GPS- and VLBI-derived Subdaily Estimates of Earth's Rotation and Their Impact on Global Solutions

Peter Steigenberger, Urs Hugentobler
Technische Universität München

Thomas Artz, Sarah Böckmann
Institut für Geodäsie und Geoinformation, Universität Bonn

Simon Lutz, Rolf Dach
Astronomisches Institut, Universität Bern

Introduction

- Subdaily variations of Earth's rotation are usually accounted for with the model recommended by the IERS Conventions 2003
- Studies of subdaily Earth rotation variations with GPS and VLBI have been carried out since more than a decade
- Study the impact of introducing GPS- and VLBI-derived subdaily ERP models in global solutions

Outline

- Estimation and comparison of subdaily ERP models from GPS and VLBI time series
- Impact of sideband constraints and a priori models
- Impact of different a priori subdaily ERP models on global GPS and VLBI solutions

Subdaily GPS and VLBI Solutions

GPS

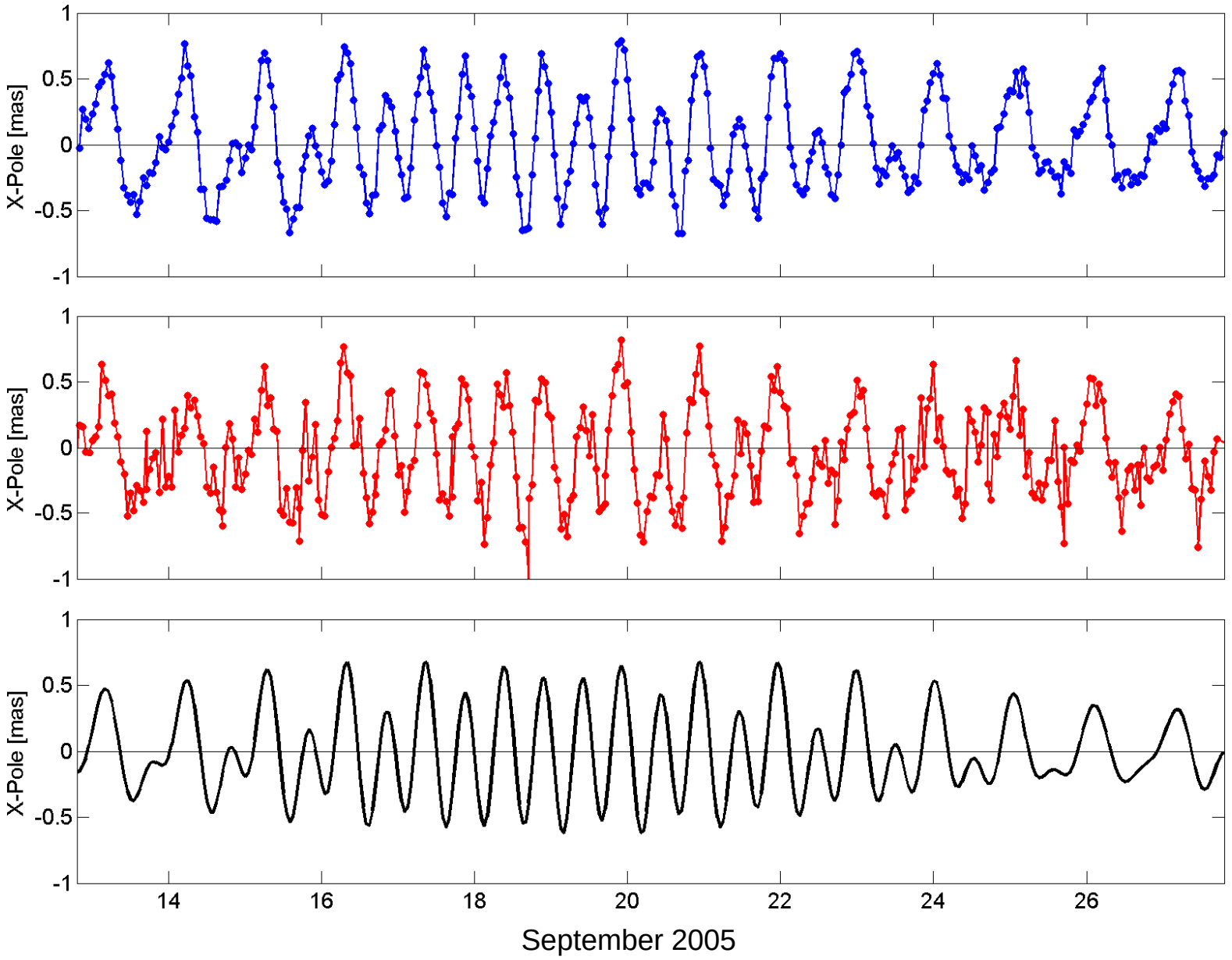
- Bernese GPS Software
- 3-day orbital arcs
- diurnal retrograde polar motion blocked

VLBI

- CALC/SOLVE
- nutation fixed to IVS quarterly solution IVS09q2e

Solution	Technique	Resolution	Time period
TUM08	GPS	2h	Jan 1994 – Dec 2007
COD09	GPS	1h	Jan 1994 – Dec 2008
IGG09	VLBI	1h	Mar 1984 – Dec 2008
TUM08C	GPS/VLBI	2h/1h	Apr 1980 – Dec 2007

Subdaily GPS and VLBI Solutions: CONT05



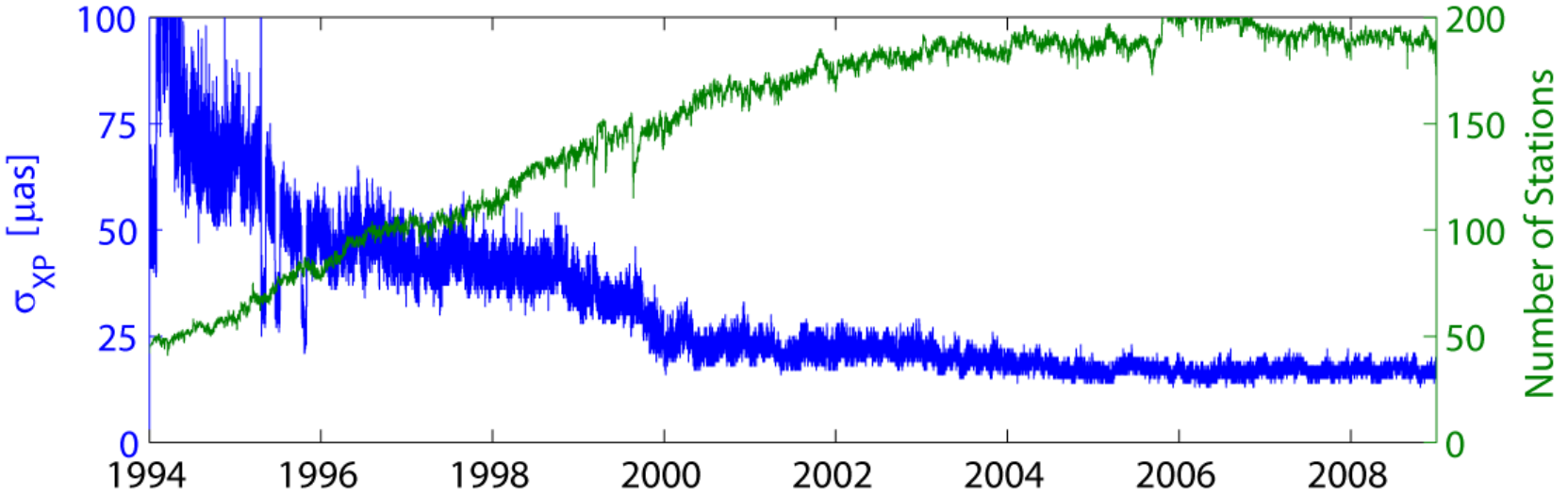
GPS COD09

VLBI IGG09

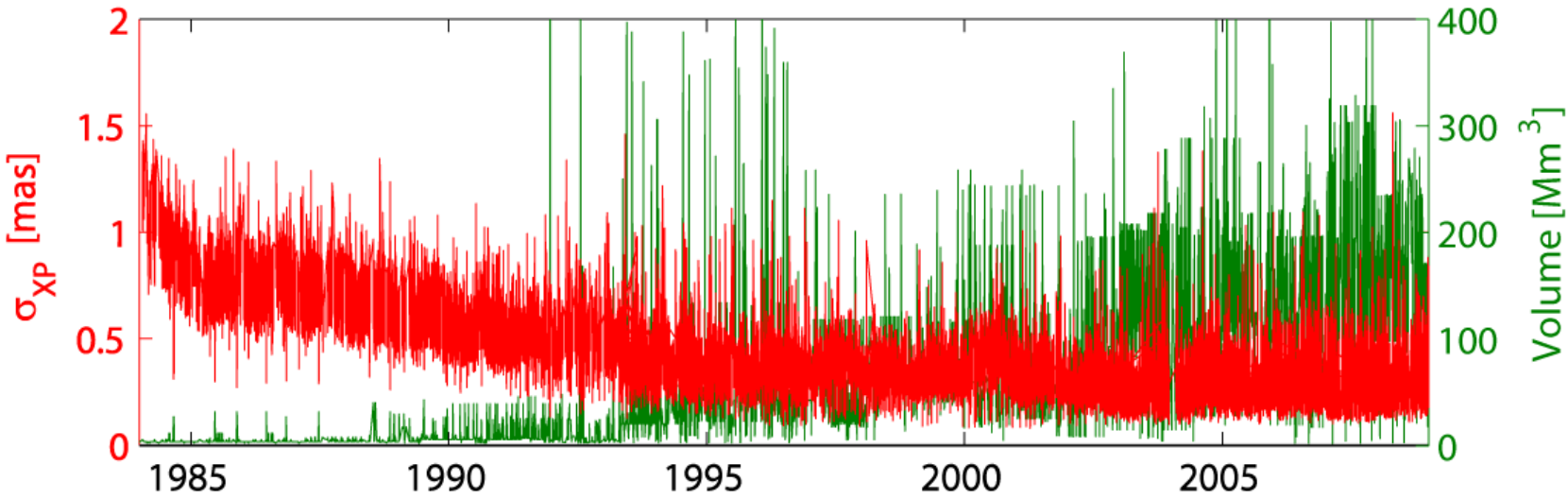
IERS2003

Formal Errors X-Pole

GPS
σ=30 μas



VBLI
σ=0.37 mas



Estimation of Subdaily ERP Models

- Estimation of **57 polar motion** and **41 UT1** ocean tidal amplitudes in a weighted least squares adjustment

$$\Delta X(t) = \sum_{j=1}^{n} \left[-p_j^c \cos\psi_j(t) + p_j^s \sin\psi_j(t) \right]$$

$$\Delta Y(t) = \sum_{j=1}^{n} \left[p_j^c \sin\psi_j(t) + p_j^s \cos\psi_j(t) \right]$$

