ	7	yes	3d	every 12h	-	CSR3.0
JPL	7	-	1.25d	-	yes	FES2004
MIT	10	yes	1d	none; 1/rev	-	-
NGS	10	yes	1d	every 12h	-	-
PDR	3	yes	3d	every 12h	-	CSR3.0
SIO	10	yes	1d	none; 1/rev	-	none
ULR	10	??	1d	-	-	FES2004

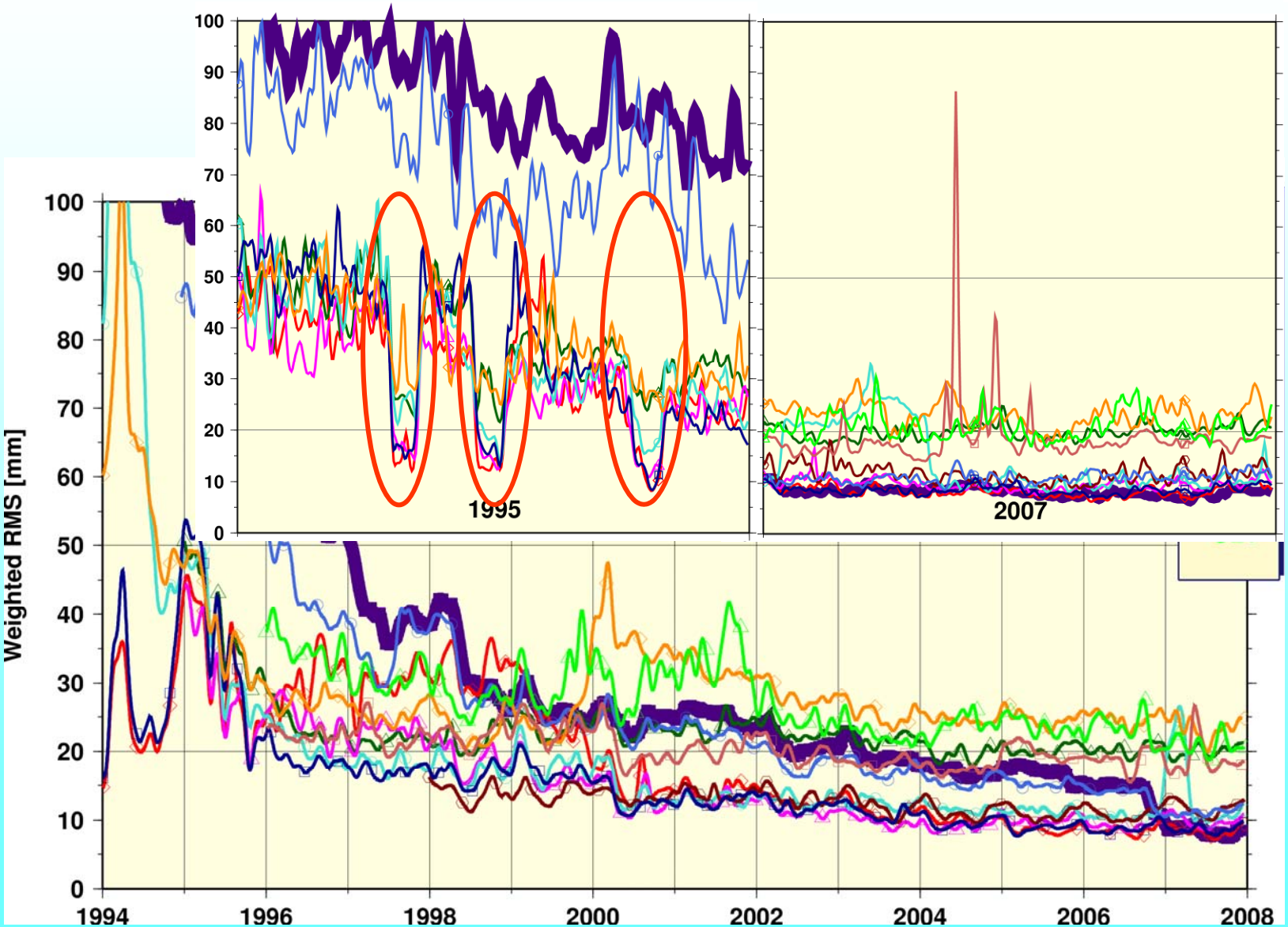
Network



AC	#sta	#ref
EM1	100	80
PD1	160	105
JP1	170	95
CO1	190	125
ES1	190	120
GF1	200	115
GT1	290	115
UL1	220	120
NG1	240	125
SI1	290	120
MI1	320	125

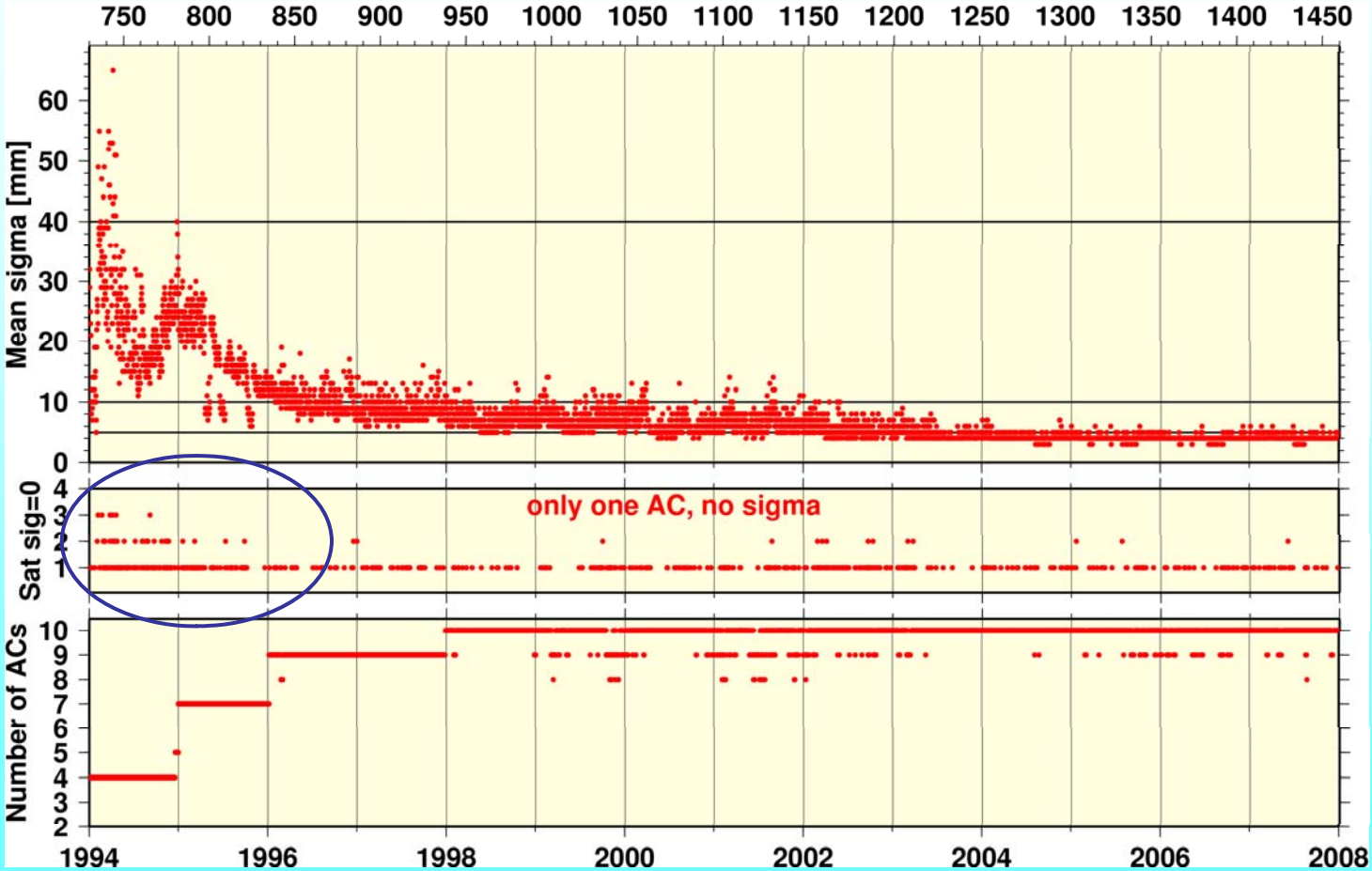
- Number of reference frame stations is critical before 1996.0

