Subdaily Earth rotation observed by GPS and VLBI

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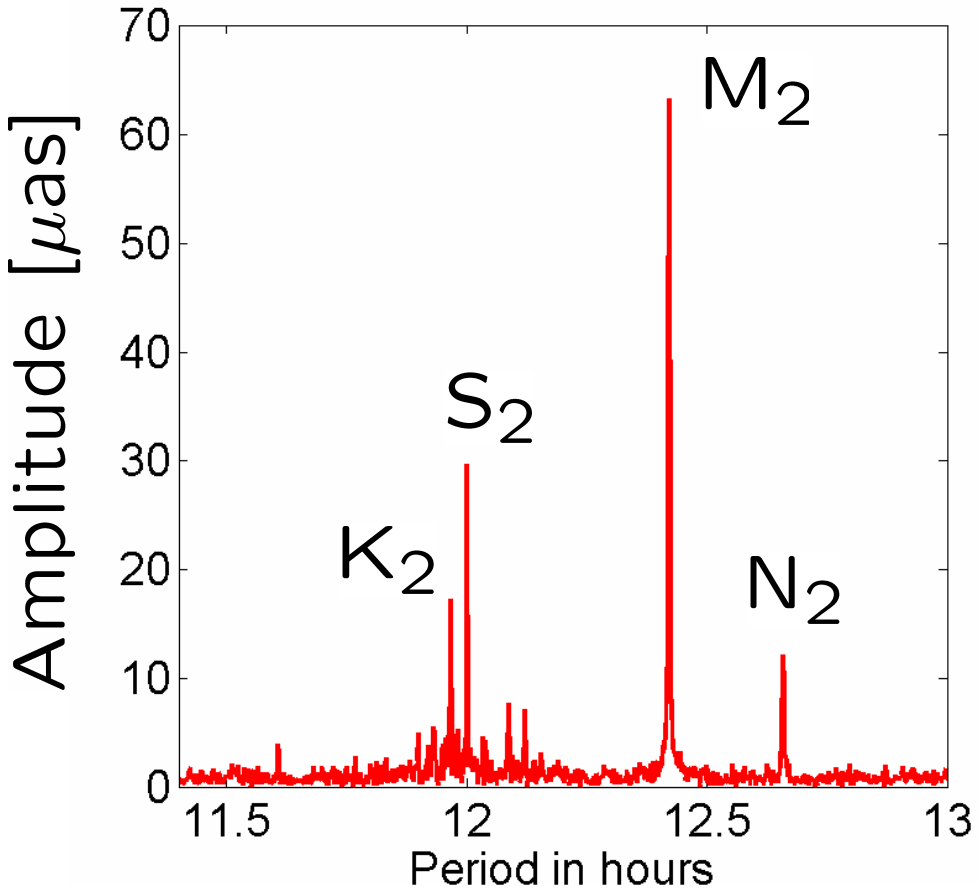
Introduction

Subdaily variations in Earth rotation are primarily driven by **ocean tides**

Outline:

- Estimation of ocean tidal amplitudes from:
  - **VLBI** solutions by DGFI and GSFC
  - 2 different reprocessed **GPS** solutions
- Comparison and combination of these models
- Residual signals

GPS-derived semidiurnal polar motion spectrum



Subdaily GPS Solutions

Complete and **homogeneous reprocessing** of a global GPS network with the **Bernese GPS Software** 5.1 by TU Munich, TU Dresden and GFZ Potsdam

	TUM08	**TUM07**
Time period	Jan 1994 – Dec 2007	Jan 1994 – Mar 2007
Orbital arc length	**3 days**	**1 day**
Reference frame	IGb00	IGS05
Number of stations	202	241
ERP time resolution	**2 hours**	**1 hour**
	Diurnal retrograde polar motion blocked	
Nutation	Fixed to IAU2000A	

Subdaily VLBI Solutions

Independent solutions computed with **different** software packages

	DGFI08	GSFC07
Time period	Jan 1984 – Dec 2006	Apr 1980 – Jul 2007
Institution	DGFI	GSFC
Software	**OCCAM**	**CALC/SOLVE**
ERP time resolution	1h	1h
Constraints PM	50 mas	45 mas/d for rates
Constraints UT	3 ms	3 ms/d for rates
Nutation	Fixed to (smoothed) estimates of a reference frame solution	

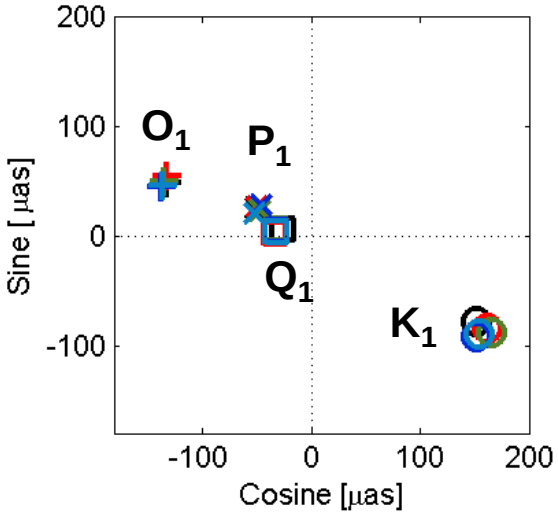
Estimation of Subdaily ERP Models

- Estimation of **57 polar motion** (PM) and **41 UT1** ocean tidal amplitudes in a least squares adjustment
- Pseudo-observations:
  - GPS: **polar motion rates, length of day**
  - VLBI: **polar motion, UT1**
- **Weighting** of the pseudo-observations with their **formal errors**
- **Constraints** for sidebands that cannot be solved for

