GNSS Estimates of Short-period Nutation

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Introduction

- Nutation offsets can only be determined with VLBI and LLR
- Feasibility of determining short-period nutation from GPS-derived nutation rates already shown a decade ago
- Homogeneously reprocessed GNSS long-time series of nutation rates provide a valuable basis for the determination of short-period nutation

<u>Outline</u>

- Estimation of nutation rates from GNSS observations
- Estimation of short-period nutation models
- Precision and convergence of GNSS nutation models
- Comparisons of different GNSS nutation models with VLBI and IAU2000A

Estimation of Nutation Parameters with GNSS

Determination of nutation offsets with GNSS not possible due to correlations with the orbital elements

$$\Delta\dot{\epsilon} = \cos\Omega \;\; \dot{i} + \sin i \sin\Omega \;\; \dot{u}_0$$

$$\Delta\dot{\psi} \sin\epsilon_0 = -\sin\Omega \;\; \dot{i} + \sin i \cos\Omega \;\; \dot{u}_0$$

$\Delta\dot{\epsilon}$	nutation rate in obliquity
$\Delta\dot{\psi}$	nutation rate in longitude
ϵ_0	mean obliquity of the ecliptic
Ω	right ascension of the ascending node
i	inclination
u_0	argument of latitude

Estimation of Nutation Models

$$\delta\Delta\epsilon(t) = \sum_{j=1}^{n} \delta\epsilon_j^c \cos\theta_j(t) + \delta\epsilon_j^s \sin\theta_j(t)$$

$$\delta\Delta\psi(t) = \sum_{j=1}^{n} \delta\psi_j^c \cos\theta_j(t) + \delta\psi_j^s \sin\theta_j(t)$$

$\delta\psi_j^s$, $\delta\psi_j^c$	sine/cosine coefficients of nutation in longitude
$\delta\epsilon_j^s$, $\delta\epsilon_j^c$	sine/cosine coefficients of nutation in obliquity
θ_j	combination of the five fundamental arguments
n	number of nutation periods