Orbit comparisons

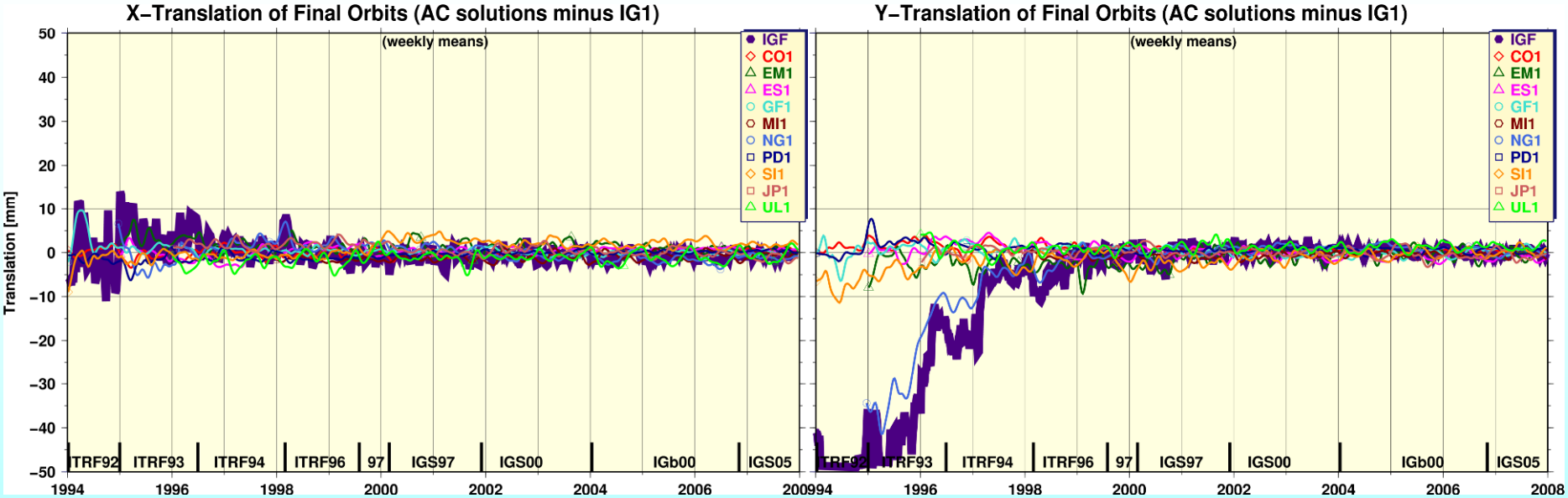


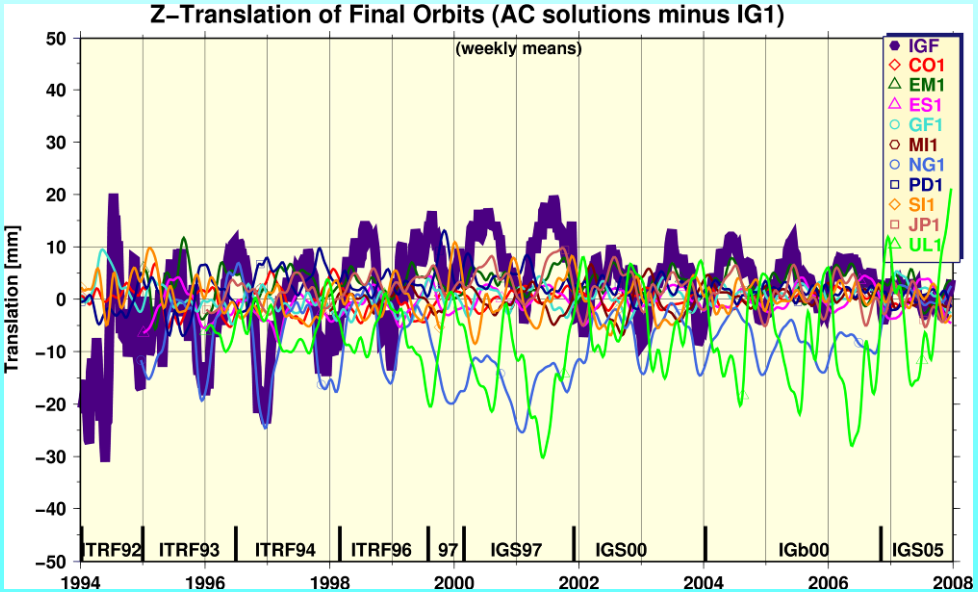
Combined SP3 – Error code

- Sigma of the combined SP3 (top)
- Number of satellites with no sigma value (sigma=0; only 1 AC) (middle)
- Number of contributing ACs (most excl. are caused by high transf.)



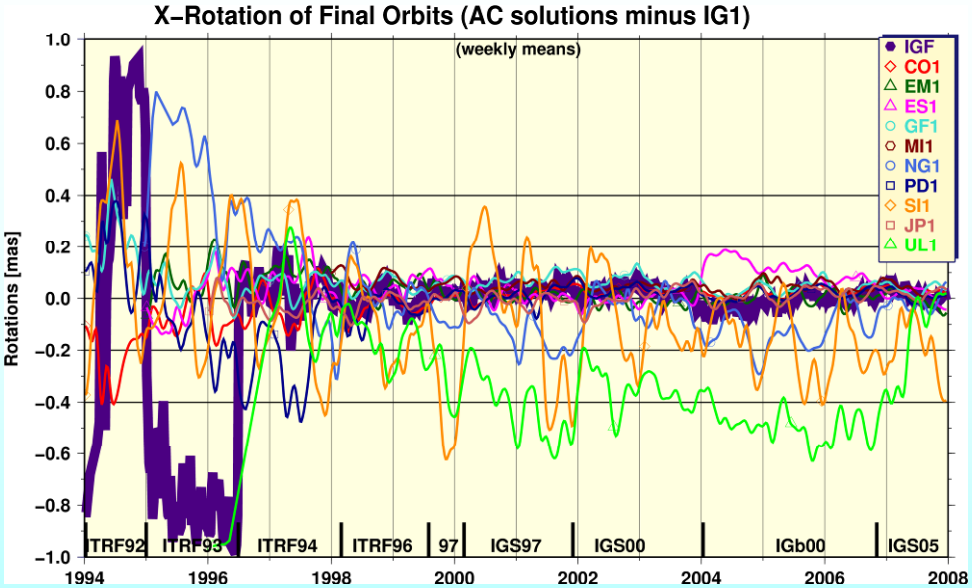
Orbit Frame Differences: Translations

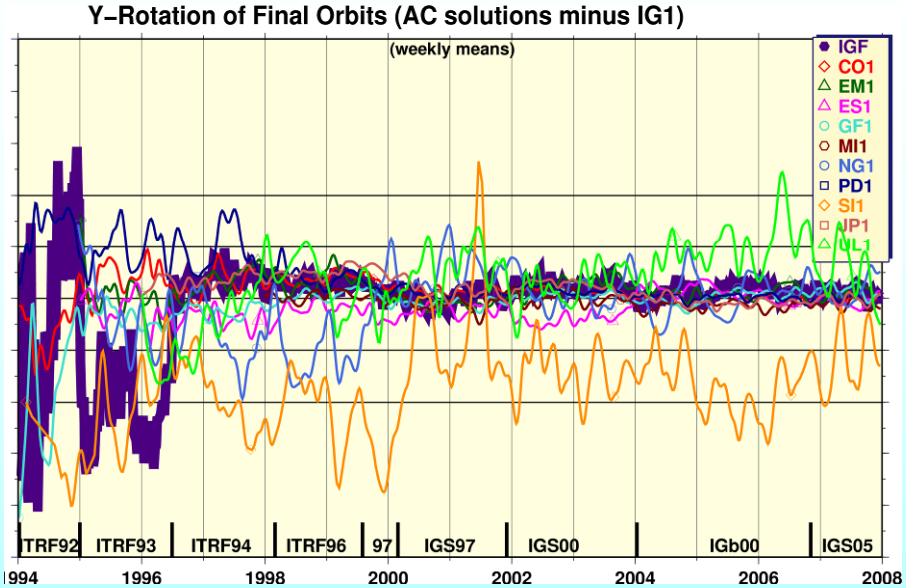


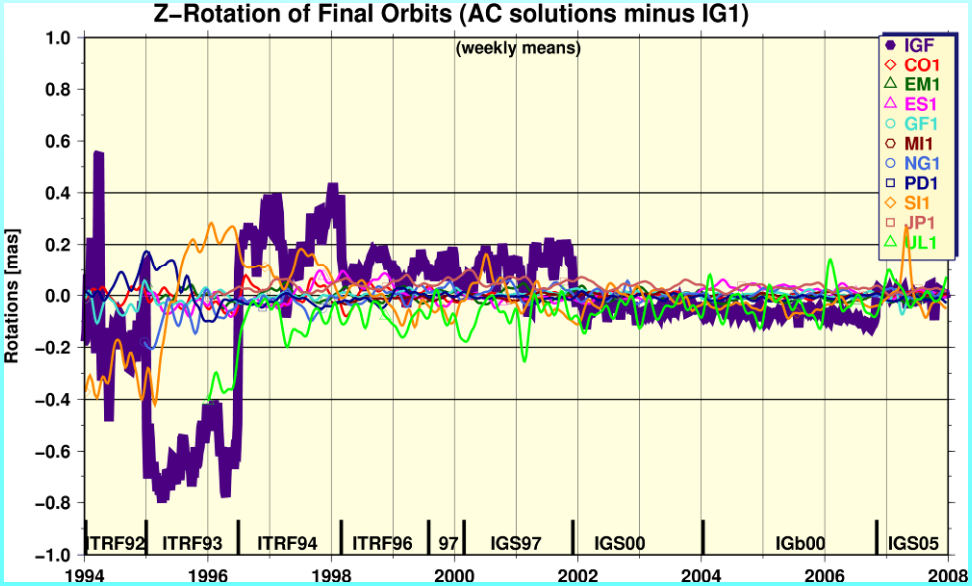


- Good internal consistency among ACs
- NG1 and UL1 have issues with Ty and Tz
- Seasonal effects in Tz, especially in operational IGS Finals and UL1