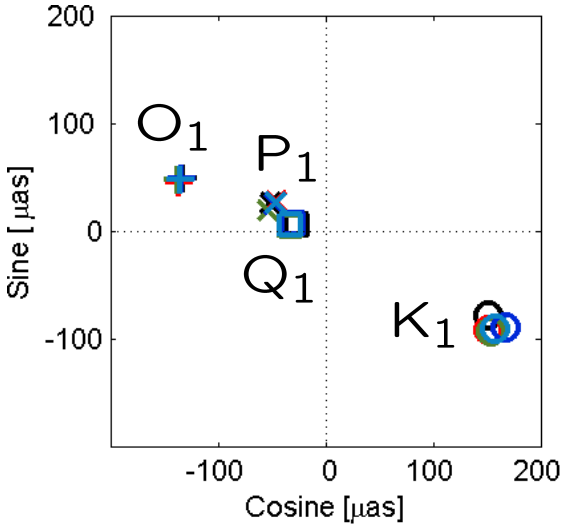
$$\Delta UT1(t) = \sum_{j=1}^{n} \left[u_j^c \cos\psi_j(t) + u_j^s \sin\psi_j(t) \right]$$

- Pseudo-observations:
  - GPS: **polar motion rates, length of day**
  - VLBI: **polar motion, UT1**
- **Constraints** for sidebands that cannot be solved for