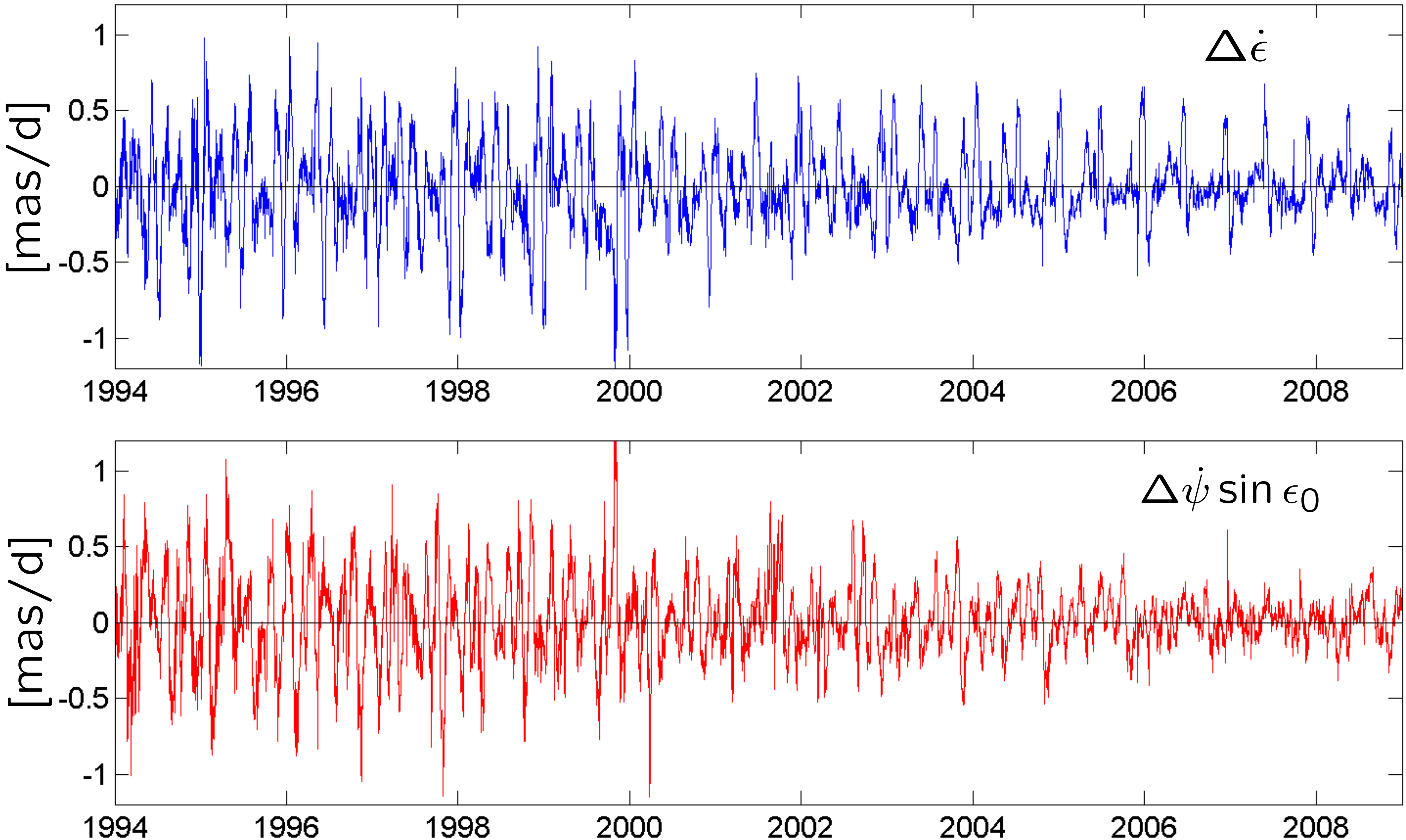
Estimation of n = 34 nutation amplitudes between 4 and 16 days in a least squares adjustment

GNSS and VLBI Solutions

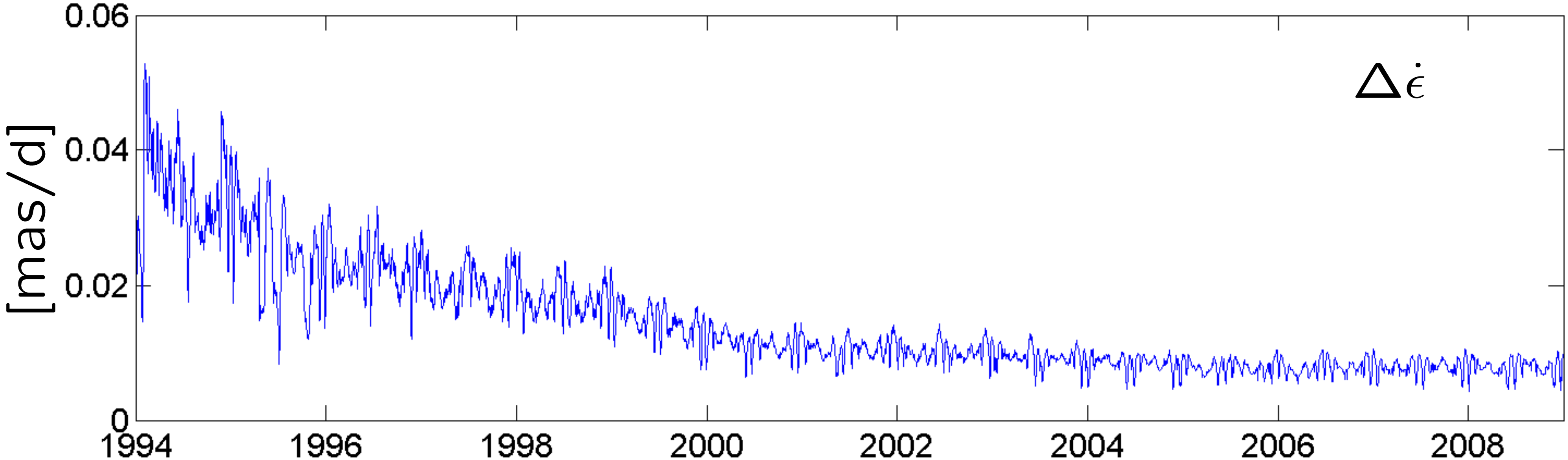
All GPS and GNSS solutions were computed with the Bernese GPS Software