Orbit Frame Differences: Rotations



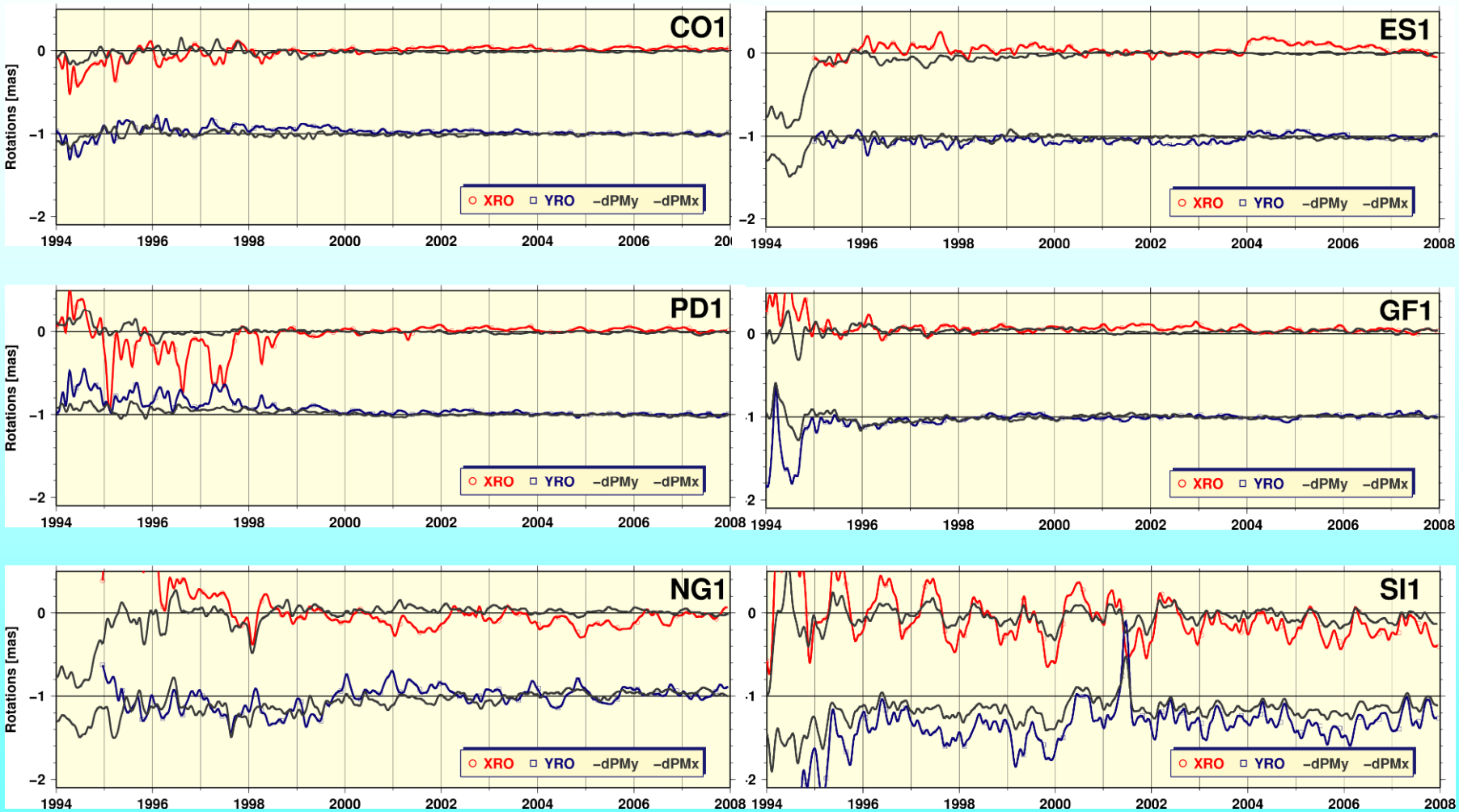




- Good internal consistency among ACs
- NG1, SI1 and UL1 have issues with Rx and Ry
- RF changes in operational IGS Finals over history

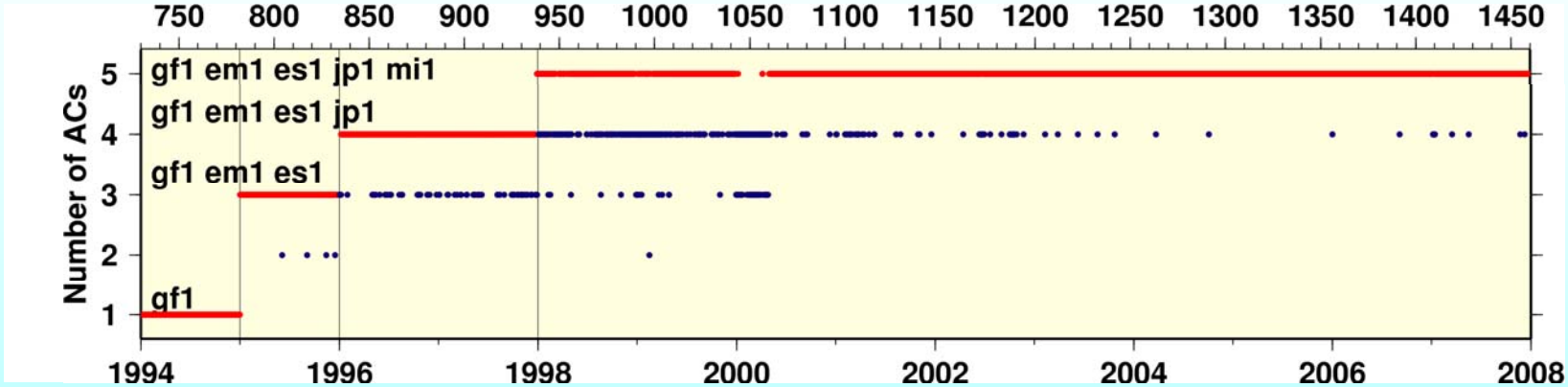
Orbit rotations & ERP differences

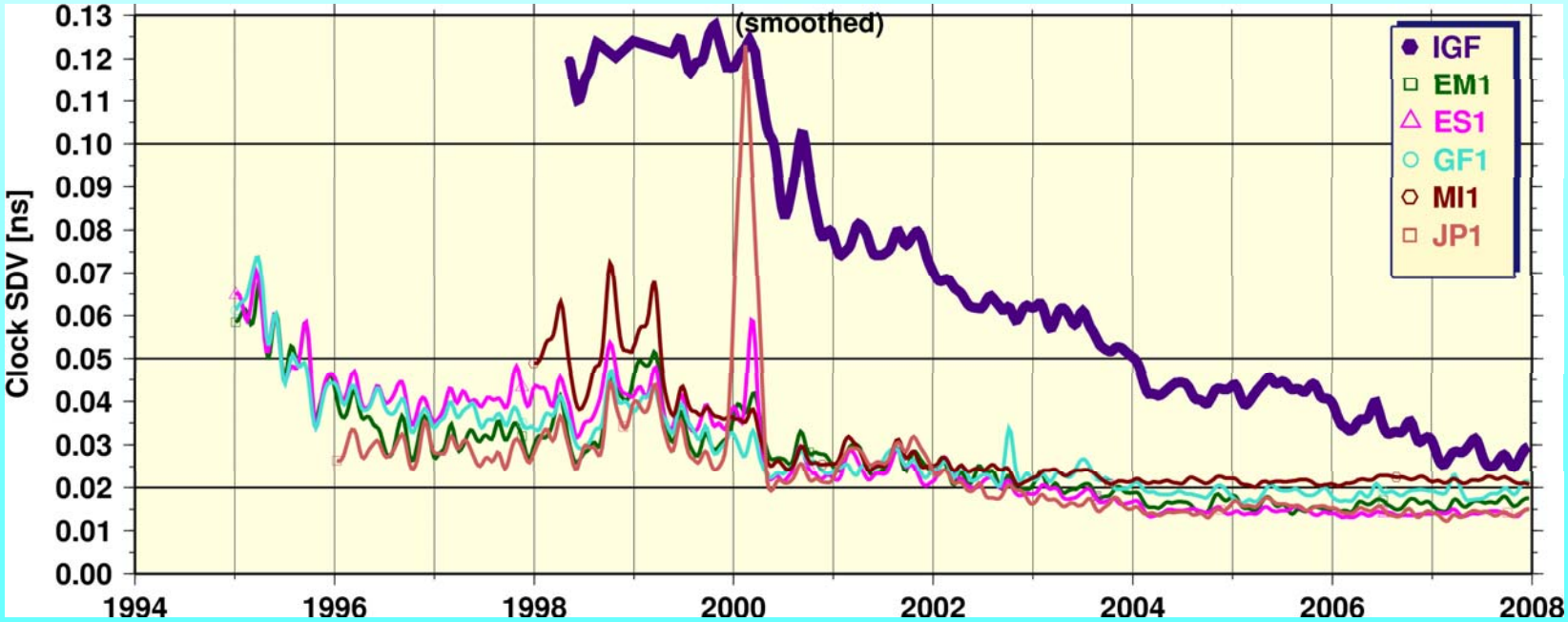
- There are some issues in aligning orbits, ERP and SINEX products