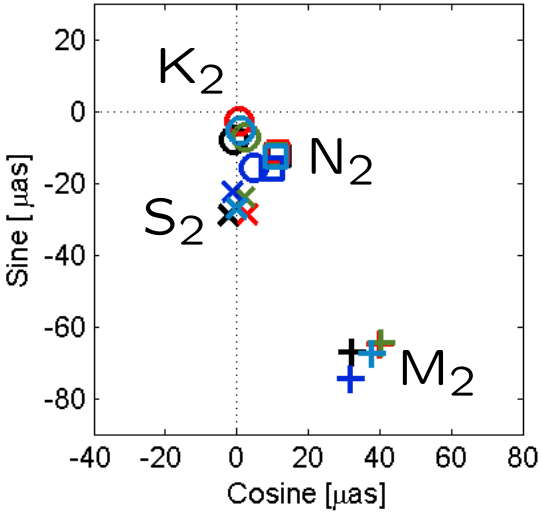
Major Tidal Constituents

Polar Motion

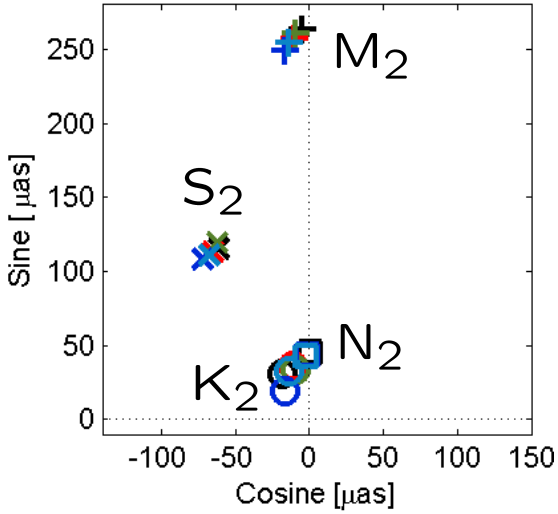
Diurnal prograde



Semi-diurnal prograde

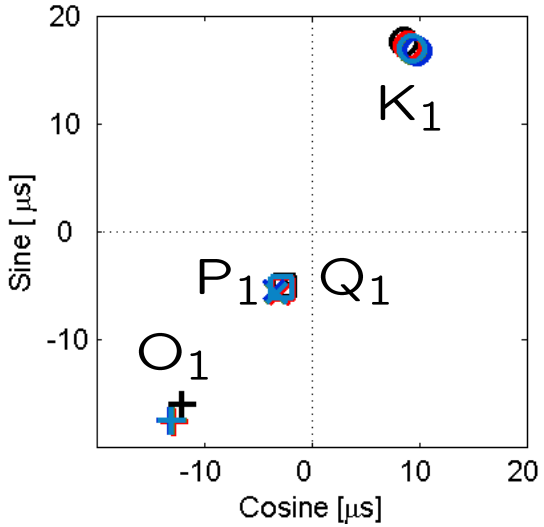


Semi-diurnal retrograde

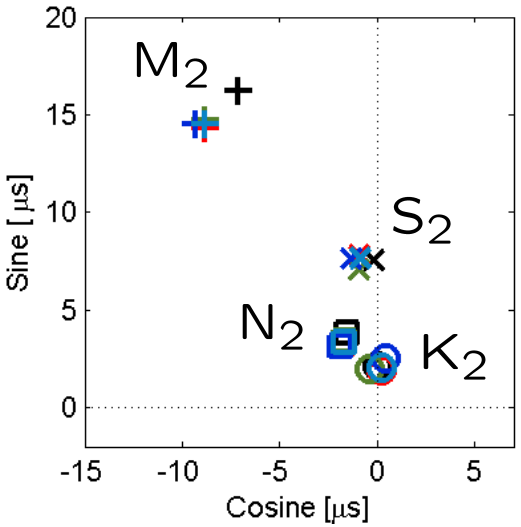


UT1

Diurnal



Semi-diurnal



TUM08

COD09

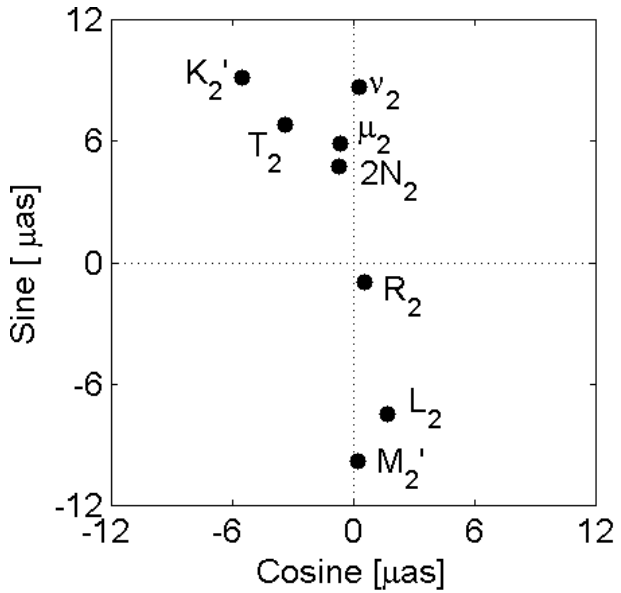
IGG09

TUM08C

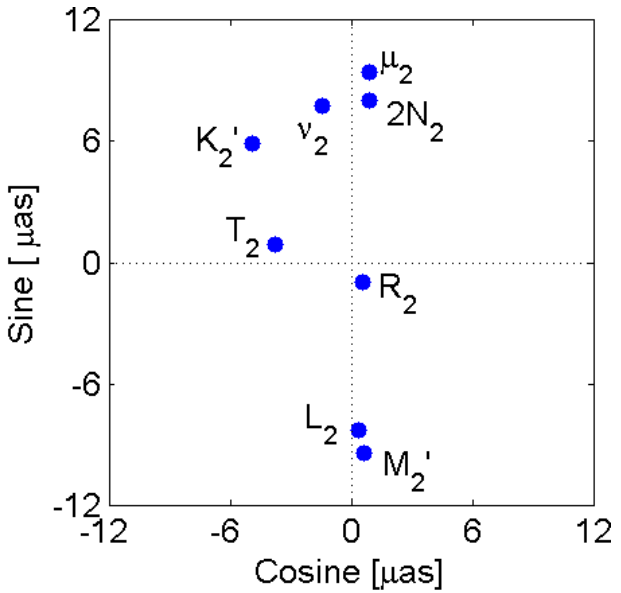
IERS2003

Small Tidal Constituents: Retrograde Polar Motion

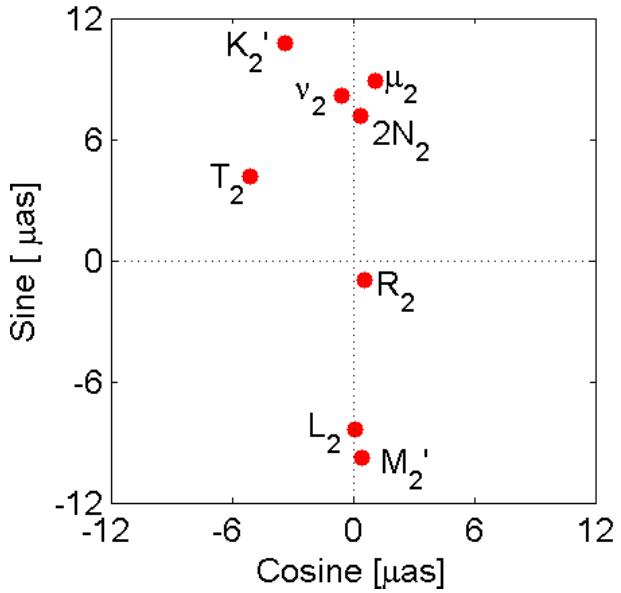
IERS2003



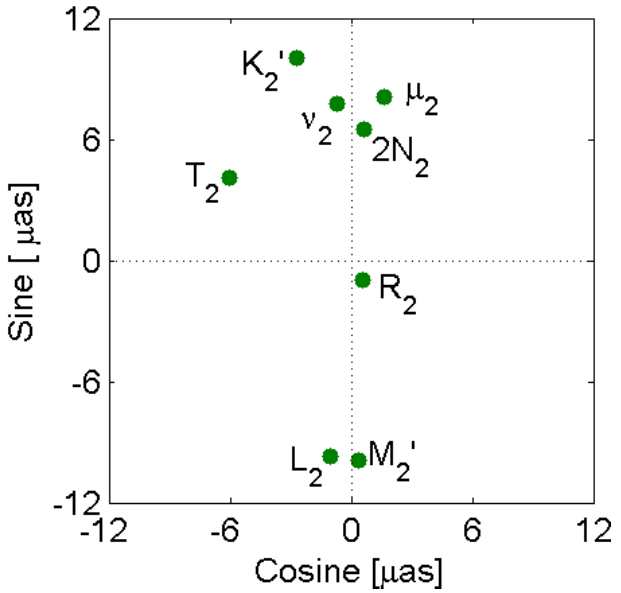
IGG09



TUM08

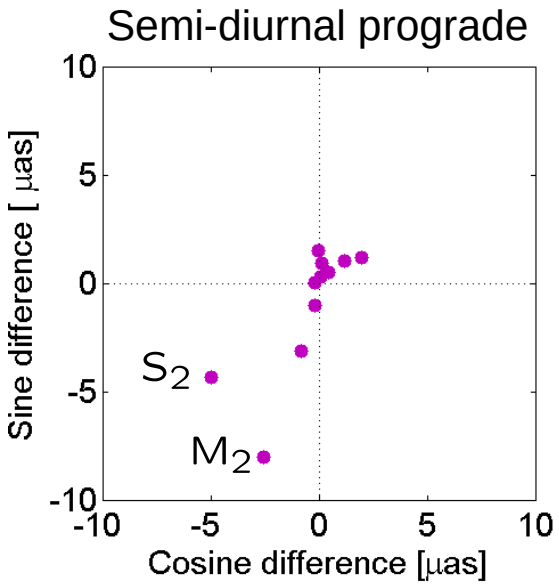


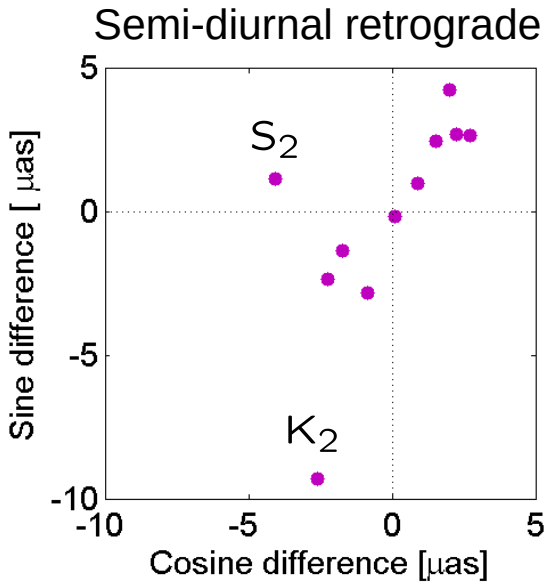
COD09

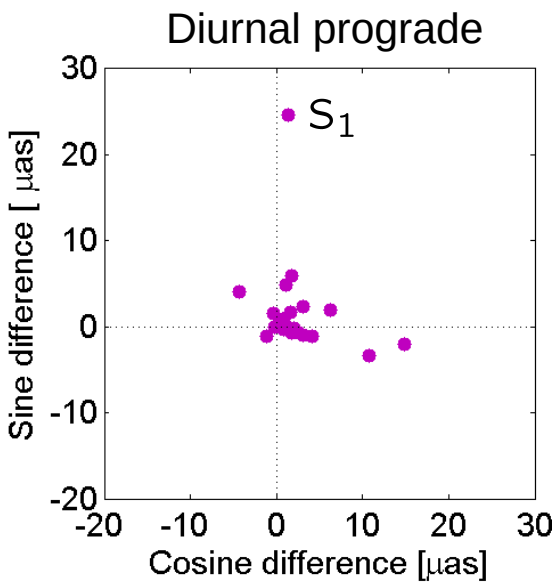


Differences of COD09 w.r.t. IERS2003

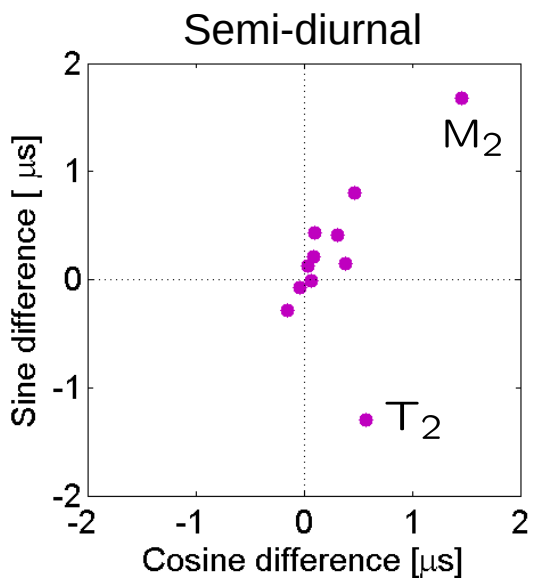
Polar Motion

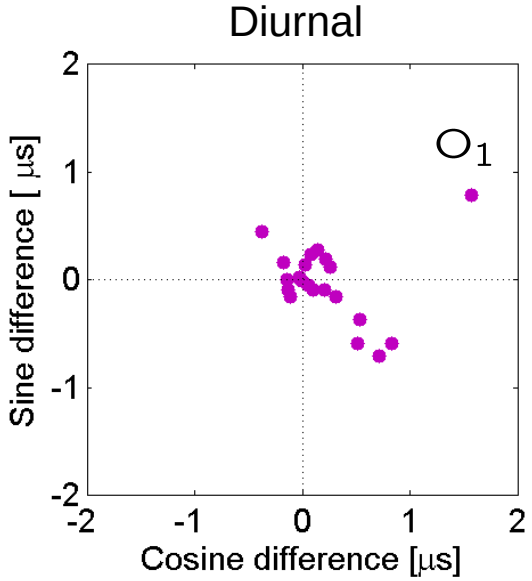






UT1





Comparison of All Estimated Tidal Constituents

Mean **RMS differences** of estimated amplitudes

PM in μas	COD09	IGG09	TUM08C	IERS2003
TUM08	4.2	4.1	1.5	3.3
COD09		4.9	4.4	4.1
IGG09			2.9	4.3
TUM08C				3.2

UT1 in μs	COD09	IGG09	TUM08C	IERS2003
TUM08	0.28	0.30	0.14	0.48
COD09		0.35	0.28	0.49
IGG09			0.20	0.59
TUM08C				0.49

Sideband Constraints

A time series of at least 18.6 years is needed to properly solve for the sidebands of the tidal constituents

Constraints for the sideband amplitudes:

$$\frac{a_{j'}}{a_j} = \frac{h_{j'}}{h_j}$$

a estimated subdaily ERP model coefficients

h tide generating potential

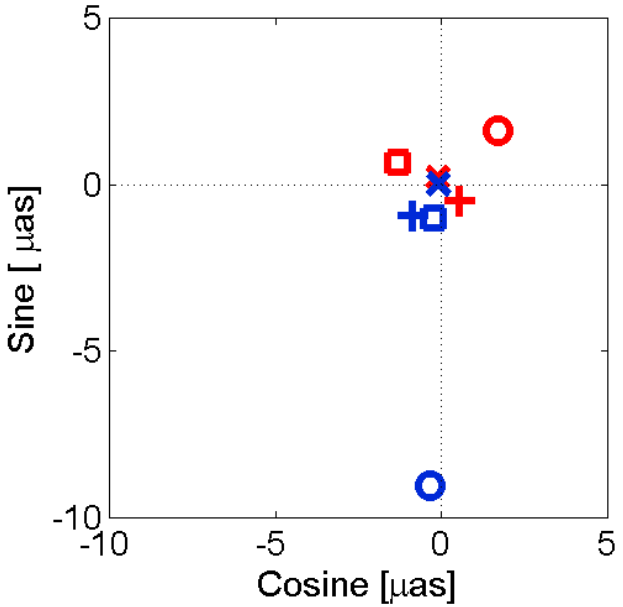
j tidal constituent

j' corresponding sideband constituent

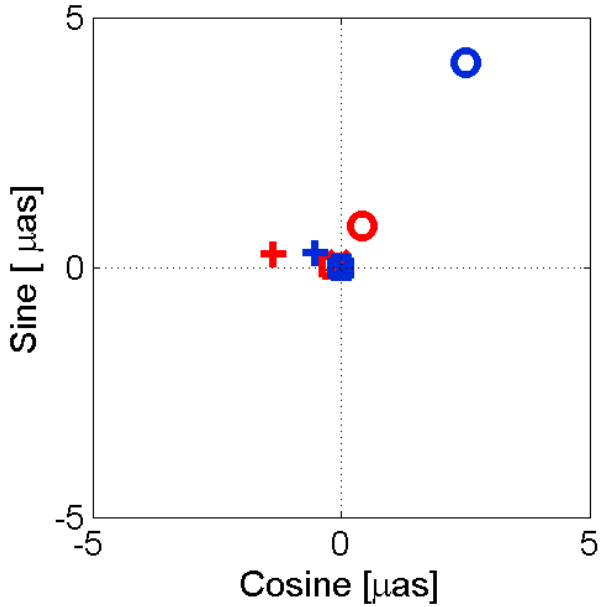
Impact of Sideband Constraints

Polar motion differences of **GPS** and **VLBI** models
with and **without** sideband constraints