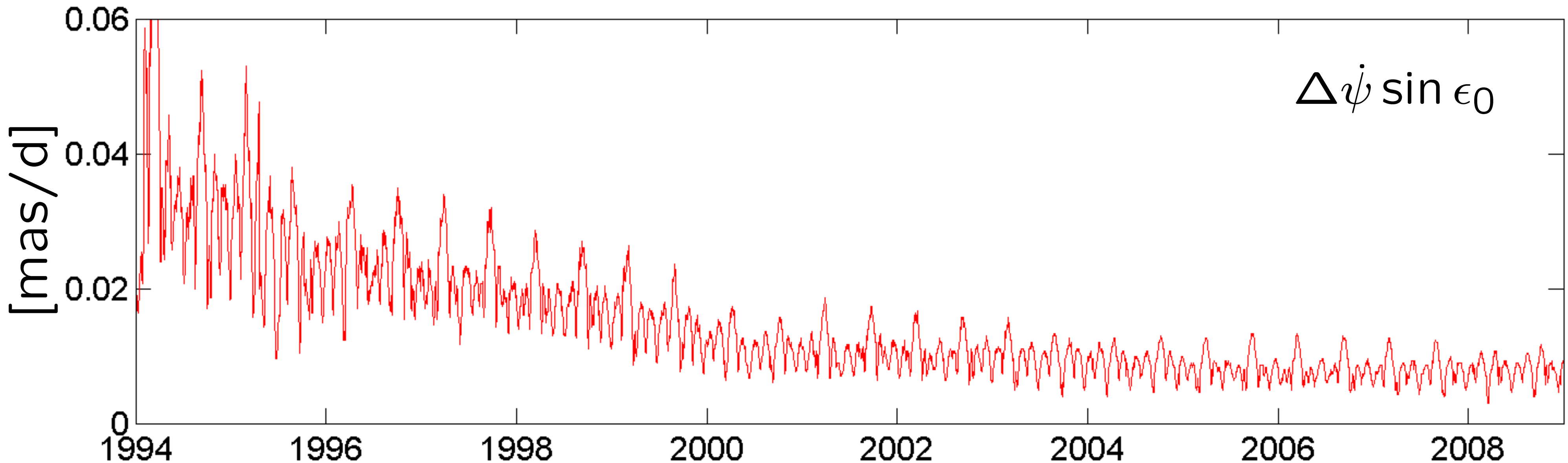
Solution	Abb.	Technique	Time Interval
CODE operat.	COD	GPS/GNSS	Jan 1994 – Mar 2009
CODE reproc.	CO1	GPS	Jan 1994 – Dec 2008
Potsdam Dresden	PD1	GPS	Jan 1994 – Dec 2008
DGFI	DGF	VLBI	Jan 1984 – Dec 2008
GSFC	GSF	VLBI	Jan 1984 – Jan 2009
GGOS-D	GIC	VLBI comb.	Jan 1984 – Dec 2005