Clock Combination

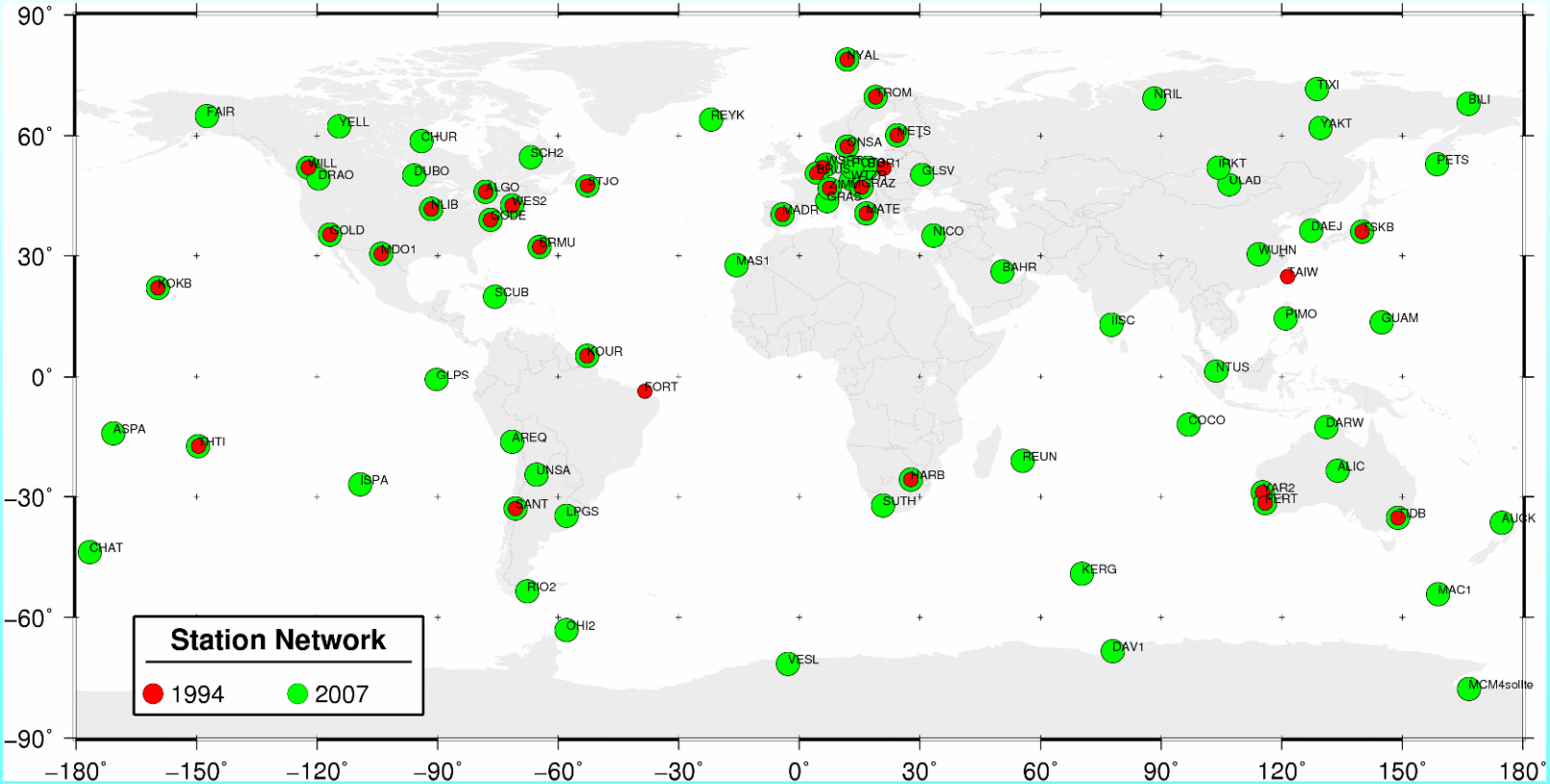
- Number of ACs increased from 1 to 5 submissions (1994 only GF1 !)
- Actual used contributions are sometimes smaller (blue) even after 1998 it goes down to 3 (or 2)
- After May 2000 more stable contributions





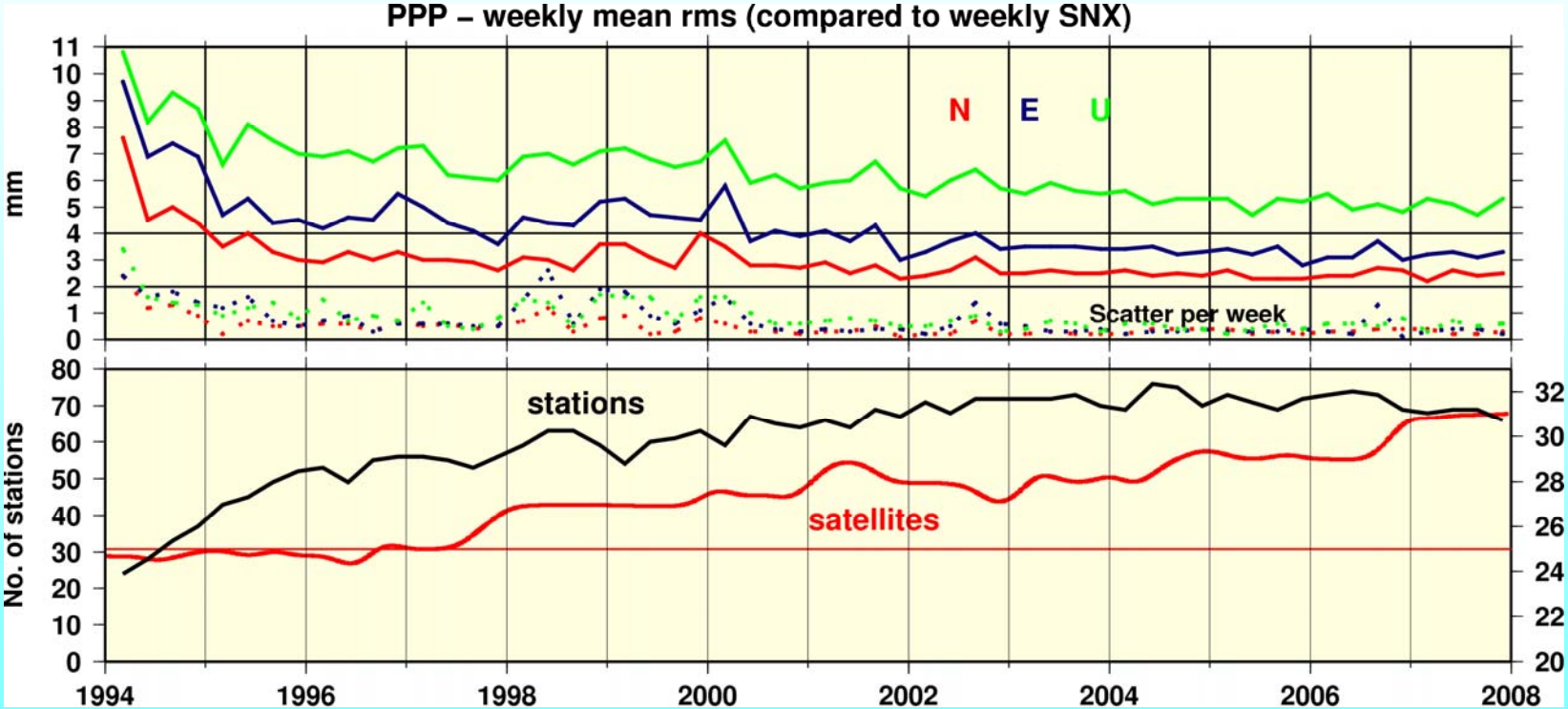
PPP – Analysis using IG1

- PPP with IG1 SP3 and clocks; each year 4 weeks analyzed
- Network of about 80 stations (goes down to ~25 in 1994)
- Helmert transformations to combined SNX for given week.
- Repeatability within a week (like PPP in operational IGS Final combination)