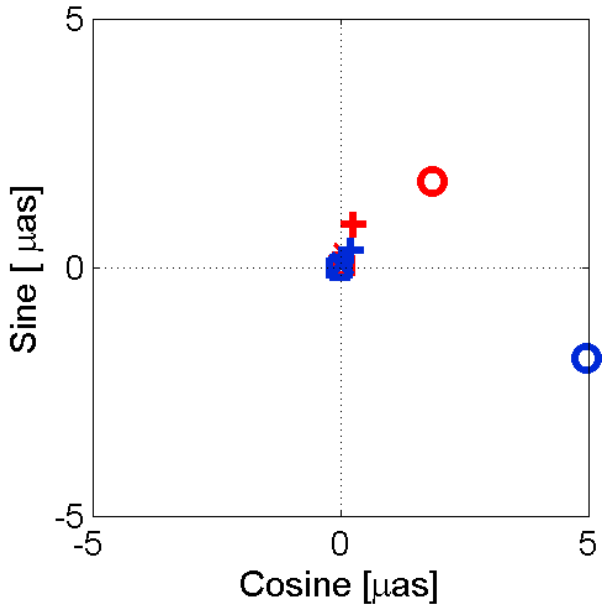
diurnal prograde

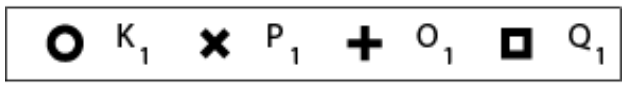


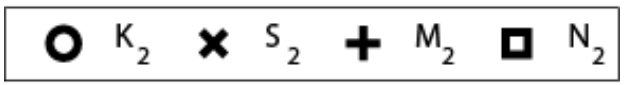
semidiurnal prograde



semidiurnal retrograde

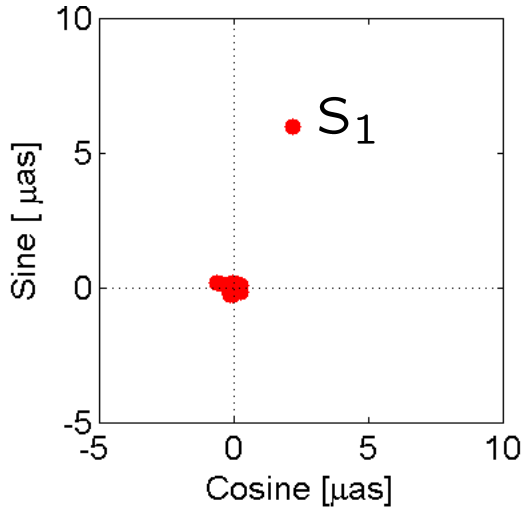




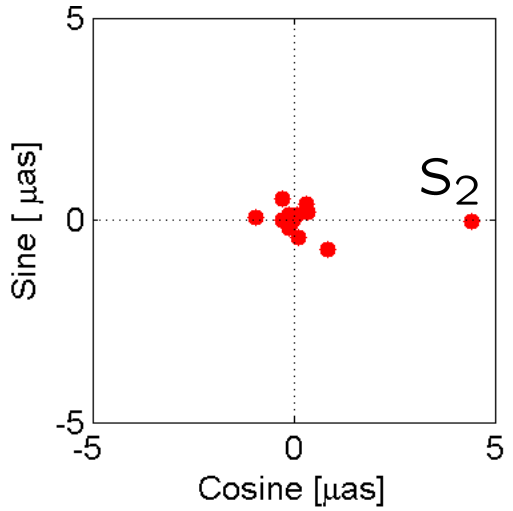


Impact of a Priori Models

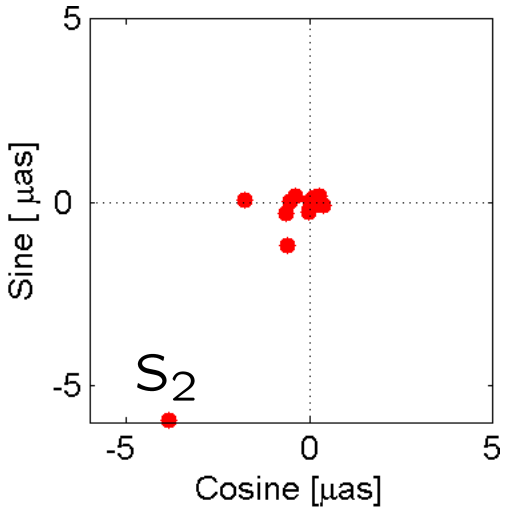
diurnal prograde PM



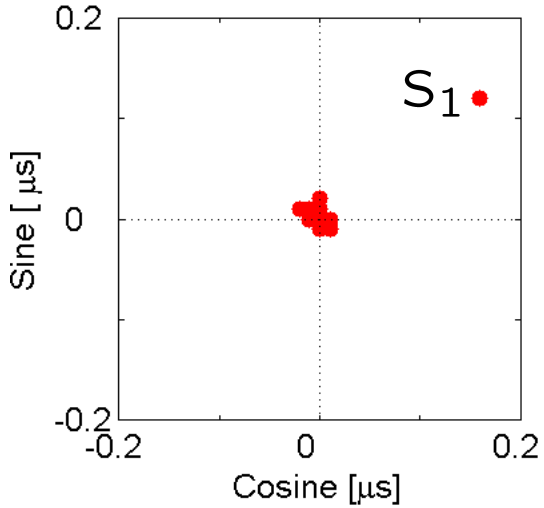
semidiurnal prograde PM



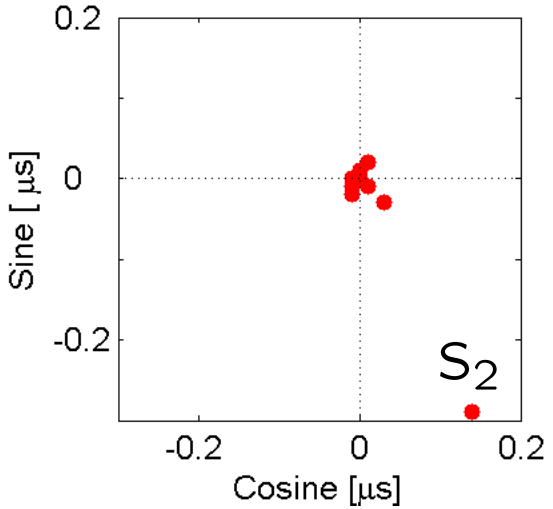
semidiurnal retrograde PM



diurnal UT



semidiurnal UT



Differences of VLBI models with IERS2003 and GSFC hf1102a a priori model

Impact on Global Solutions

Aliasing effects:

- 24 hours batches (GPS and VLBI)
- Orbit repeat period (GPS)

Global GPS and VLBI solutions with different subdaily a priori ERP models

GPS: Jan 2000 – Dec 2008

IERS2003	Reference solution
TUM08	GPS, 2h
COD09	GPS, 1h
IGG09	VLBI, 1h
TUM08C	GPS/VLBI, 2h/1h

VLBI: Mar 1984 – Dec 2008

IERS2003	Reference solution
IGG09	VLBI, 1h
hf1102a	GSFC model for CALC/SOLVE

Aliasing Effects

$$T_{\text{alias,j}} = \frac{2\pi T}{|\Delta\phi_{\text{tide,j}}|} \qquad \Delta\phi_{\text{tide,j}} = 2\pi \left[\frac{T}{T_{\text{tide,j}}} - \text{NINT}\frac{T}{T_{\text{tide,j}}} \right]$$

$T_{\text{alias,j}}$	Alias period of tidal constituent j
$T_{\text{tide,j}}$	Period of tidal constituent j
T	24^h or orbit repeat period of $23^h\ 56^m$

24^h processing batches

Tide j	$T_{\text{tide,j}}$	$T_{\text{alias,j}}$
M_2	12.42 h	14.8 d
J_1	23.10 h	25.6 d
P_1	24.07 h	364.6 d

Orbit repeat period

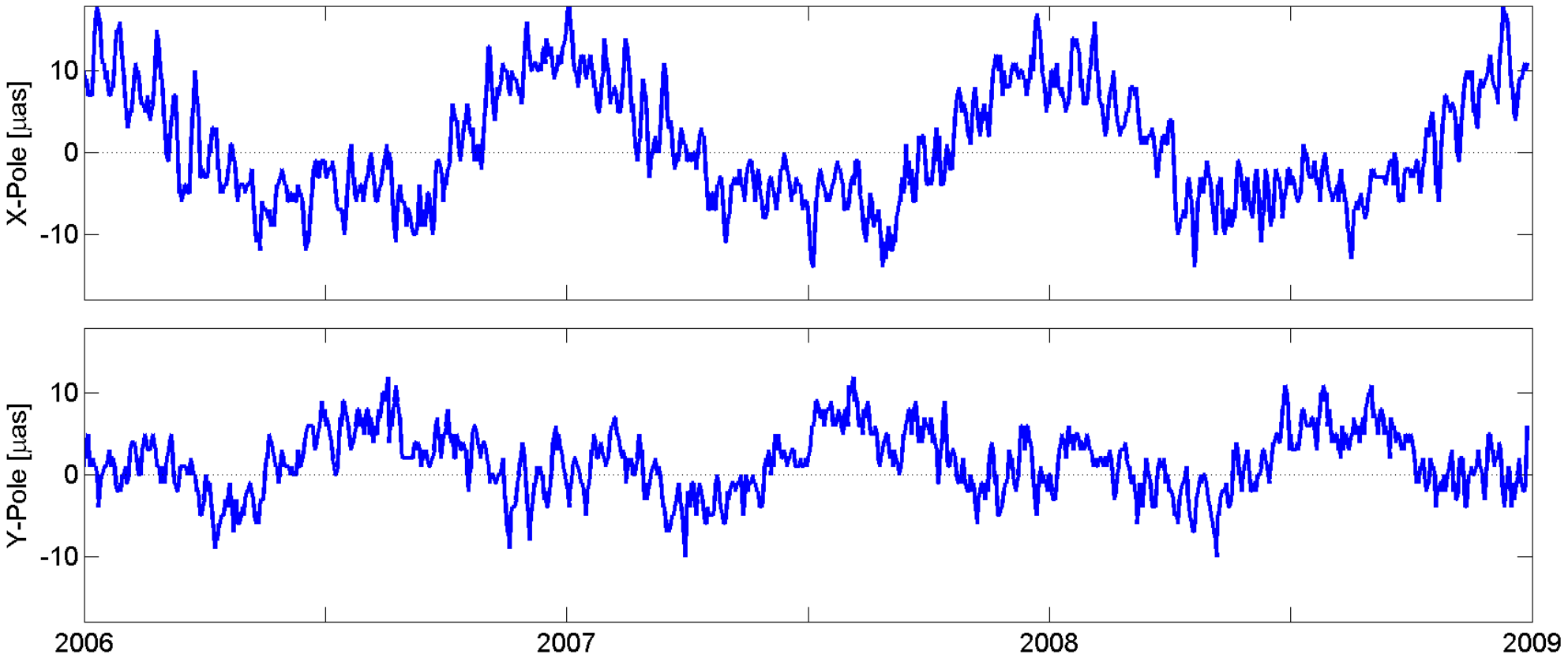
Tide j	$T_{\text{tide,j}}$	$T_{\text{alias,j}}$
M_2	12.42 h	13.6 d
J_1	23.10 h	27.6 d
P_1	24.07 h	180.9 d

GPS Earth Rotation Parameters: IERS2003/COD09 (1)

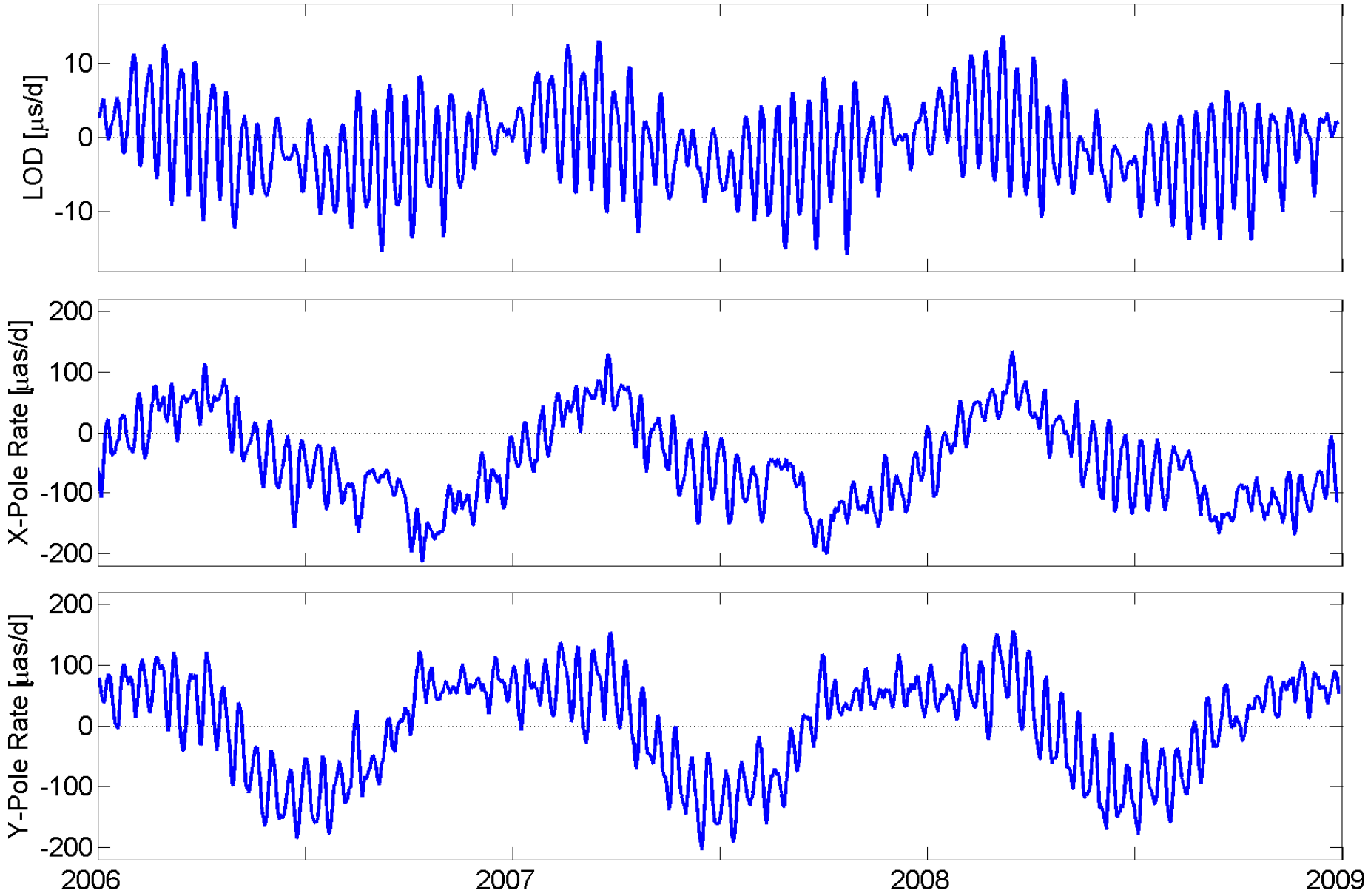
ERP difference time series of the GPS solutions IERS2003 and COD09