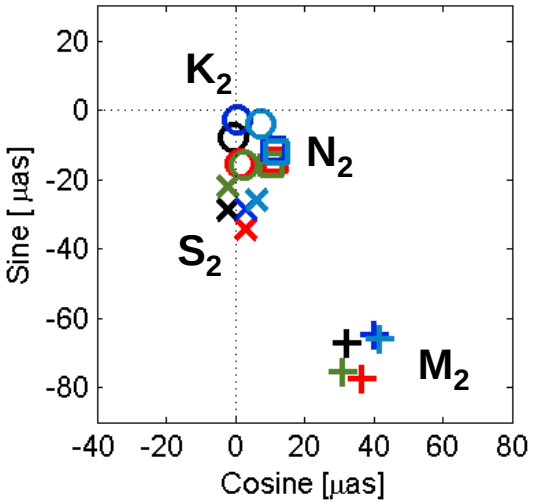
Major Tidal Amplitudes

Polar Motion

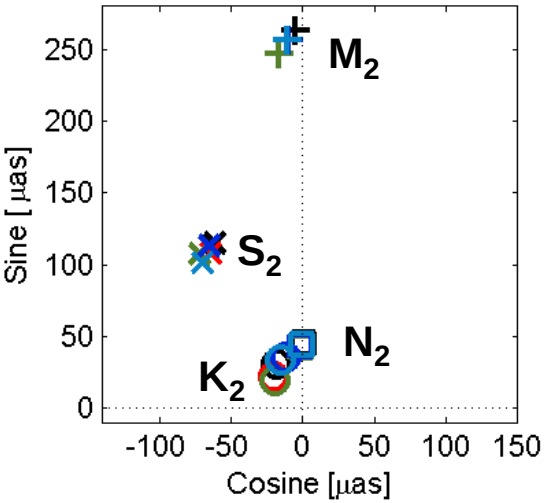
Diurnal prograde



Semi-diurnal prograde

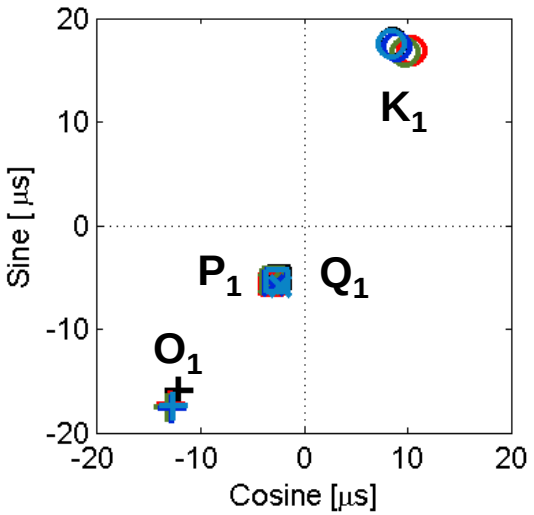


Semi-diurnal retrograde

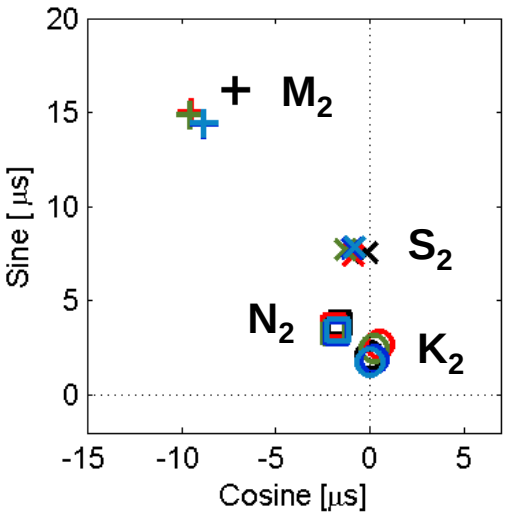


UT1

Diurnal



Semi-diurnal



DGFI08

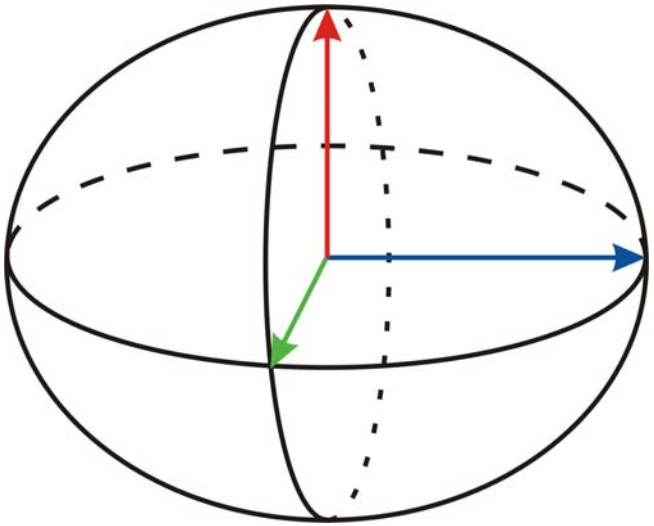
GSFC07

TUM08

TUM07

IERS2003

Libration



Triaxial shape of the Earth

$$a \neq b \neq c$$

Additional tidal torques:

$$L_z = \frac{3GM(B-A)}{2r^3} \sin^2\Theta \sin 2(\Lambda - \Lambda_0)$$

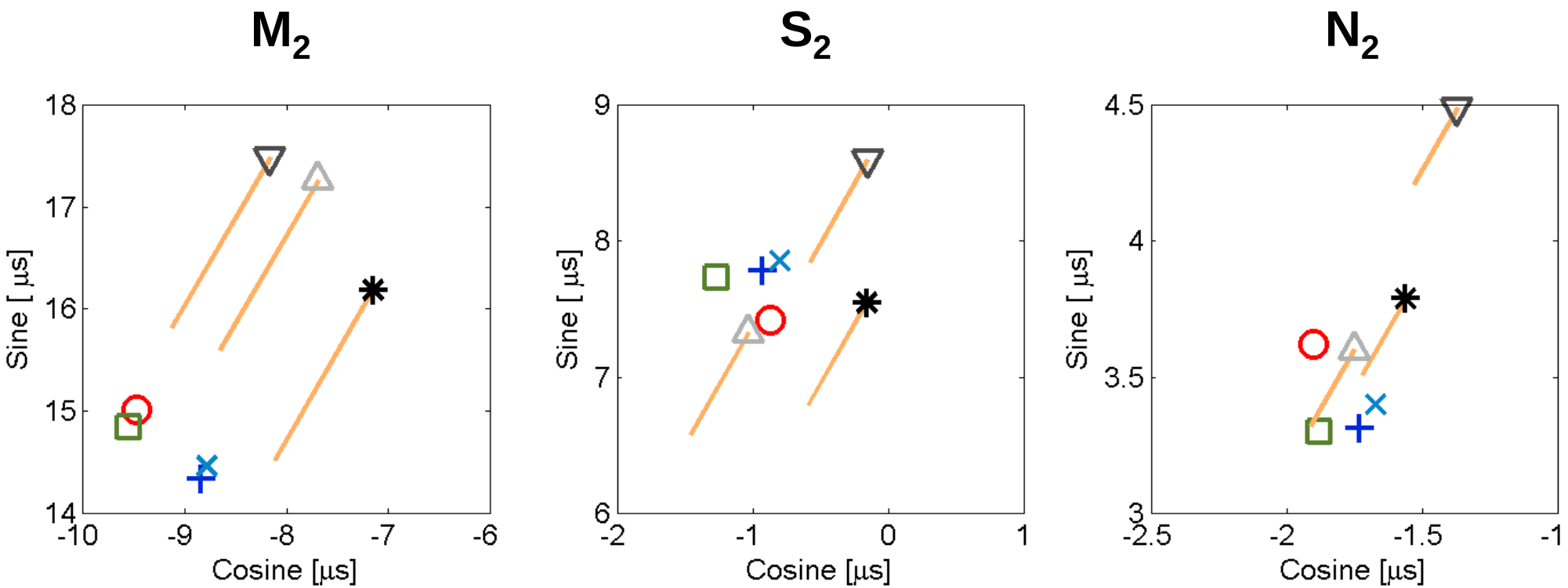
$$L_{xy} = -\frac{3iGM(B-A)}{4r^3} \sin 2\Theta e^{-i(\Lambda - 2\Lambda_0)}$$