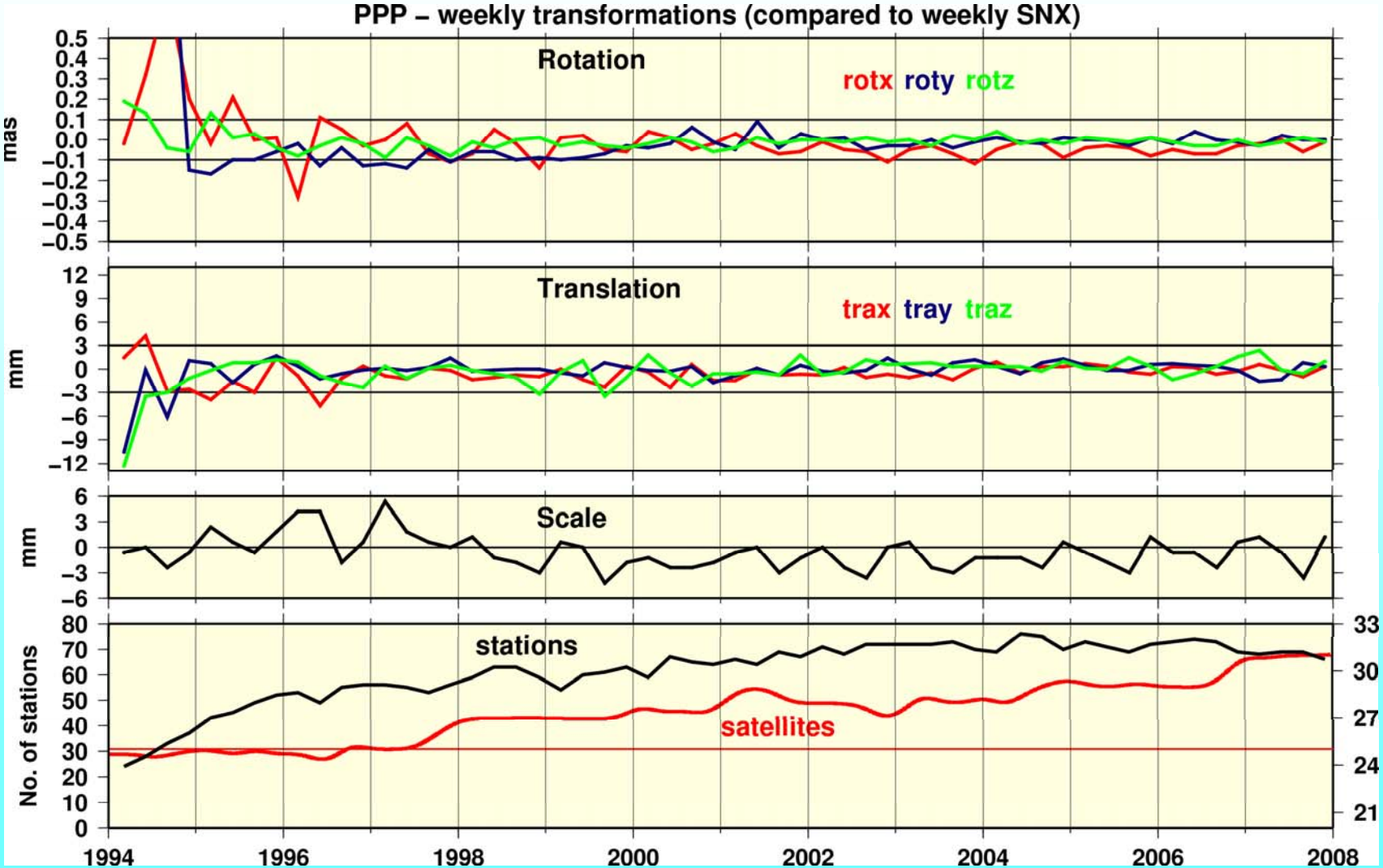
PPP – Station RMS

- **Weekly mean rms fit (over all stations) between the PPP computed station coordinates and the weekly SINEX in N E U (plus number of sta & sat)**



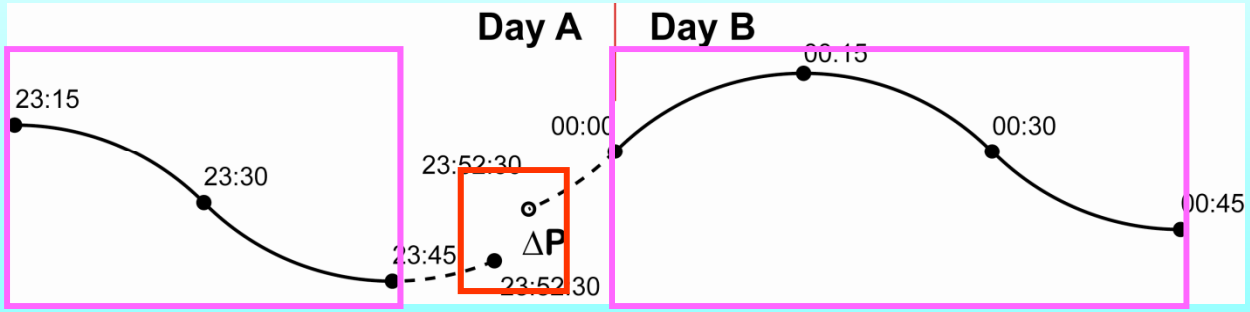
PPP – Frame transformations

- Rotation, translation, scale from that Helmert transformations



Orbit discontinuities

- Fit orbits for each day with BERNE (6+9) orbit model
  - fit orbit SP3 positions as pseudo-observations for Days A & B
  - parameterize daily fit with 3 positions, 3 velocities, plus 3 solar radiation pressure terms in each of 3 directions for each SV
- Propagate daily fits to 23:52:30 epoch on Day A
- Compare SP3 positions at 23:52:30 on Day A
  - 1D magnitude of midpoint discontinuity (ΔP) is:

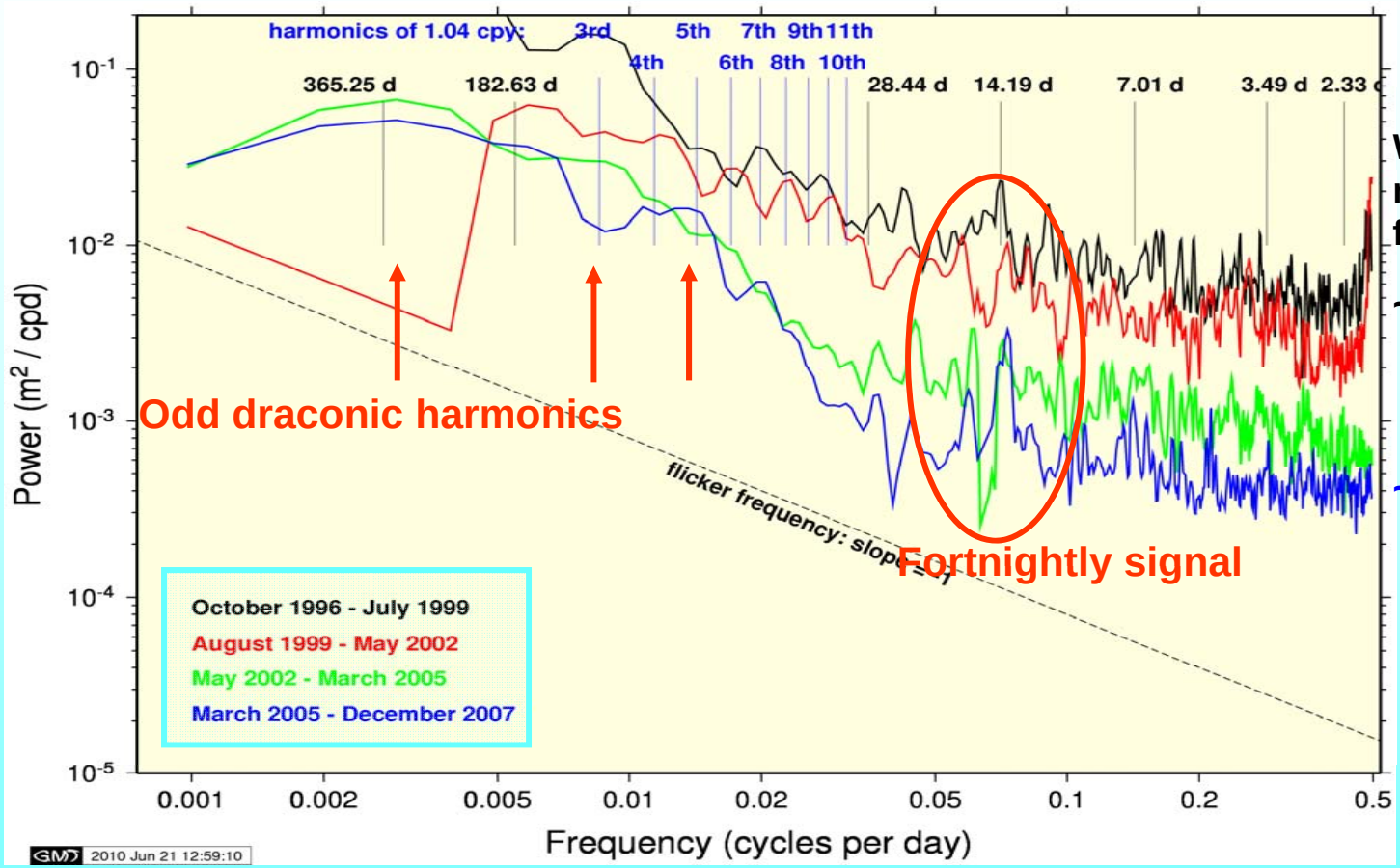


$$\Delta P = \frac{|X_{igs} - X_{calc}| + |Y_{igs} - Y_{calc}| + |Z_{igs} - Z_{calc}|}{3}$$

- The observed orbits spectra have been calibrated for the error spectrum of the fit procedure by fits at 23:45:00 [*Griffiths & Ray, 2009*]