Estimated parameters per daily solution:

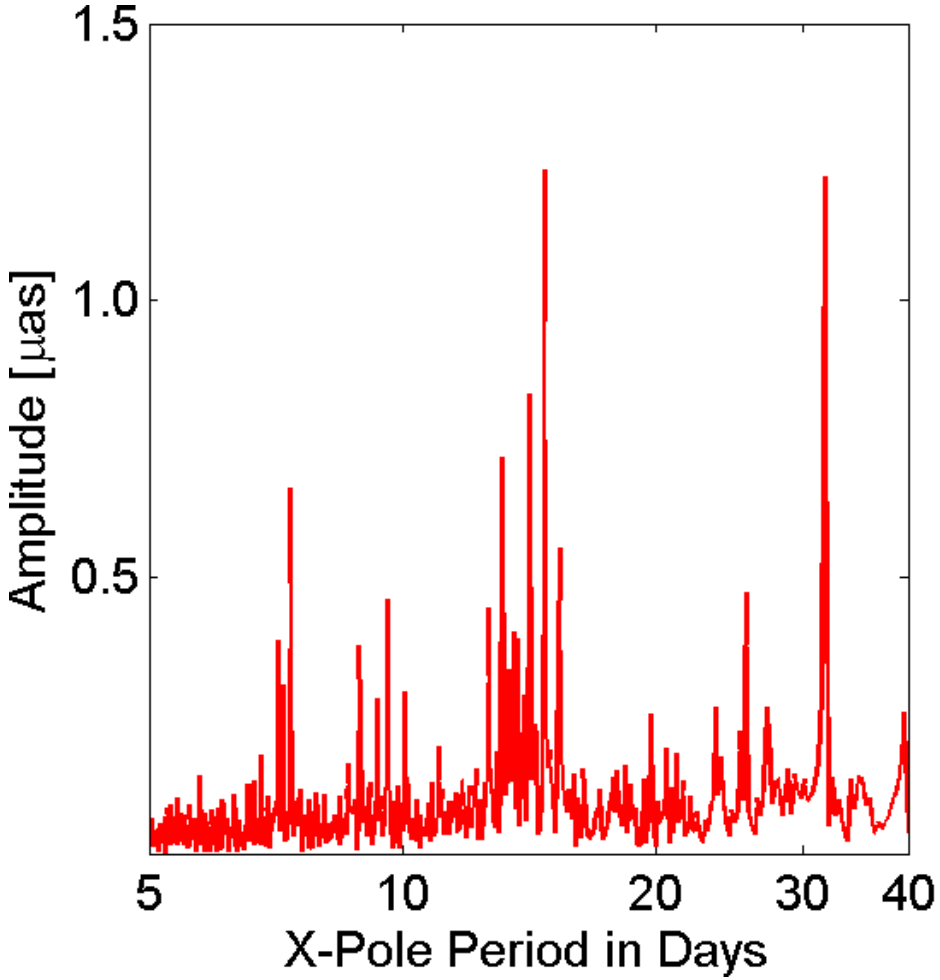
- Offset and rate for polar motion
- Rate for UT1 (=-LOD)

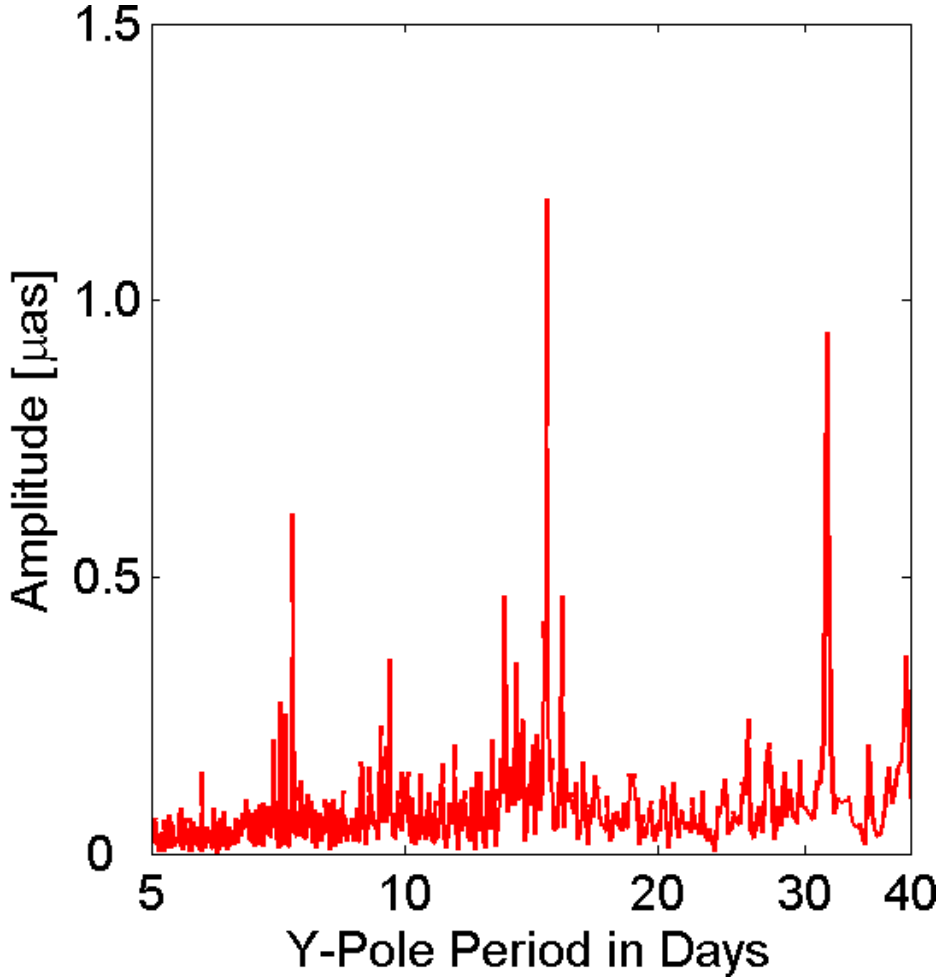


GPS Earth Rotation Parameters: IERS2003/COD09 (2)