CODE Reprocessed (CO1) Nutation Rates

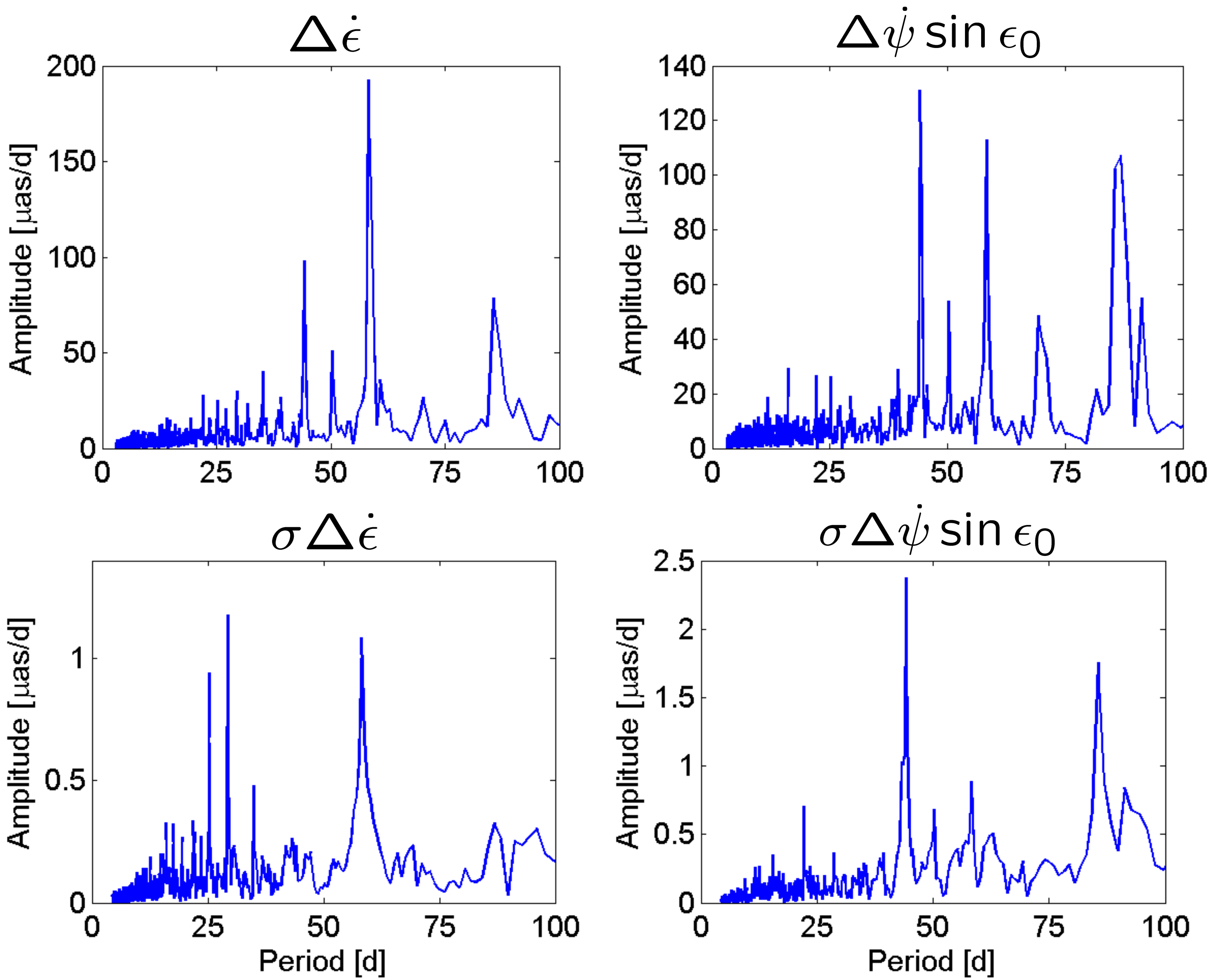


Formal Errors of