Semidiurnal spin libration

Diurnal prograde polar motion libration

Chao et al. 1991

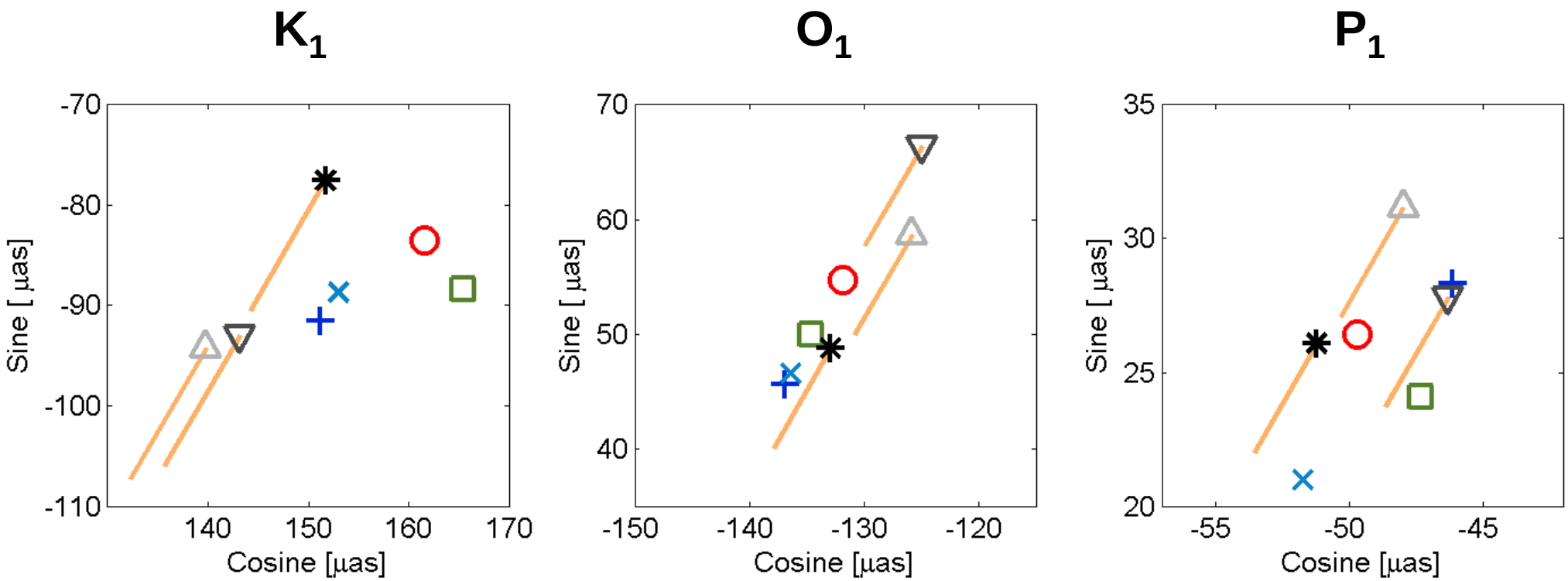
Semidiurnal Spin Libration



VLBI	GPS	Altimetry	
DGFI08	TUM08	▽ TPXO.6	✱ IERS2003
GSFC07	TUM07	△ GOT99.2	

Libration
Chao et al. 1991

Diurnal Polar Motion Libration



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Comparison of Subdaily ERP Models

Mean **RMS differences** of estimated amplitudes

PM in μas	GSFC07	TUM08	TUM07	IERS2003	IERS2003 +Libration
DGFI08	2.7	4.5	4.9	4.5	5.0
GSFC07		4.2	4.7	4.5	4.9
TUM08			3.8	3.3	3.2
TUM07				4.4	4.2

UT1 in μs	GSFC07	TUM08	TUM07	IERS2003	IERS2003 +Libration
DGFI08	0.25	0.34	0.44	0.56	0.50
GSFC07		0.34	0.44	0.59	0.51
TUM08			0.28	0.48	0.38
TUM07				0.50	0.42

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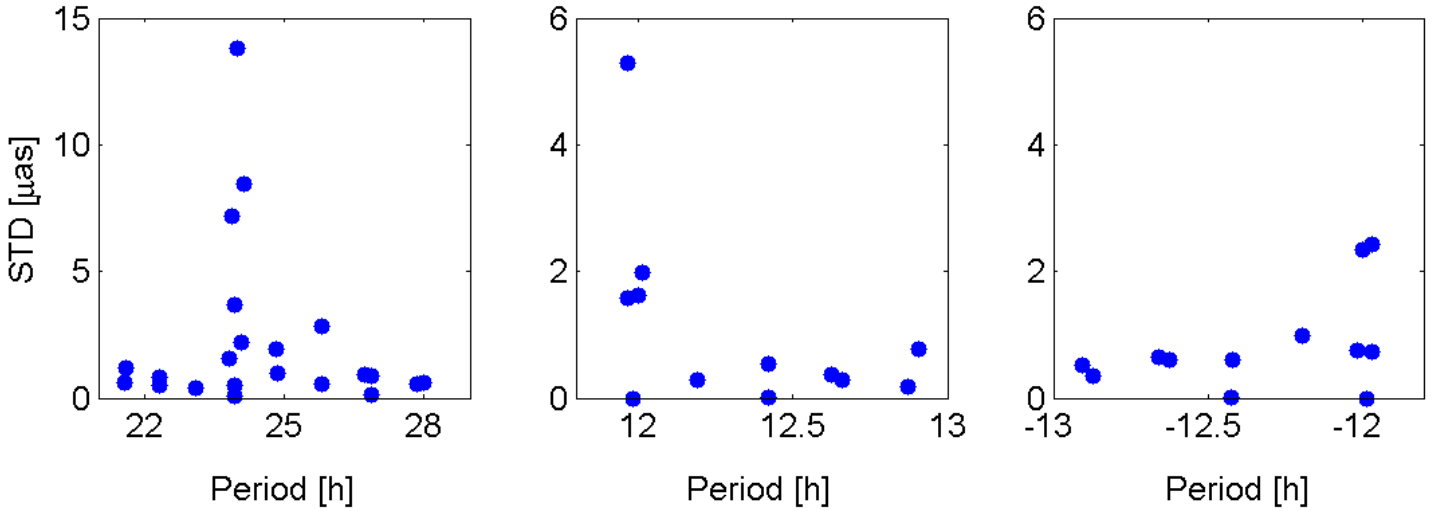
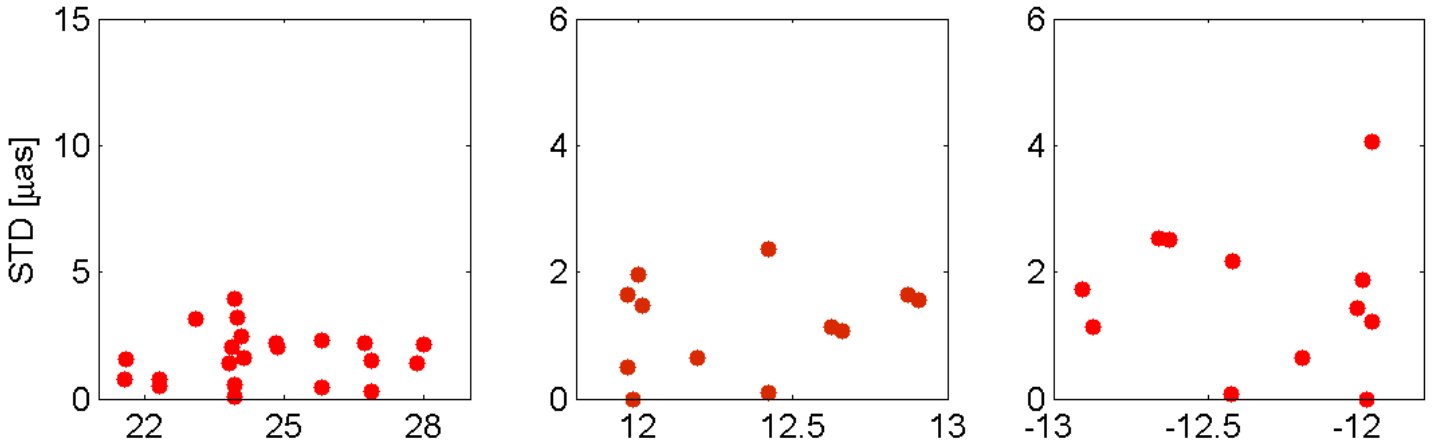
Stability of Subdaily ERP Amplitudes