Spectra for IG1 Orbit Jumps – Along track

- Stacked over all SVs & lightly smoothed

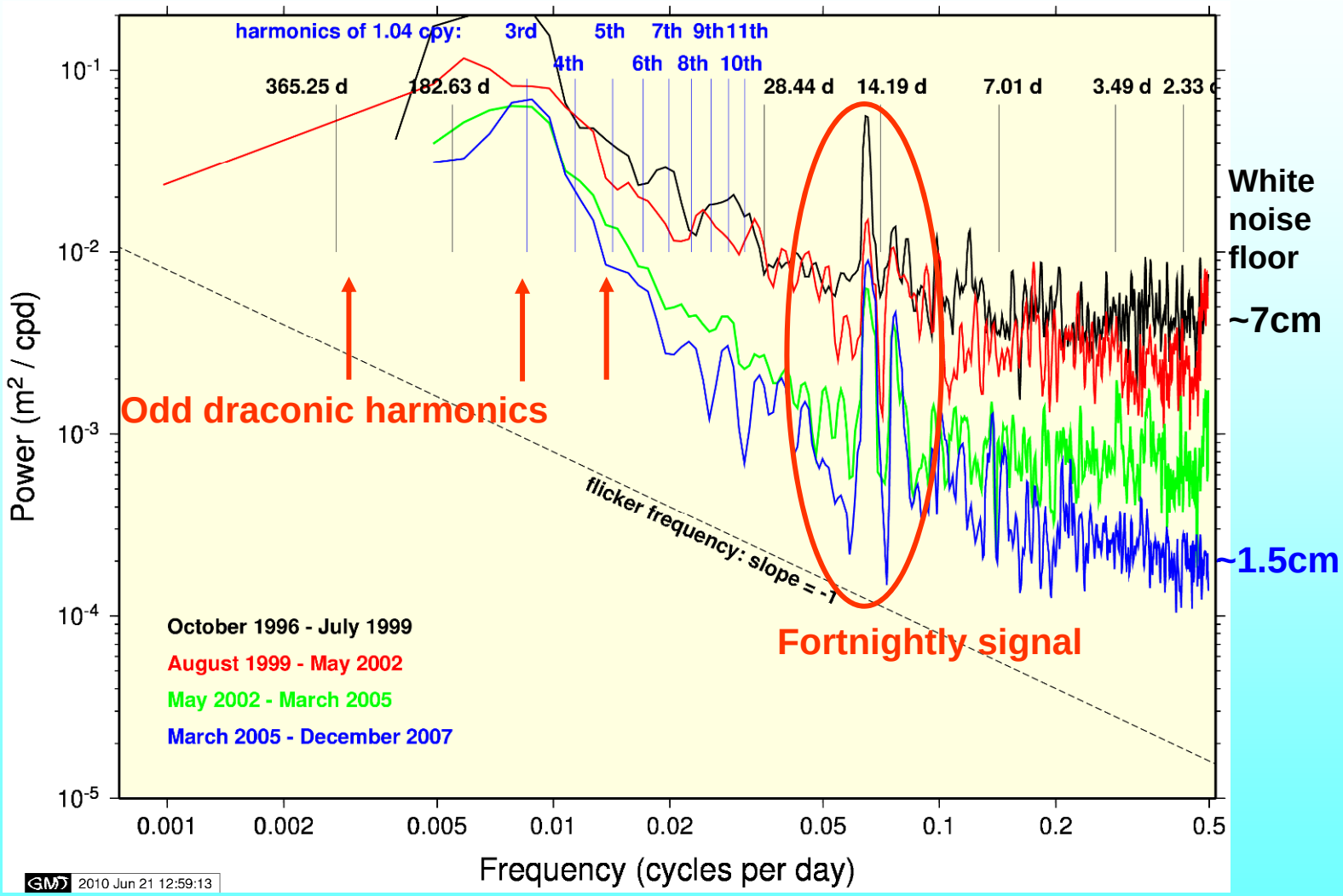


White noise floor ~5cm

~2cm

- Background errors follow ~flicker noise on seasonal time scales
- Improvement of white noise floor form 1996 to 2007: factor 3
- Unexplained peaks at fortnightly frequencies and odd draconic harmonics

Spectra for IG1 Orbit Jumps – Cross track



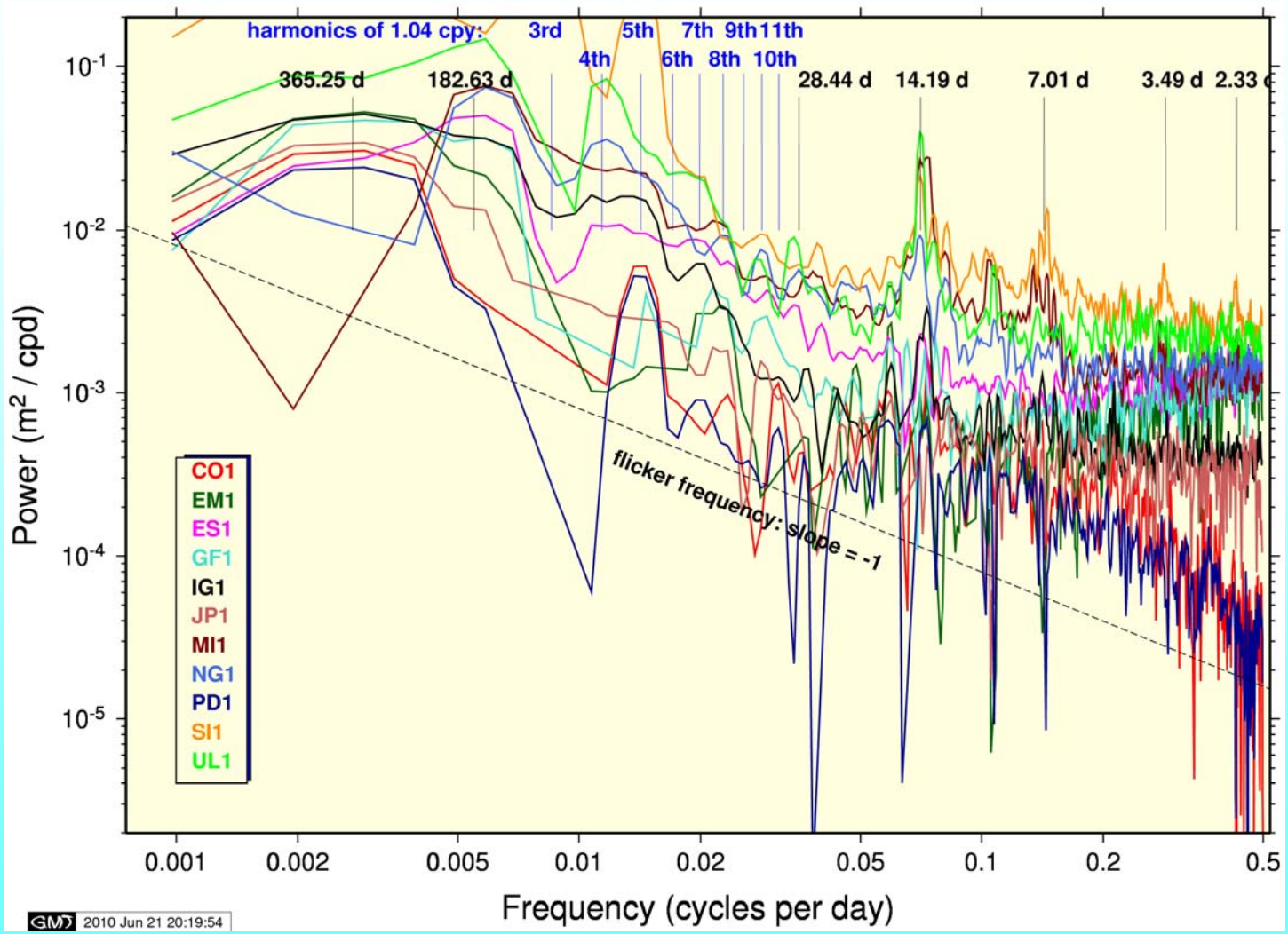
White noise floor

~7cm

~1.5cm

Spectra for AC Orbit Jumps – Along track

- **Interval Mar 2005 – Dec 2007**



IG1 (2 cm)
JP1 30h arc (1.7cm)

PD1 3d arc
CO1 3d arc (0.5cm)

Summary

- IG1 Products available at CDDIS (named repro1)
- Products are aligned to IGS05 !!! (orbits and clocks)
- Based on orbit jumps, precision/accuracy of IG1 orbits ranges from
  - ~7/sqrt(2) cm in 1996 - 1999 to
  - ~2/sqrt(2) cm in 2005 - 2007
- Orbits and clocks allow for precise PPP with
  - precision of 3-4 mm horizontal and 5-6 mm up after 2000
  - and about 50% worse going back to 1996,
  - before 1996 there may be some issues, especially in the frame alignment.