CO1 Nutation Rates

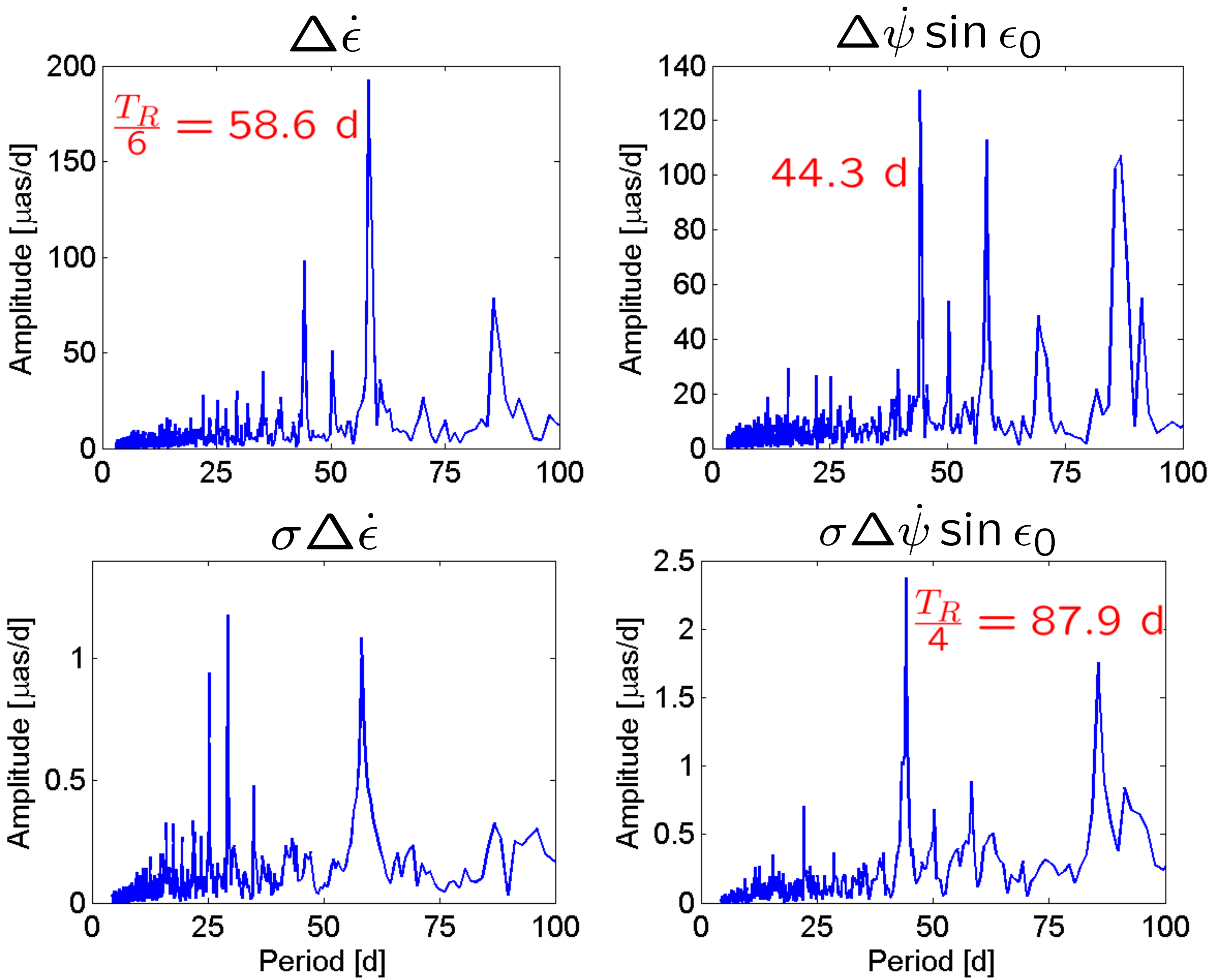




CO1 Nutation Rate Spectra