Standard deviations of 7 ERP models estimated from different time windows



Polar motion
GPS: TUM08

6 years GPS data
1994 - 2005
shifted by 1 year



Polar motion
VLBI: GSFC07

11 years VLBI data
1984 - 2006
shifted by 2 years

Stability of Subdaily ERP Amplitudes

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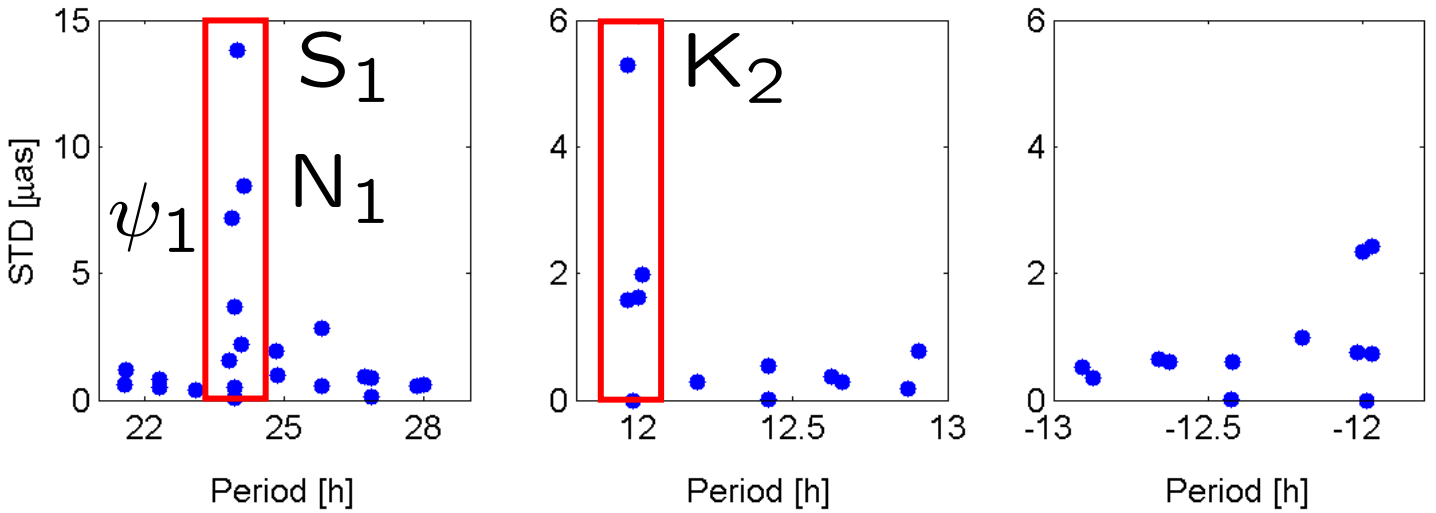