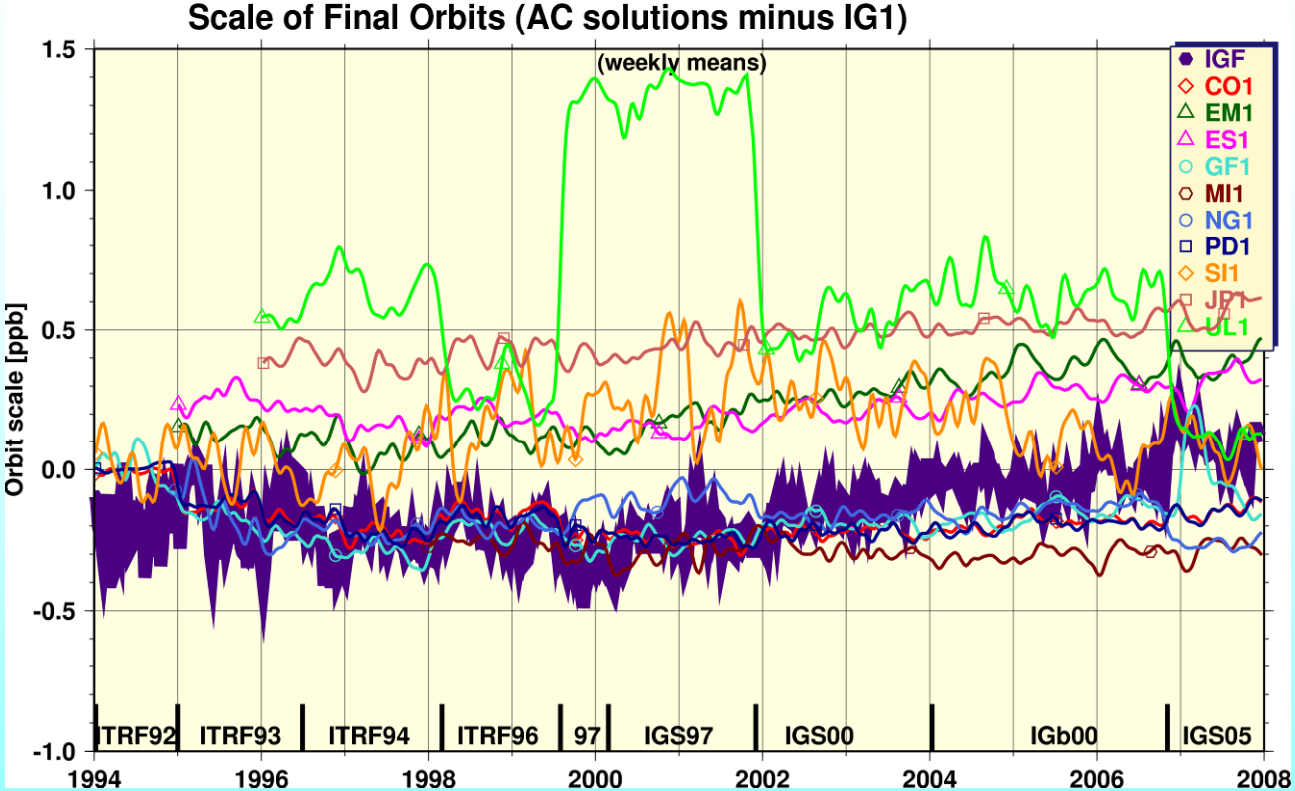
- We thank all the ACs for their enormous effort in realizing this reprocessing results
- The closer evaluation of the ACs submission will allow them to resolve some identified problems for the next reprocessing.

GFZ
Helmholtz Centre
POTSDAM

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

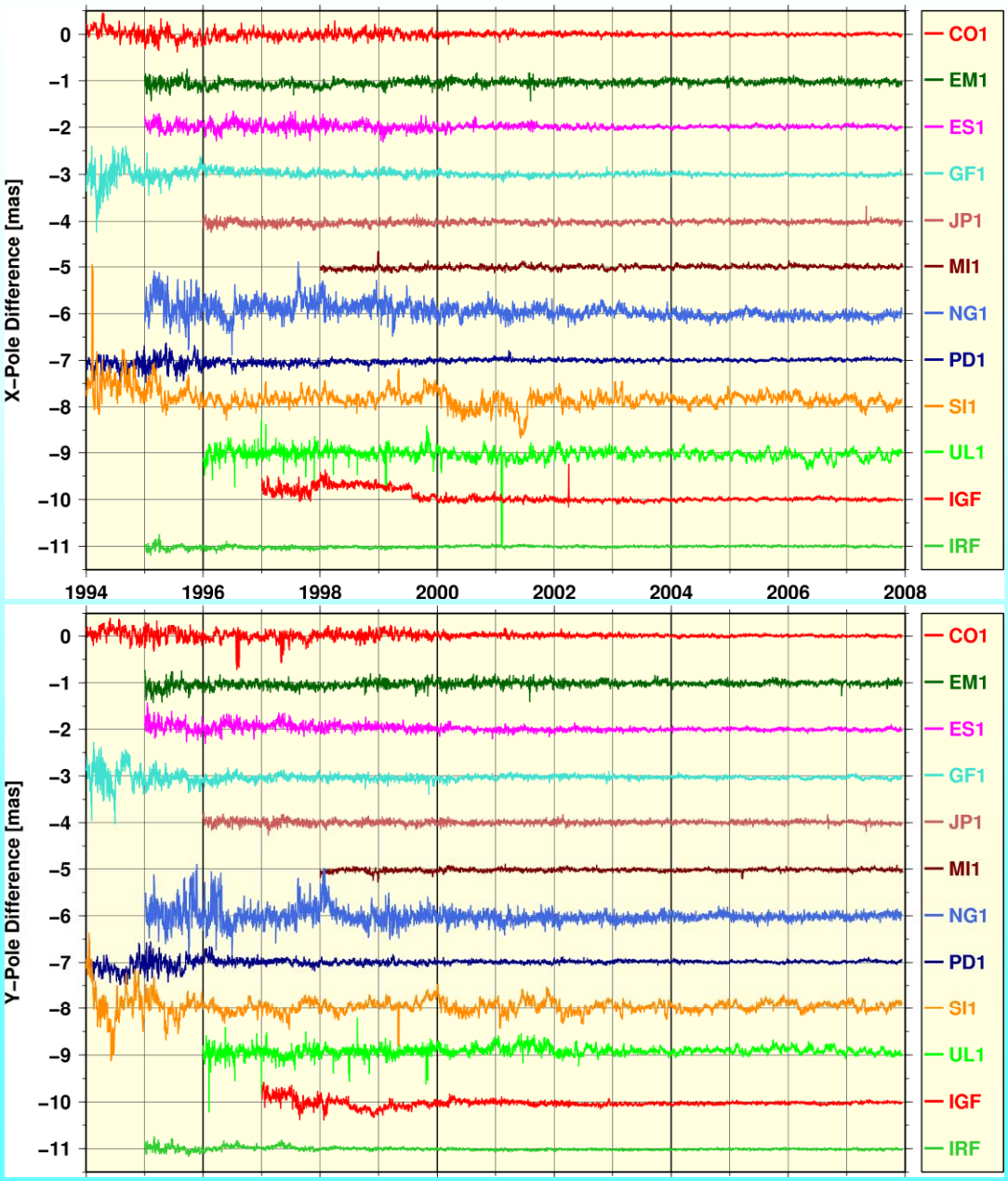
Thank you for your attention

Orbit Frame Differences: Scale



- Scale bias for each ACs
- Higher fluctuations for UL1 and SI1

ERP X&Y

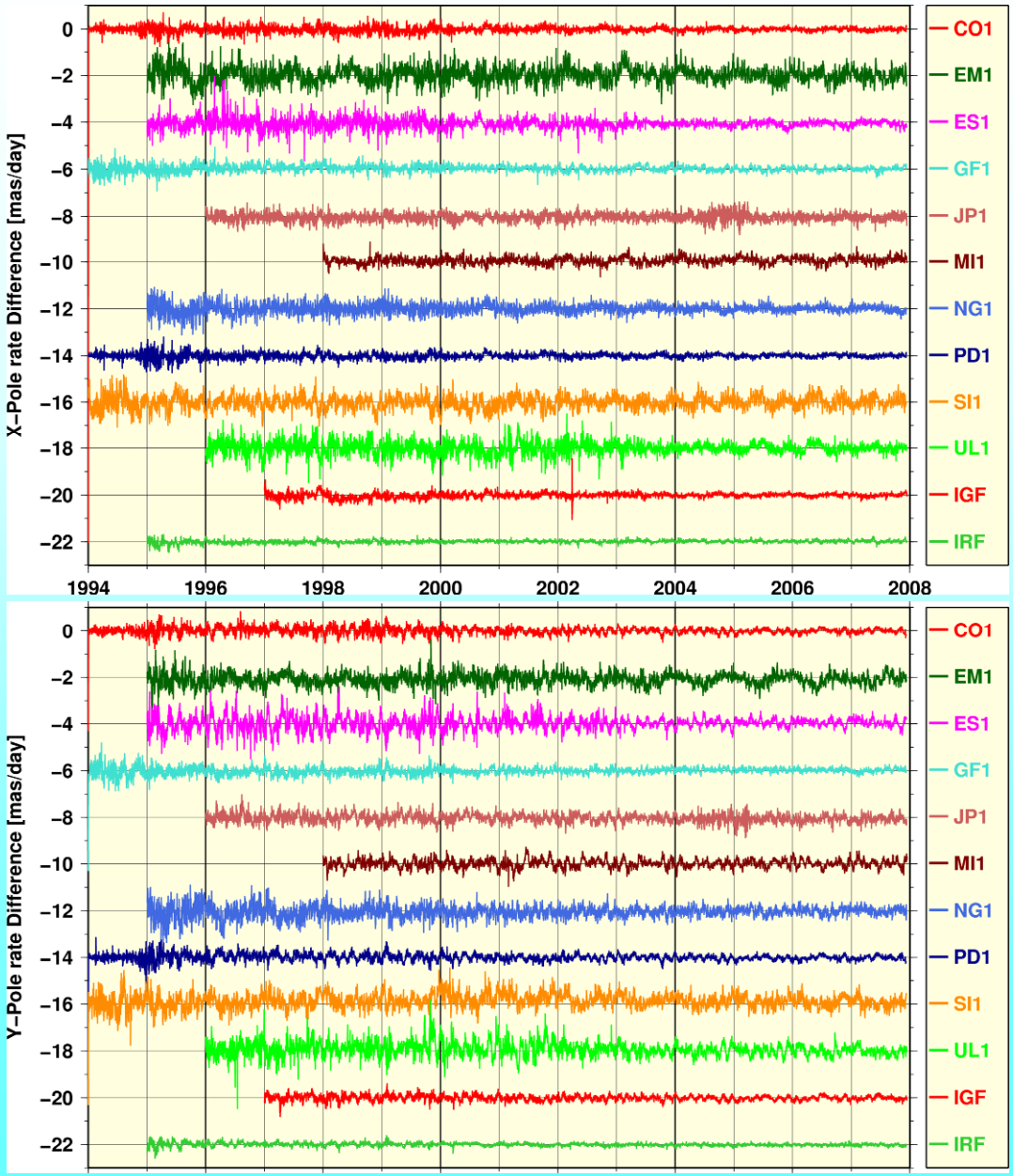


- AC RMS differences

XP µas	1996 -1999	2000 -2003	2004 -2007
CO1	75	36	22
EM1	95	63	49
ES1	88	45	34
GF1	68	40	27
JP1	68	45	35
MI1	57	39	31
PD1	69	29	24
NG1	234	107	78
SI1	228	209	173
UL1	115	171	107