CO1 Nutation Rate Spectra



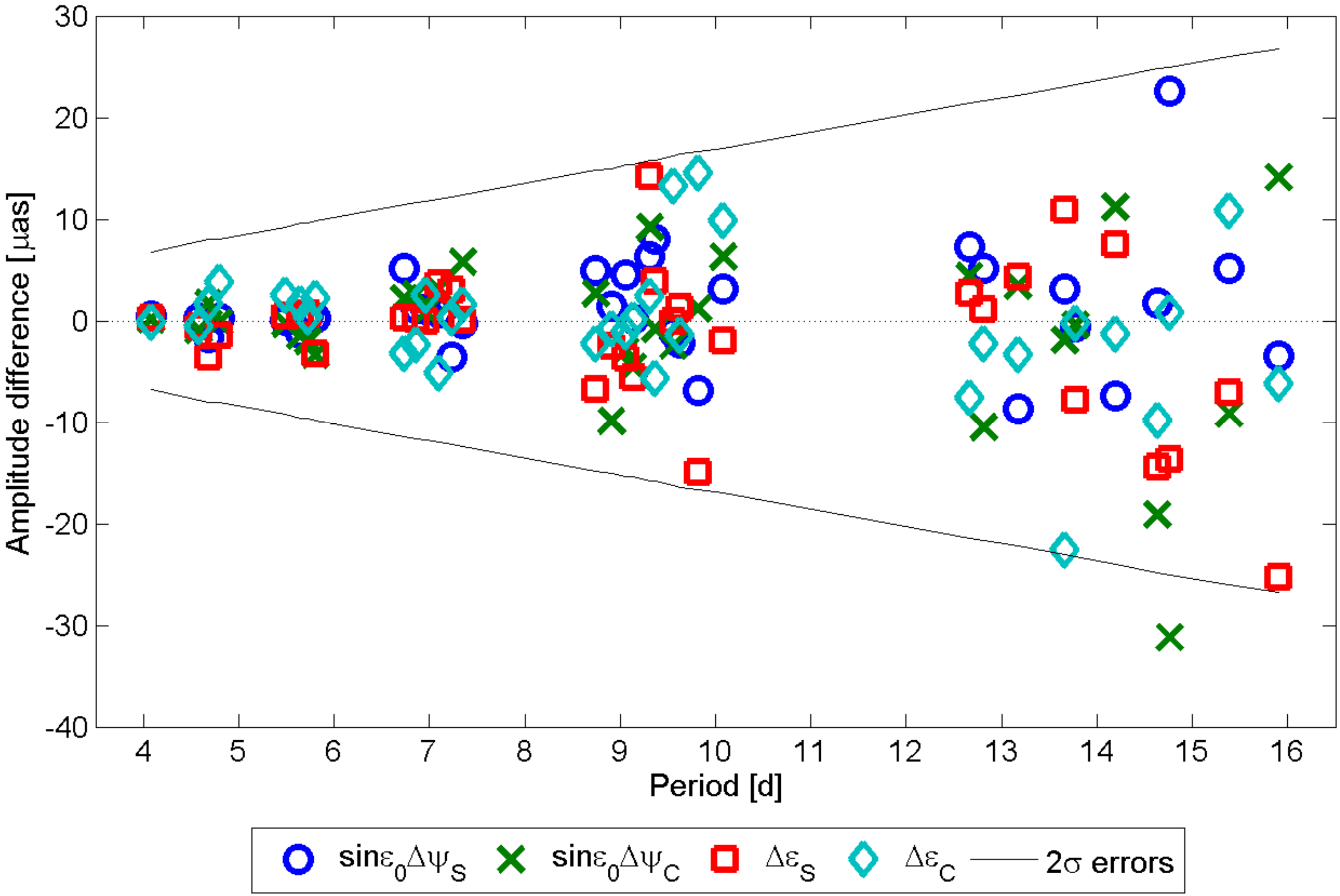
$T_R = 351.5$ d

Draconitic year