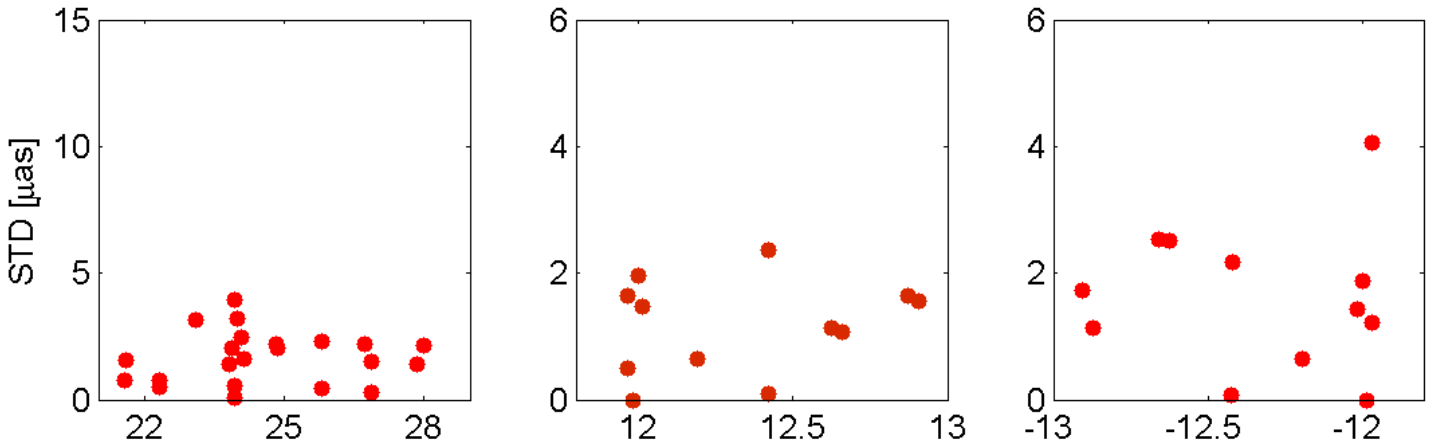

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Impact of GPS Orbit Length

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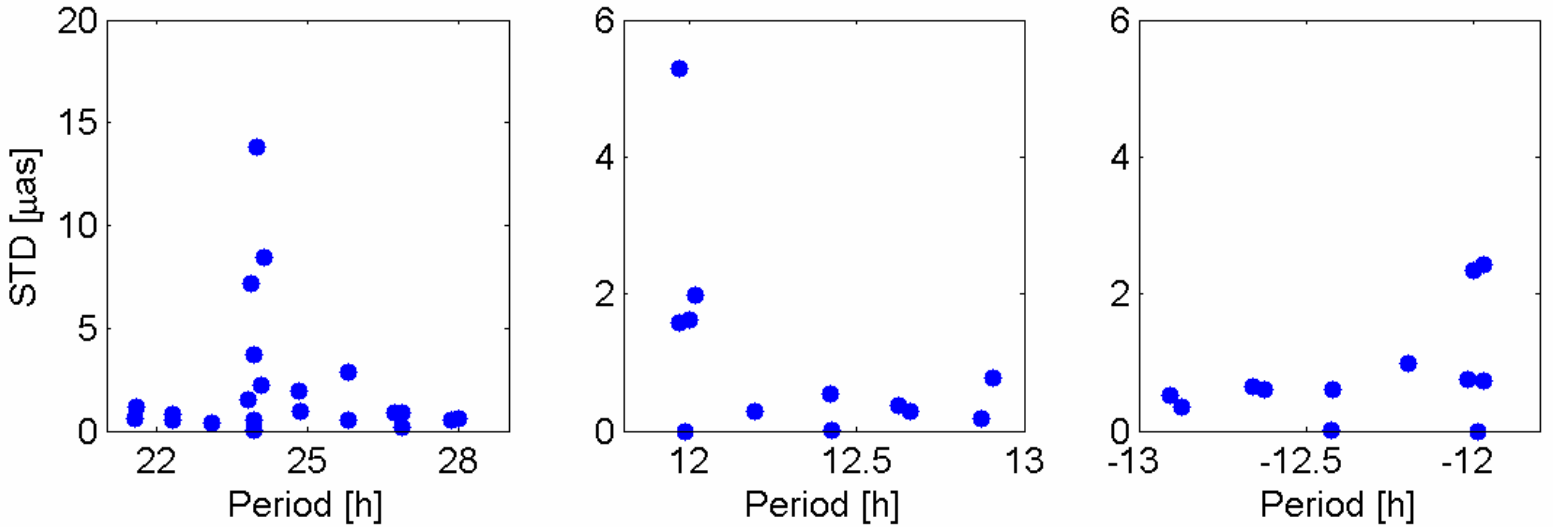
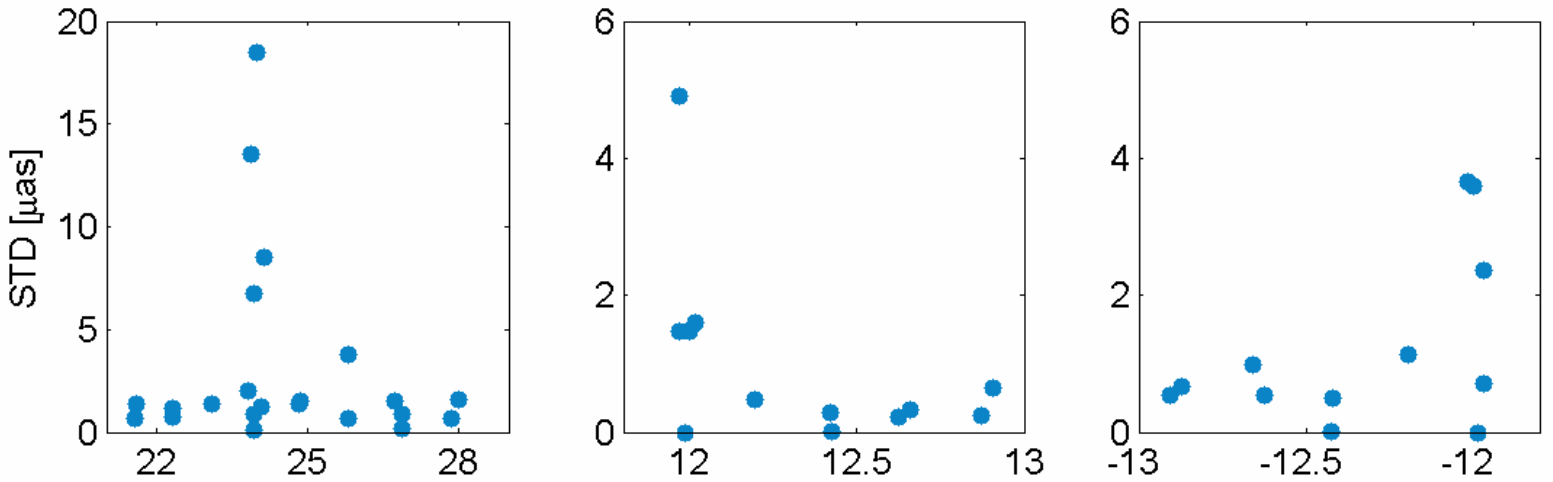