- Good consistency among AC's ERPs
- IG1 and IGS differ in early years
- NG1, SI1 and UL1 have some issues with earlier years

ERP rate X&Y



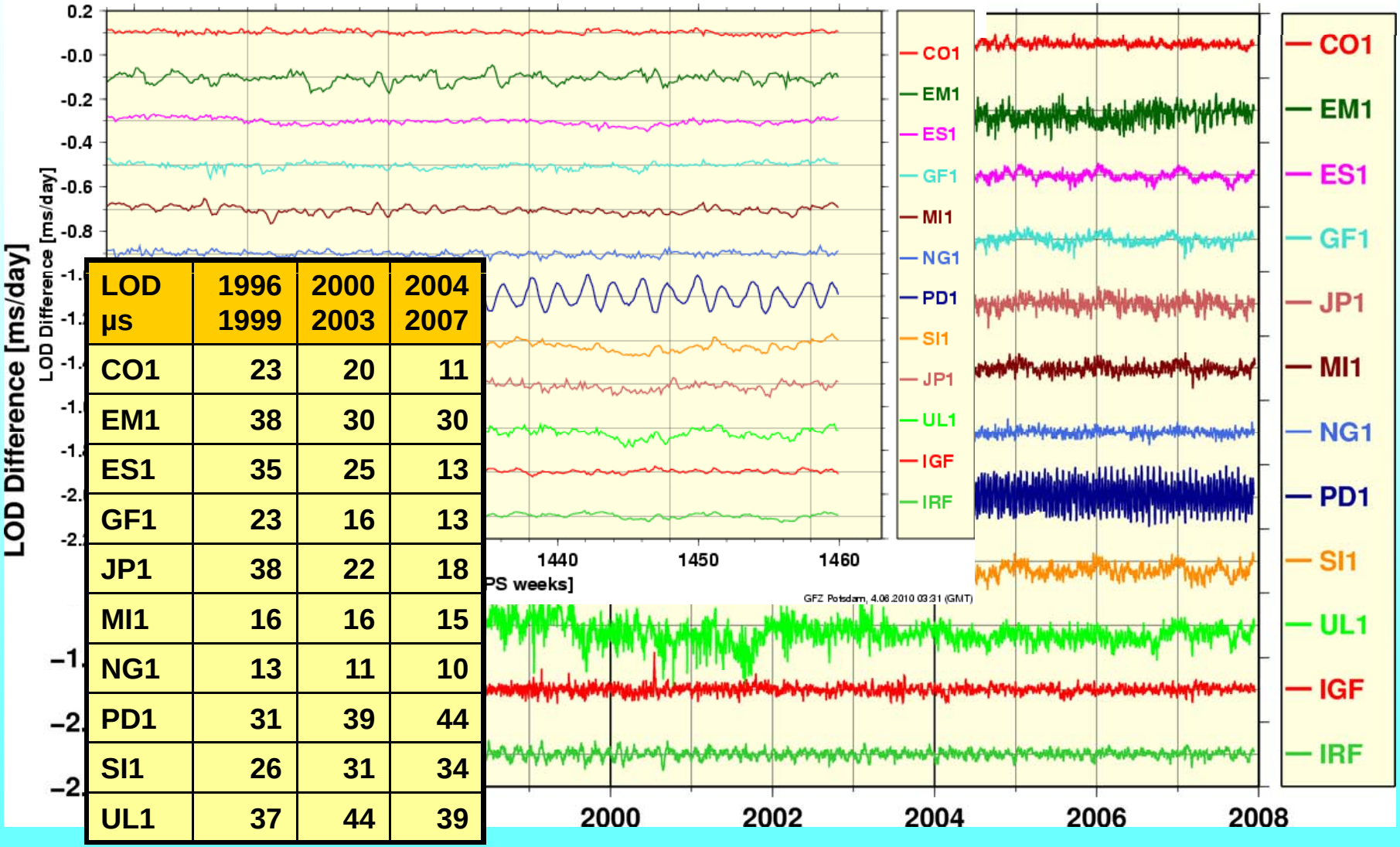
XPrate µas/d	1996 1999	2000 2003	2004 2007
CO1	167	109	78
EM1	330	337	270
ES1	304	194	129
GF1	163	121	97
JP1	188	160	182
MI1	149	165	178
NG1	248	181	134
PD1	138	100	77
SI1	282	279	251
UL1	324	302	171

- ACs with continuity constraints (pos and rate): CO1, GF1, PD1,

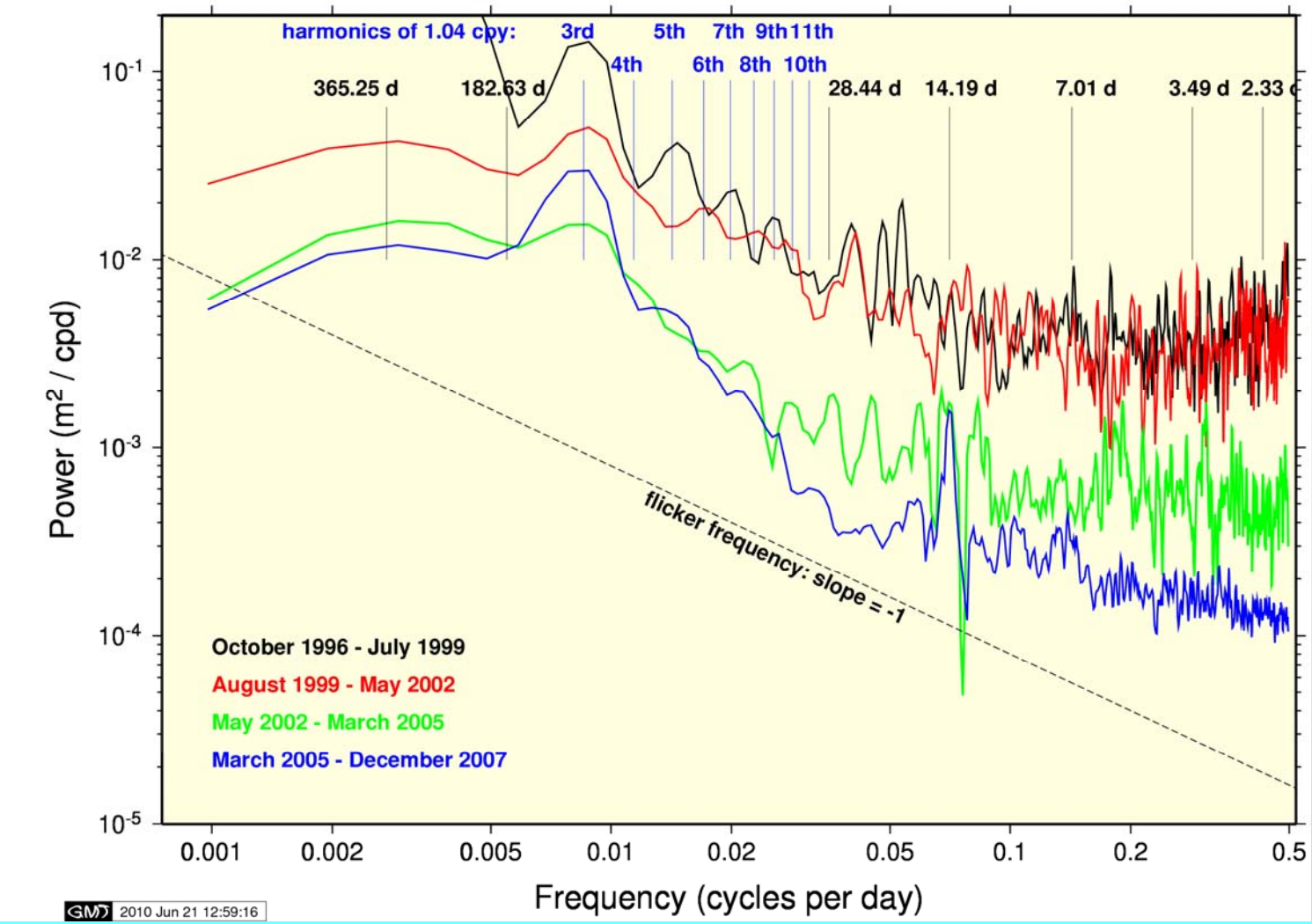
LOD

- Tidal effects at PD1 ?

LOD µs	1996 1999	2000 2003	2004 2007
CO1	23	20	11
EM1	38	30	30
ES1	35	25	13
GF1	23	16	13
JP1	38	22	18
MI1	16	16	15
NG1	13	11	10
PD1	31	39	44
SI1	26	31	34
UL1	37	44	39



Spectra for IG1 Orbit Jumps - Radial



White noise floor

~6cm

~1.3cm