„GPS-year“

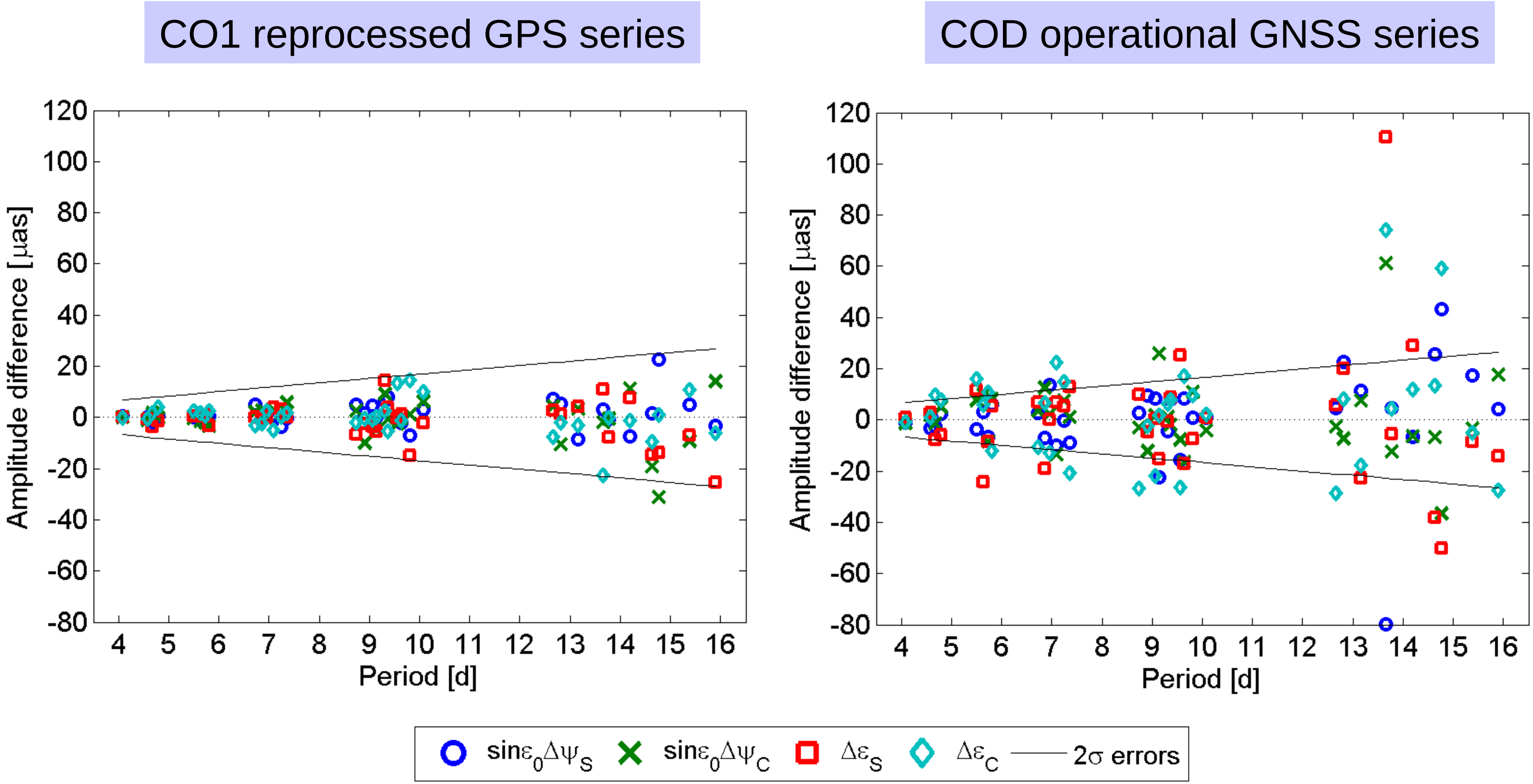
Orientation of the orbital planes w.r.t. the Sun