3-day orbits
TUM08

polar motion
2h resolution

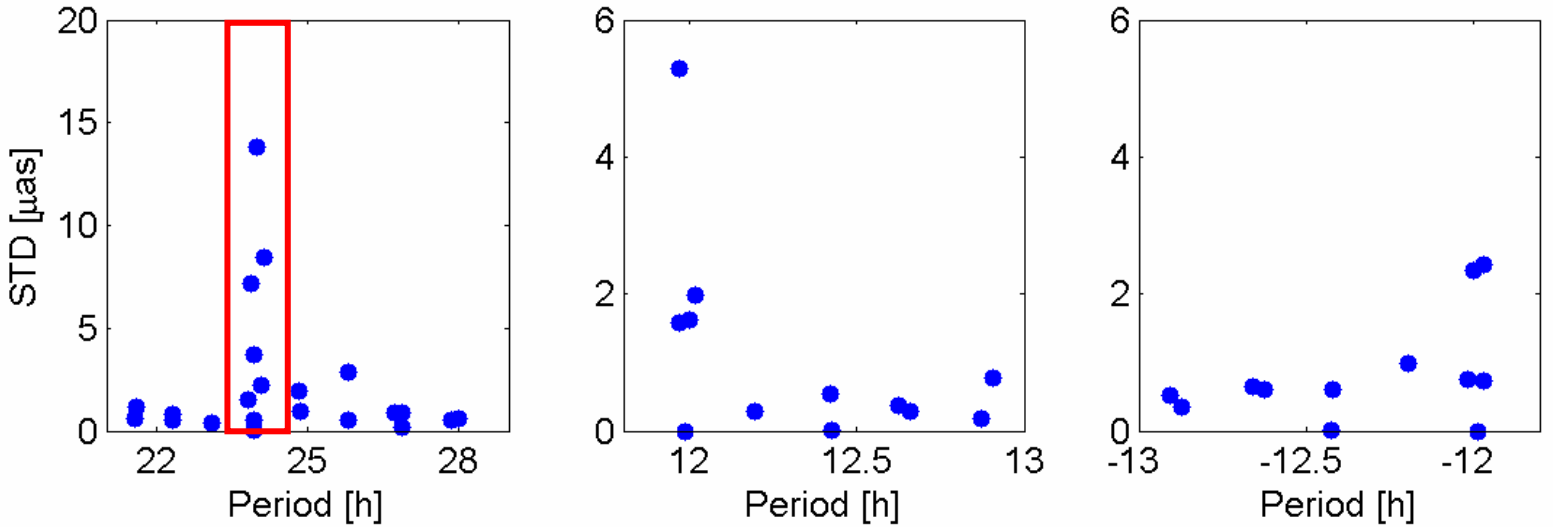


1-day orbits
TUM07

polar motion
1h resolution

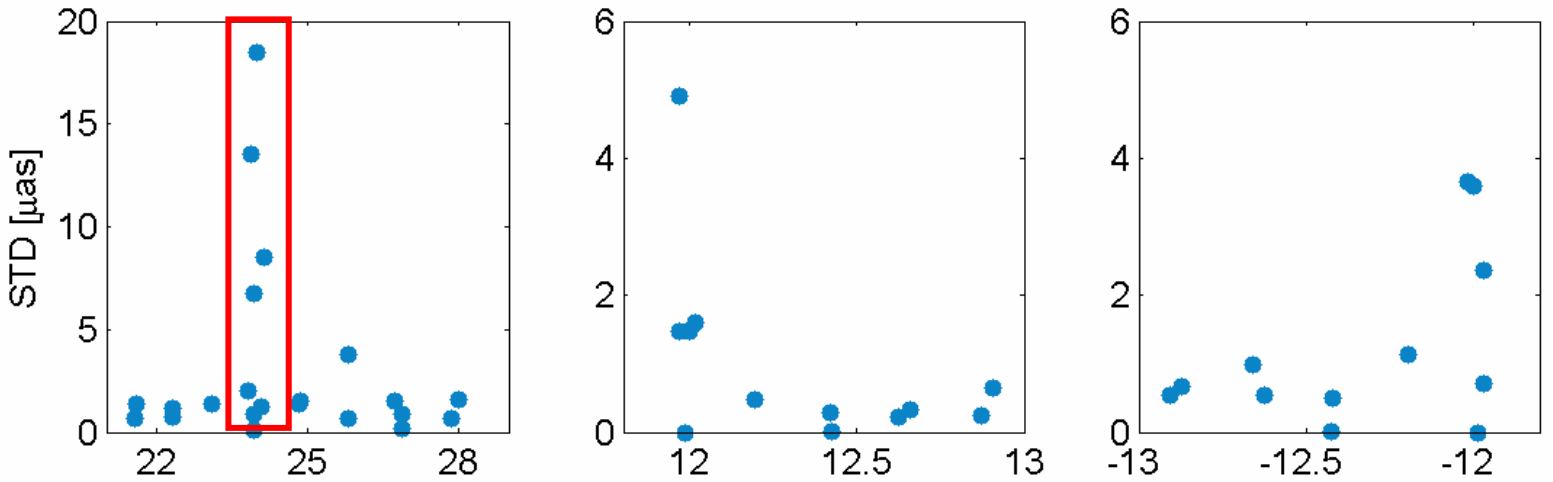
Impact of GPS Orbit Length

Standard deviations of 7 ERP models estimated from different time windows



3-day orbits
TUM08

polar motion
2h resolution

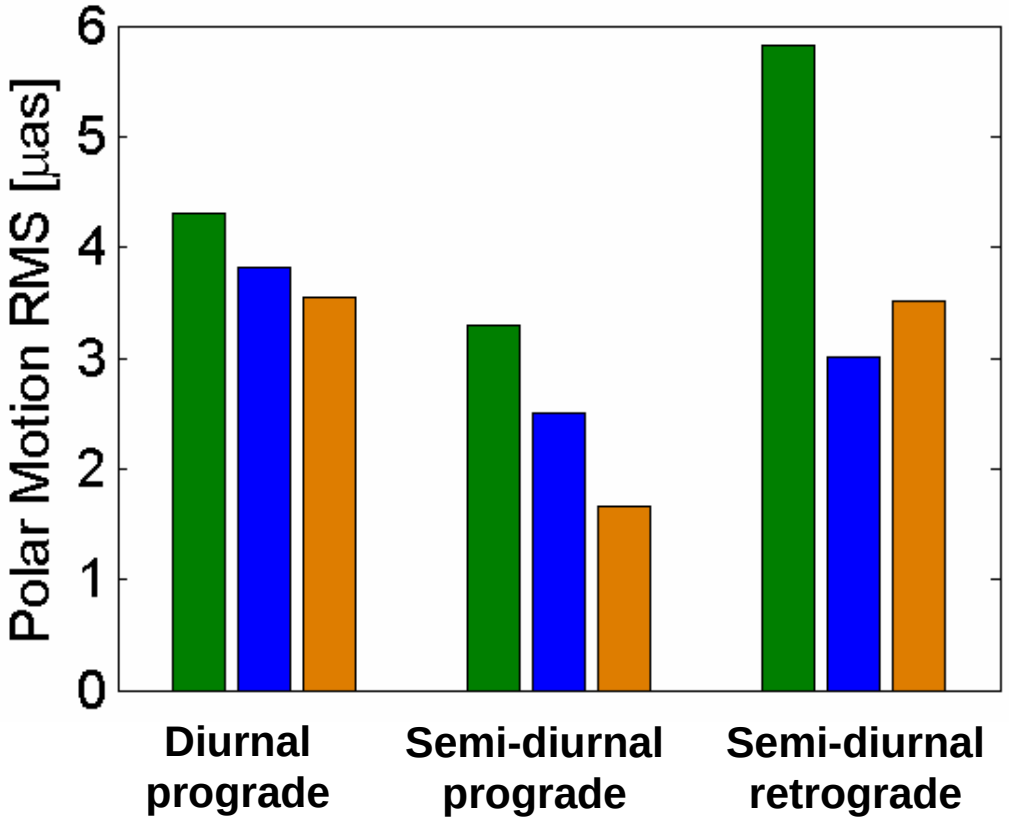


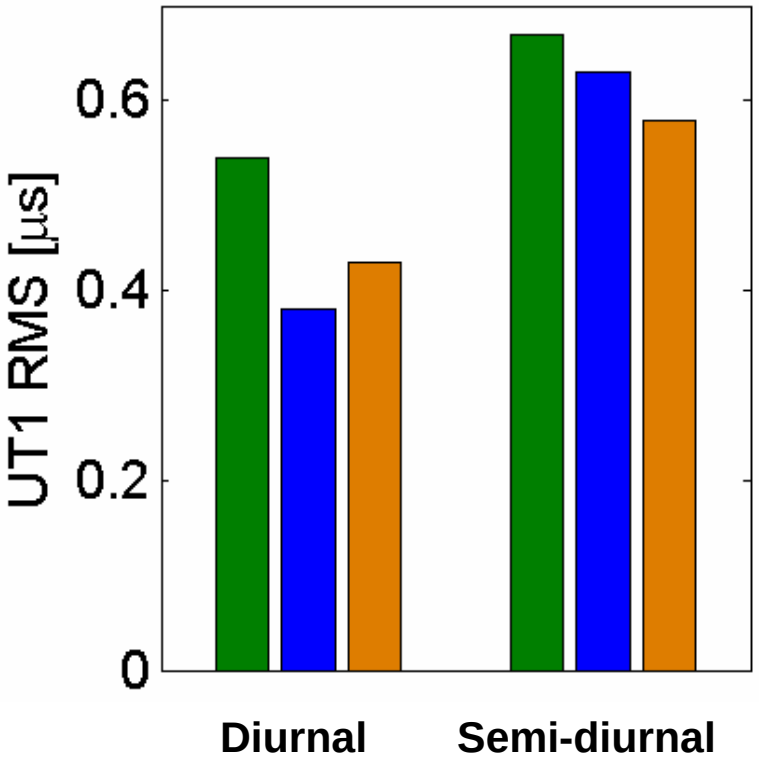
1-day orbits
TUM07

polar motion
1h resolution

Combined GPS/VLBI Model: GSFC07+TUM08

Mean RMS differences of estimated amplitudes w.r.t. IERS2003

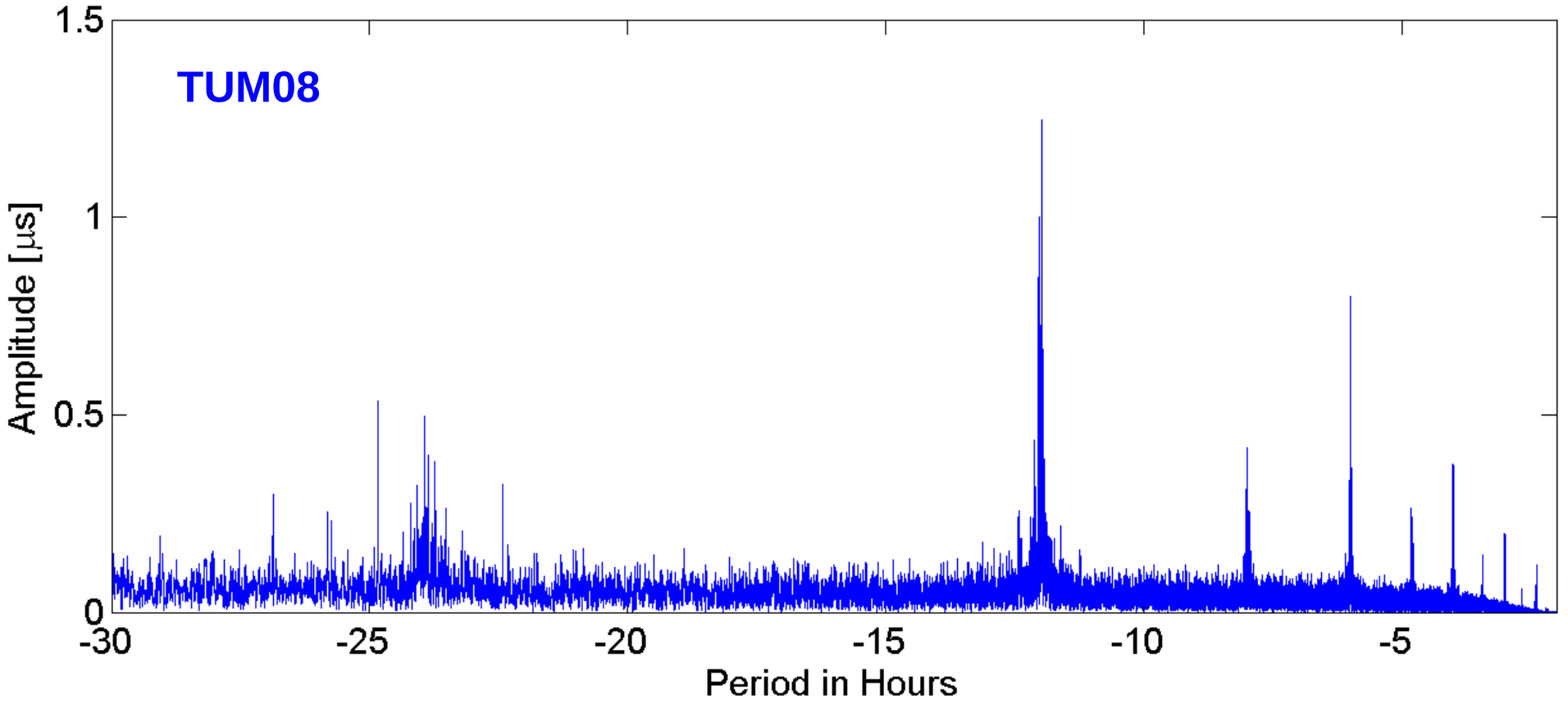




GSFC07 TUM08 Combined

Residual Amplitudes