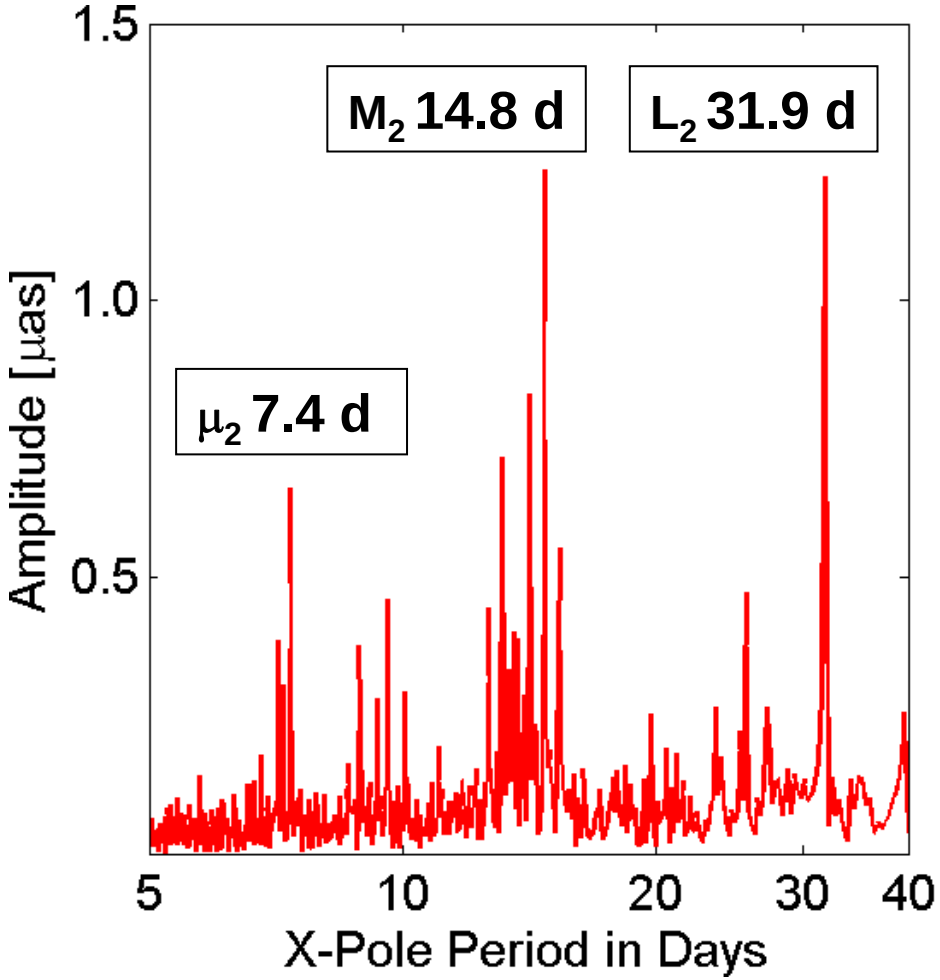
Spectra ERP Differences: IERS2003/COD09

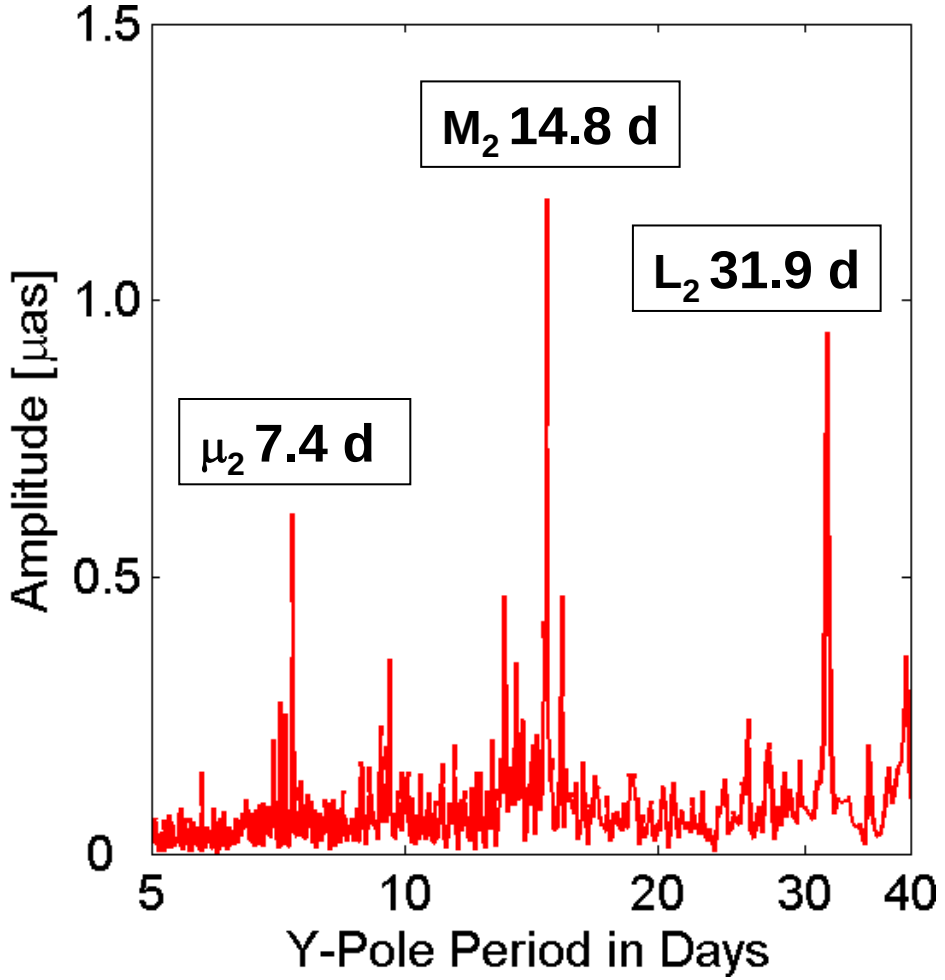




Spectra ERP Differences: IERS2003/COD09

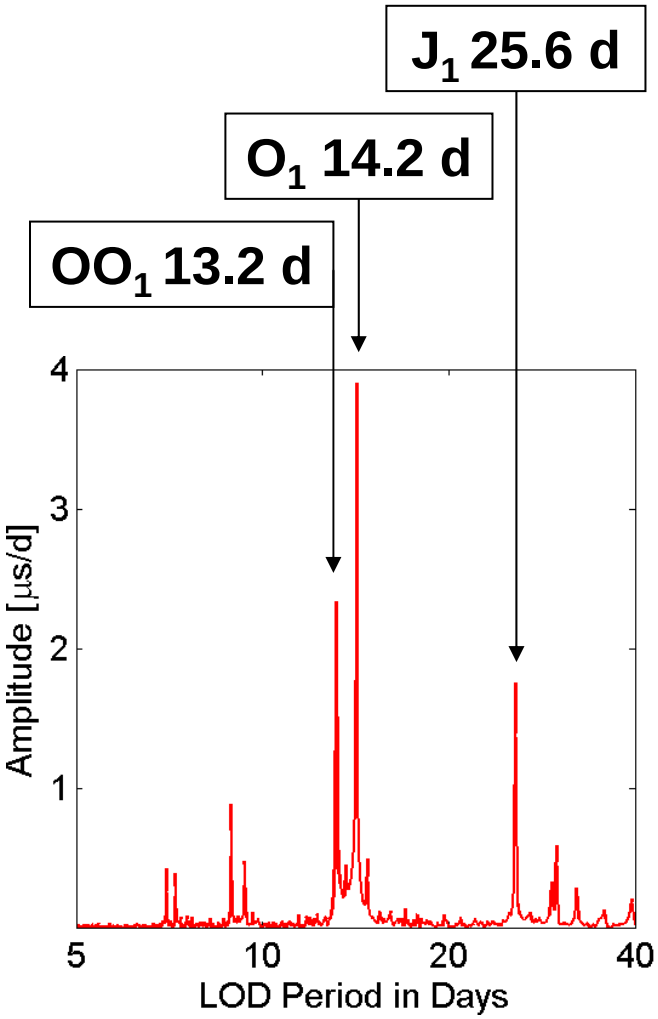
Aliasing effects between 24 hours and …

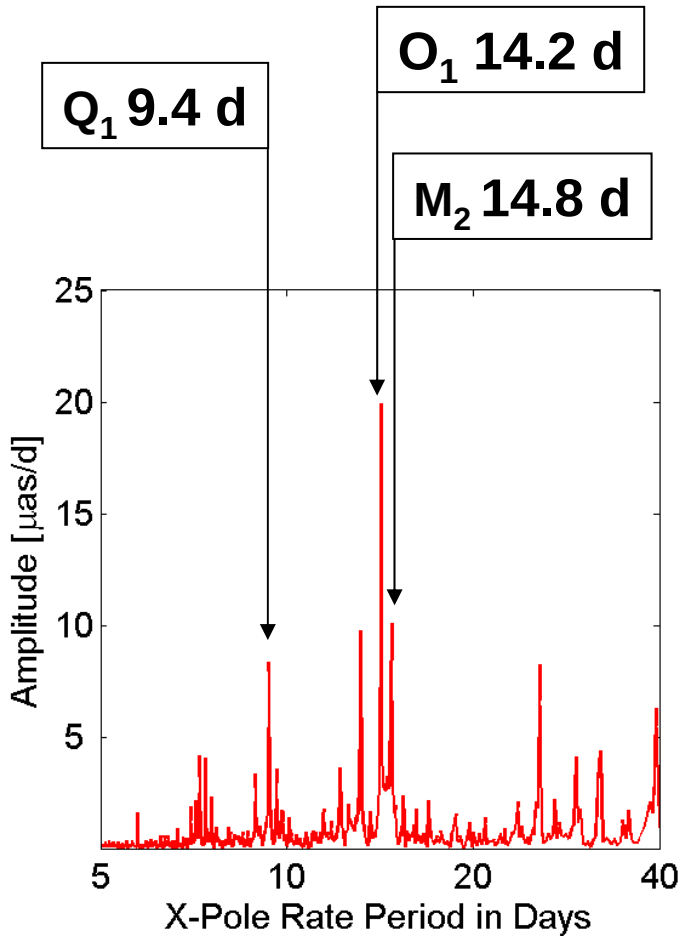


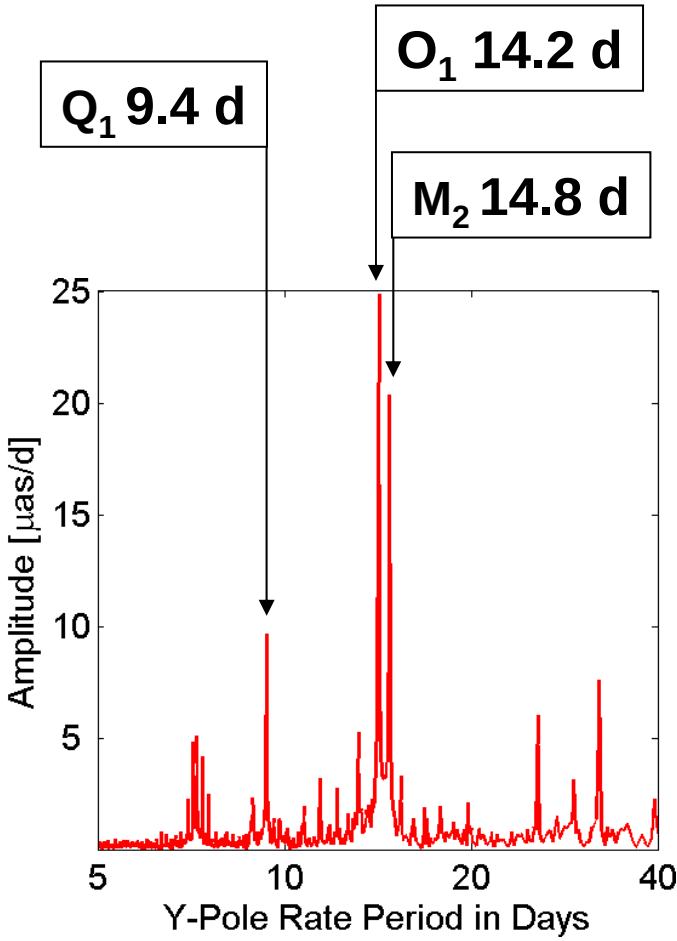