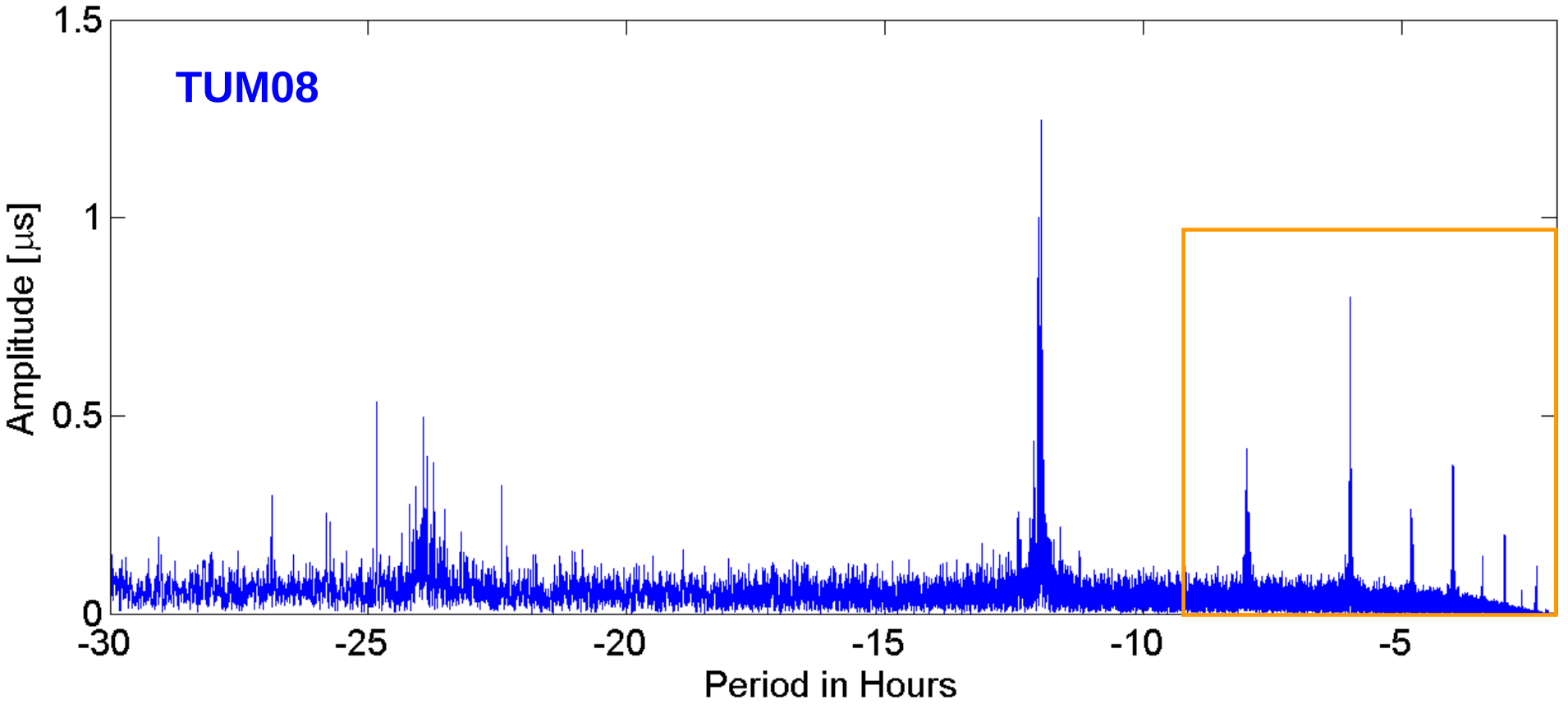
UT1 residual spectrum w.r.t. the estimated subdaily ERP model



Residual Amplitudes

UT1 residual spectrum w.r.t. the estimated subdaily ERP model

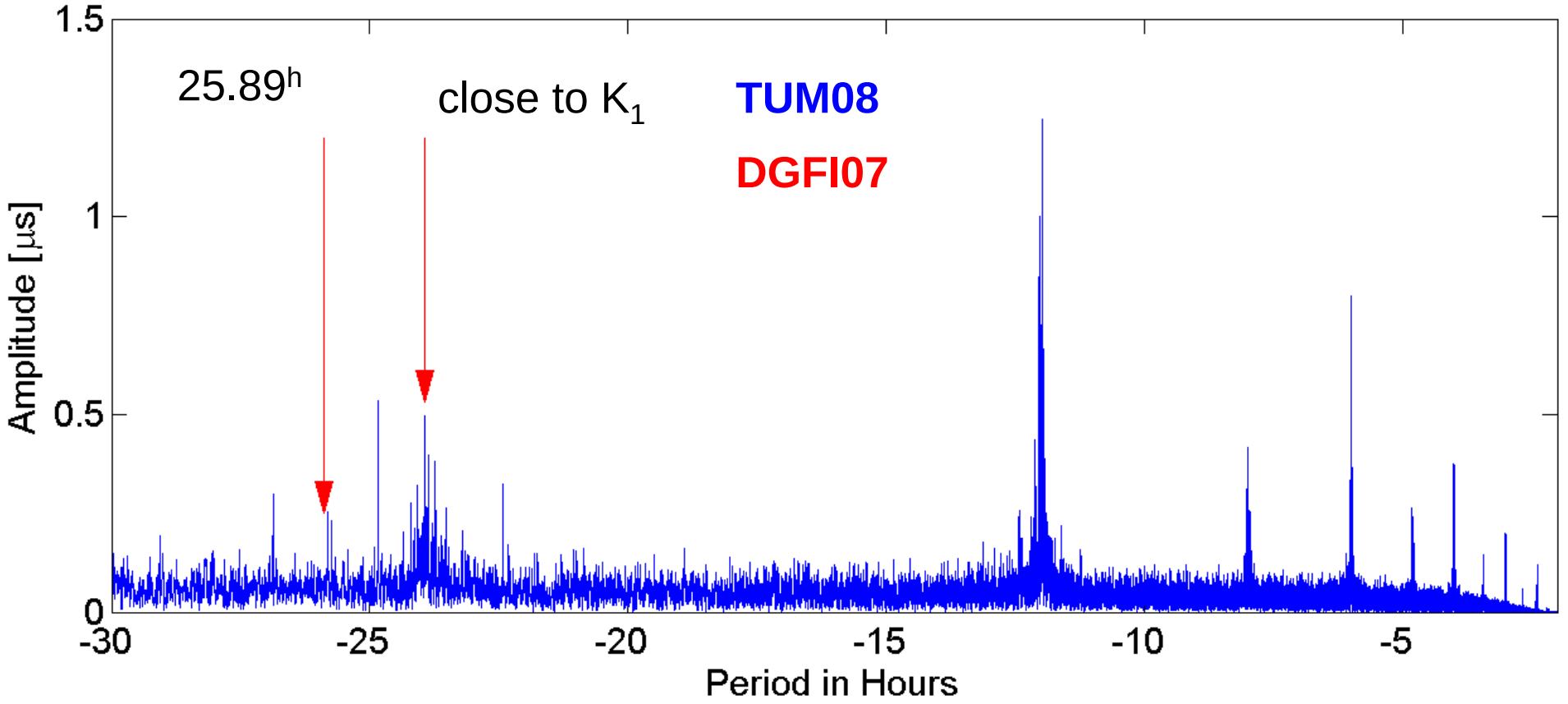
High-frequency peaks at $\frac{24^h}{n}$, $n = 3, 4, ..., 12$



Residual Amplitudes

UT1 residual spectrum w.r.t. the estimated subdaily ERP model

Significant VLBI amplitudes iteratively computed with the CLEAN algorithm



Conclusions

- The GPS- and VLBI-derived major ocean tidal amplitudes have in general:
  - an **accuracy** of about **4-7 μas** for **polar motion** and **0.3-0.7 μs** for **UT1**
  - a **precision** of about **1-2 μas** for **polar motion** and **0.1-0.3 μs** for **UT1**
- **Semidiurnal spin libration** can clearly be detected by GPS **and** VLBI.
- The situation for polar motion libration is less conclusive.
- However, **libration should be included** in the subdaily ERP model recommended by the IERS as the **space geodetic techniques** are **sensitive** to this effect.
- GPS-derived amplitudes close to 12 and 24 hours suffer from systematic effects. Artifacts at high frequencies that are not present in VLBI.
- A **combination of GPS and VLBI data** significantly **reduces** the **differences** w.r.t. the IERS2003 model.