Spectra ERP Differences: IERS2003/COD09

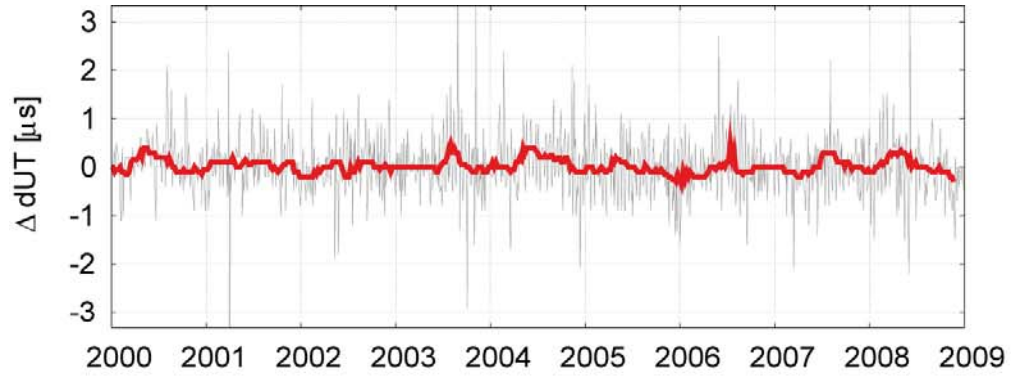
Aliasing effects between 24 hours and …

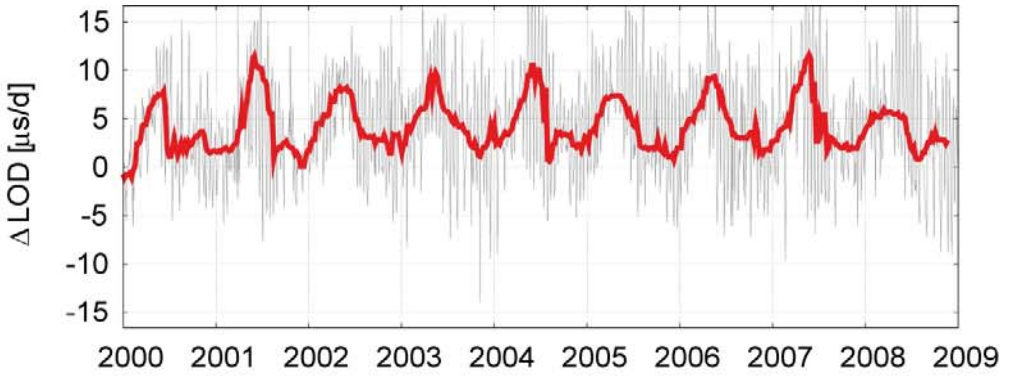


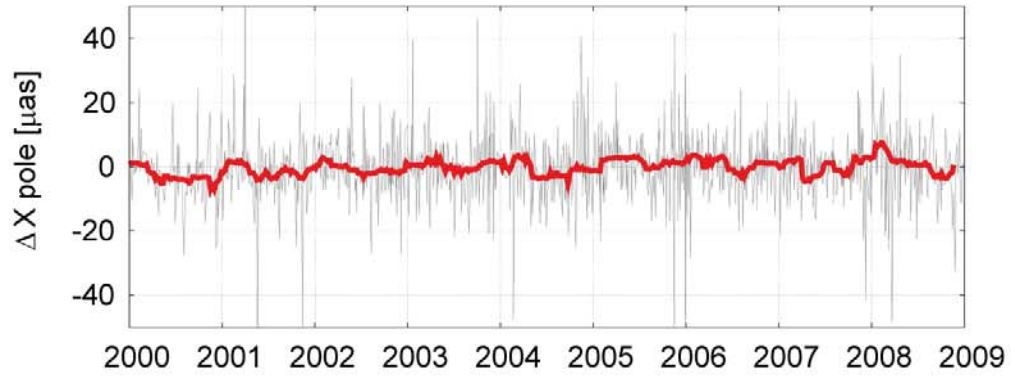


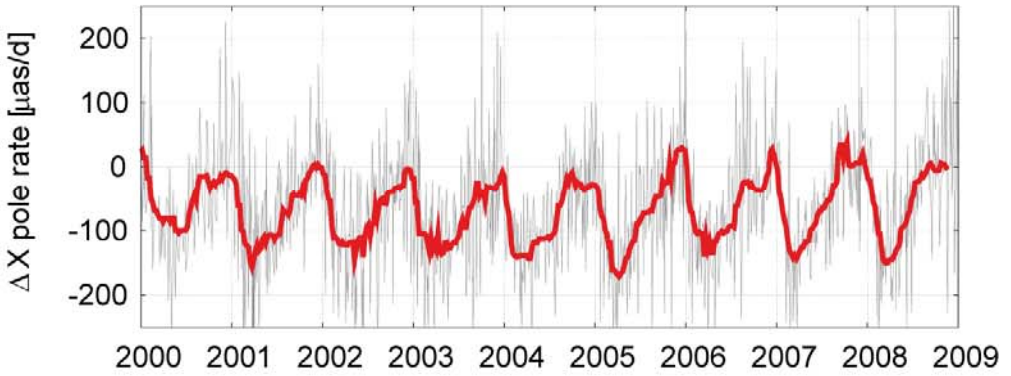


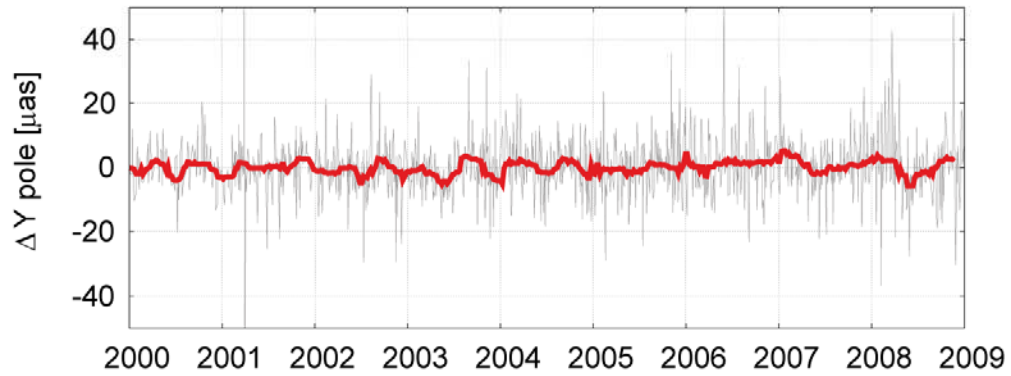
VLBI Earth Rotation Parameters: IERS2003/IGG09

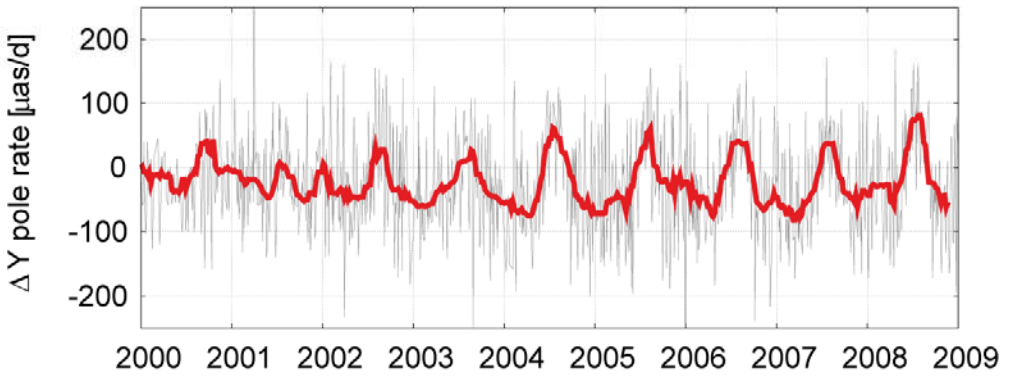






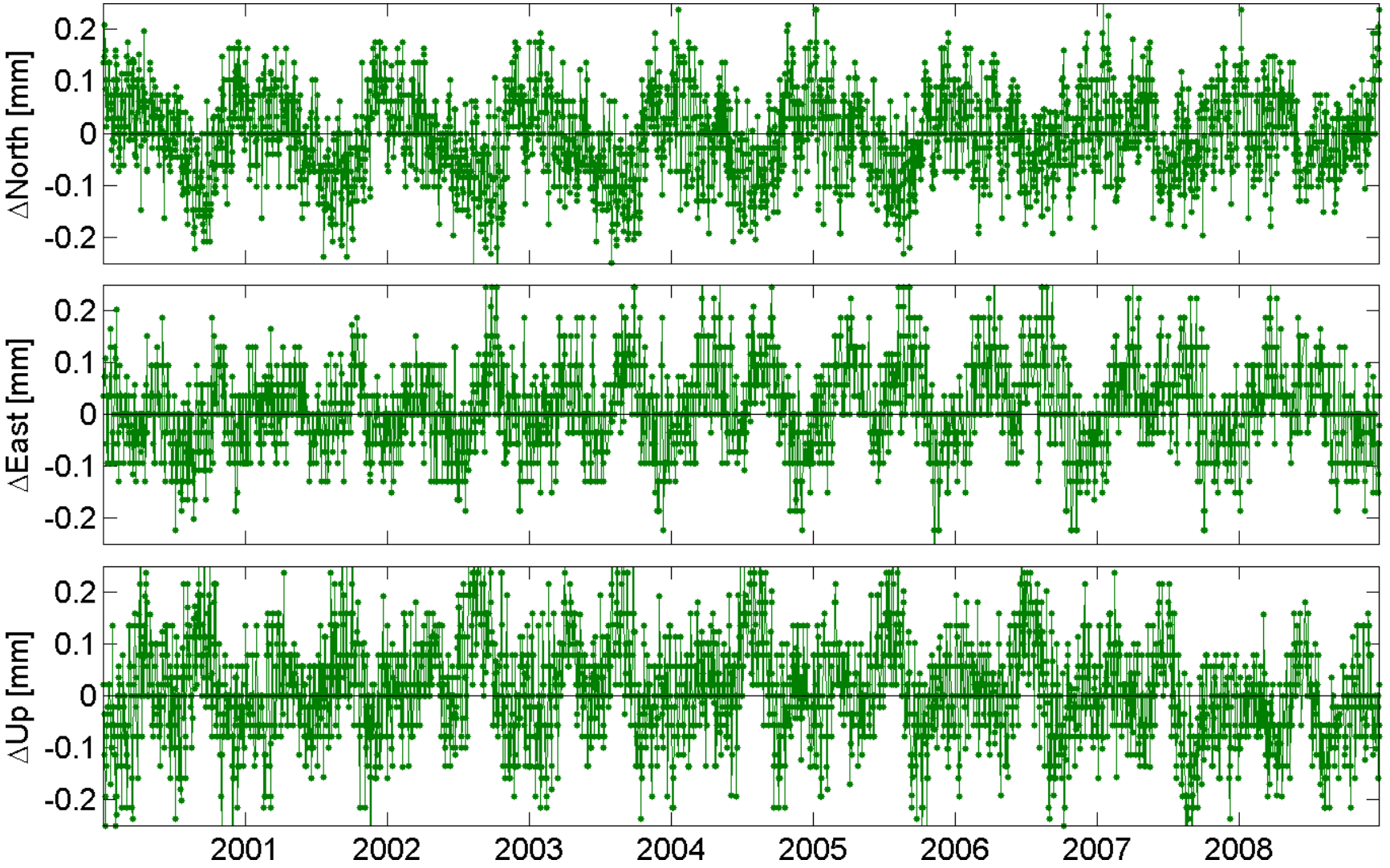






GPS Station Coordinates: IERS2003/COD09

BOR1, Borowiec, Poland



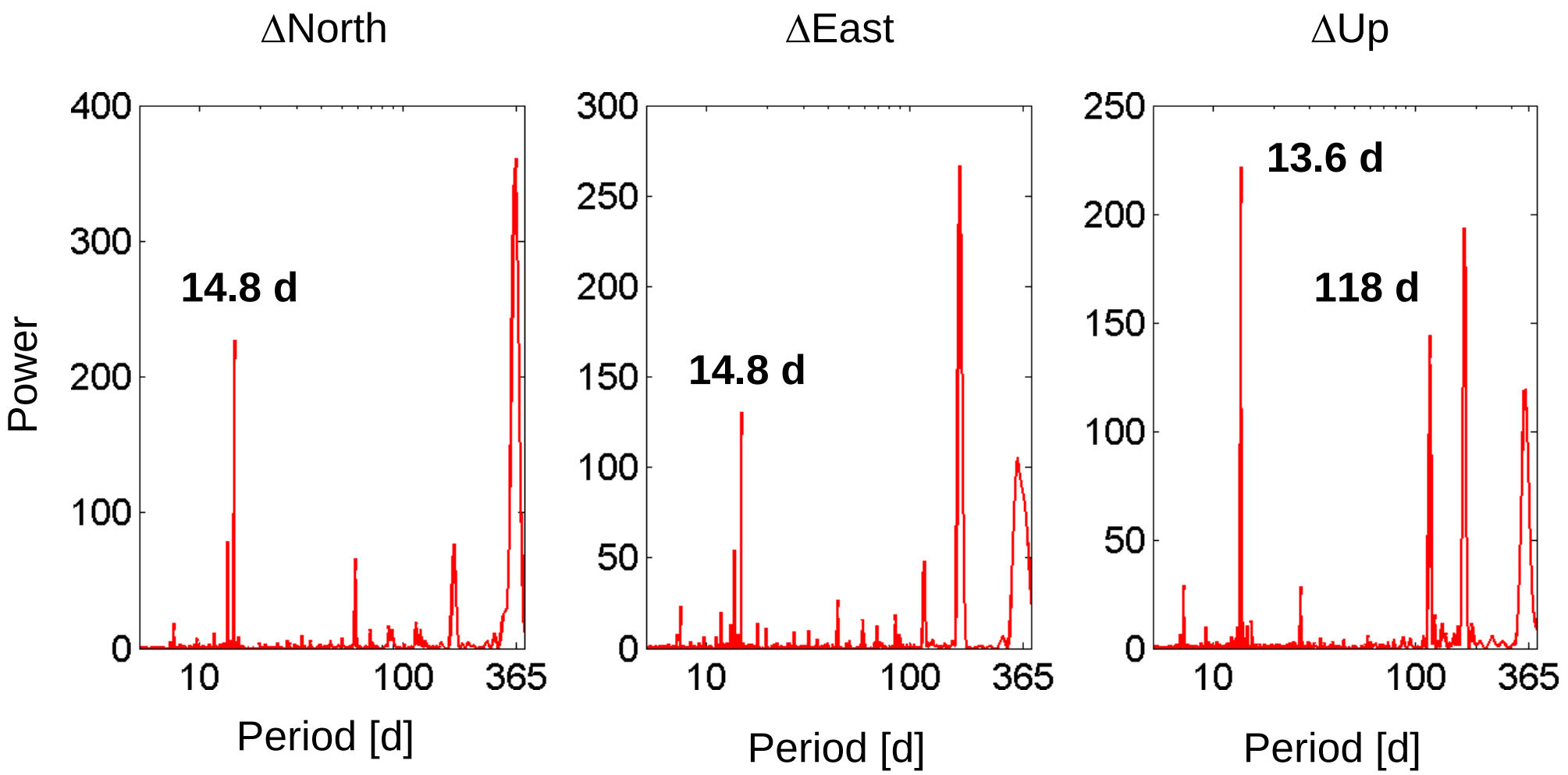
STD_N 0.08 mm

STD_E 0.08 mm

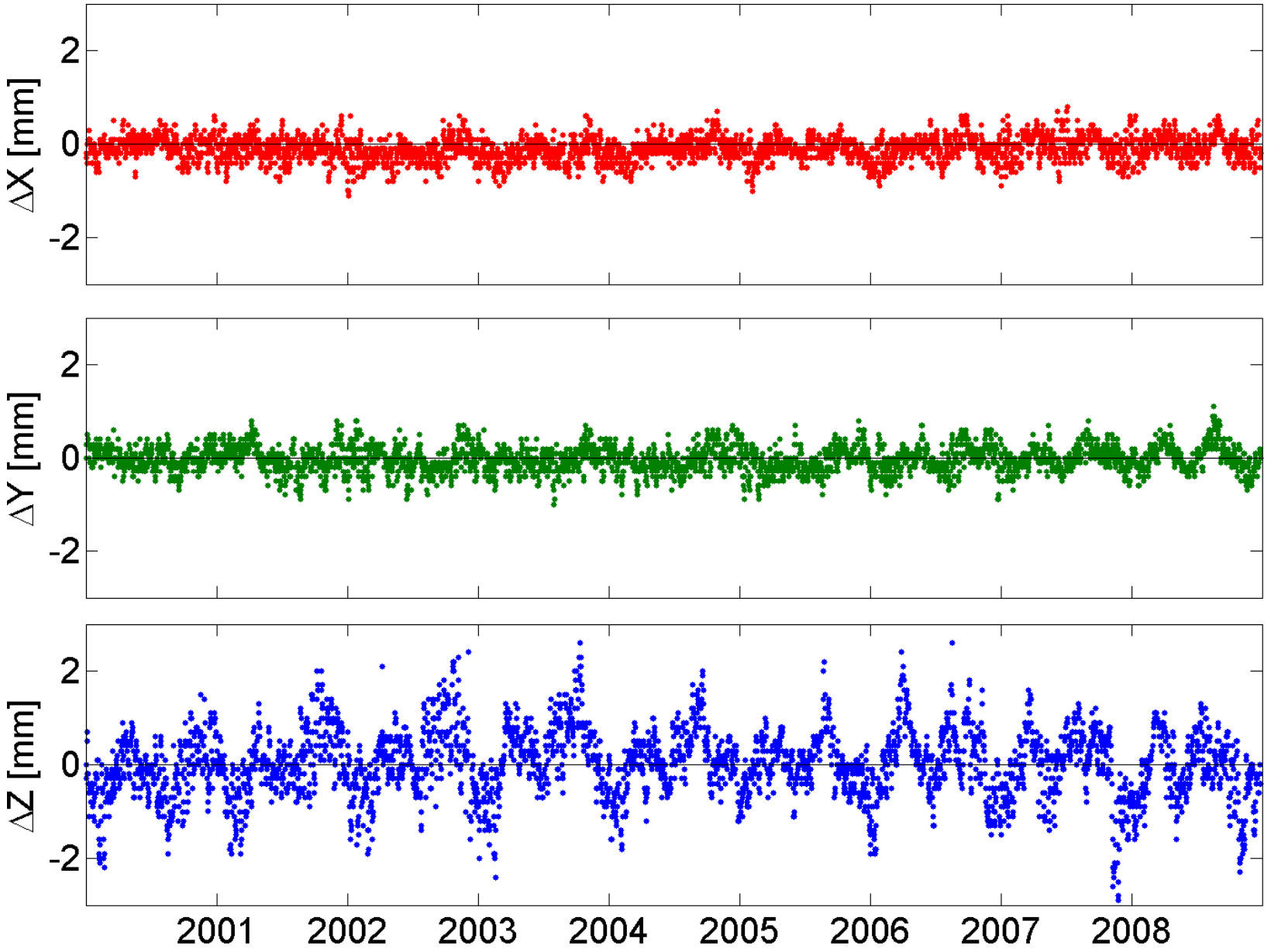
STD_U 0.10 mm

Spectra Coordinates Differences: IERS2003/COD09

BOR1, Borowiec, Poland



GPS Geocenter: IERS2003/COD09

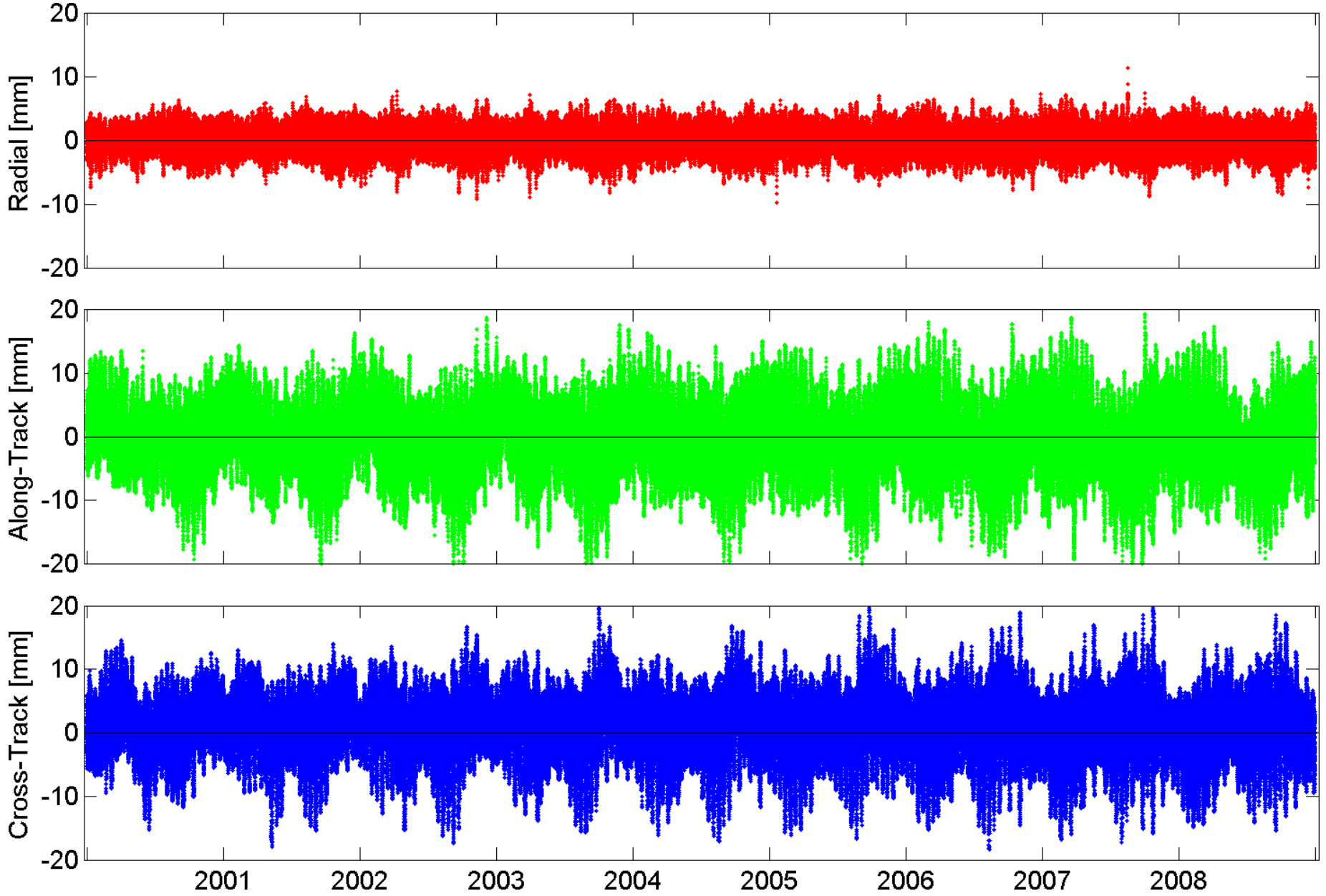


STD_X 0.26 mm

STD_Y 0.28 mm

STD_Z 0.73 mm

Orbit Residuals: IERS2003/COD09



Conclusions

- GPS- and VLBI-derived subdaily ERP estimates agree on the **5 μas level for polar motion** and **0.3 μs level for UT1**
- Impact of different subdaily ERP models on global solutions visible in different parameter types:
  - Earth rotation parameters:
    - ± 15 μas for polar motion
    - ± 100 μas/d for polar motion rates
    - ± 10 μs/d for LOD
  - Coordinate time series: few 1/10 mm level
  - Geocenter: below 1 mm for X and Y, up to 2 mm for Z
  - Satellite orbits: up to 2 cm
  - Several **aliasing periods** clearly visible, more pronounced for GPS compared to VLBI