Differences of CO1 w.r.t. IAU2000A

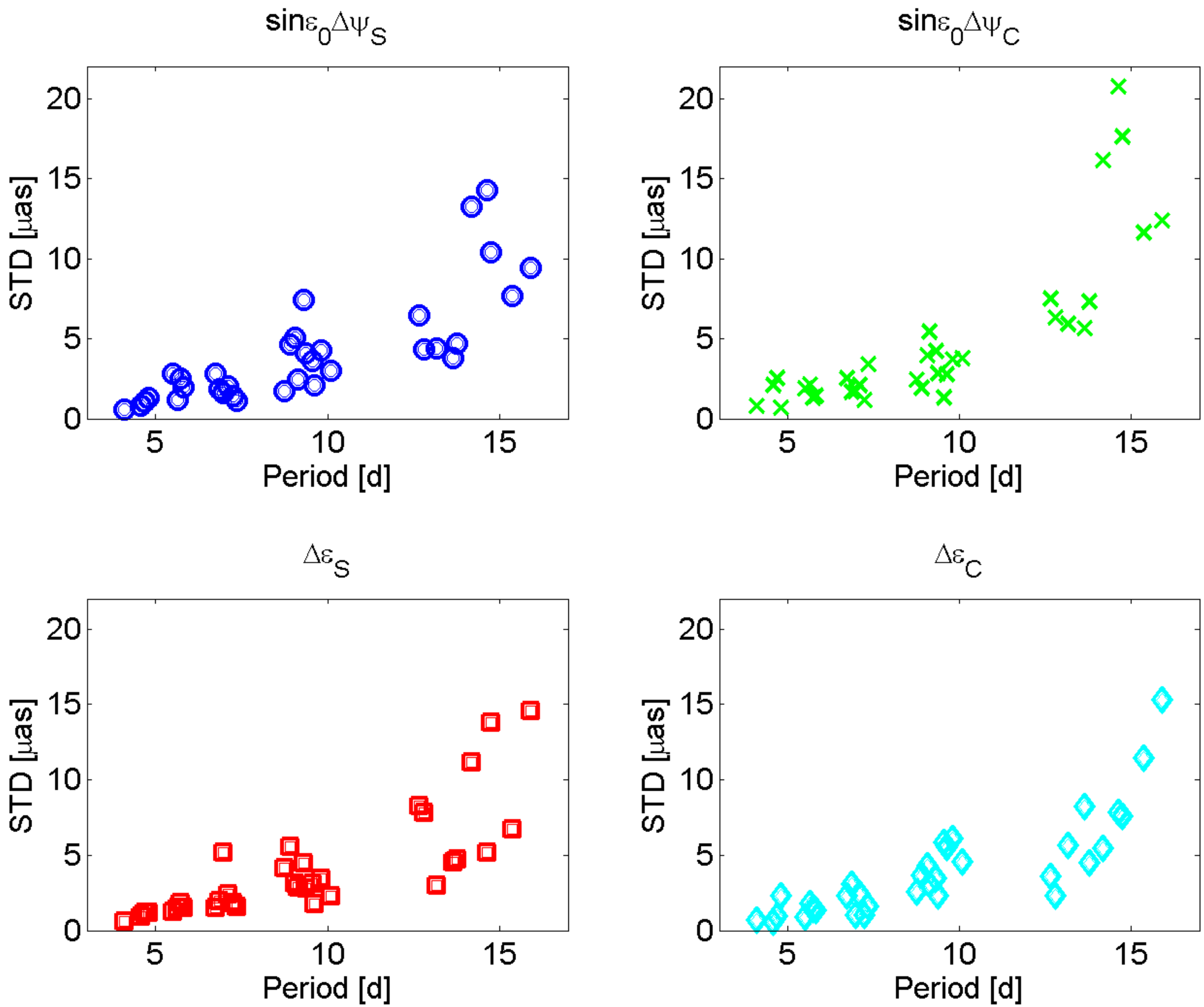


Reprocessed vs. Operational Series

Differences with respect to IAU2000A

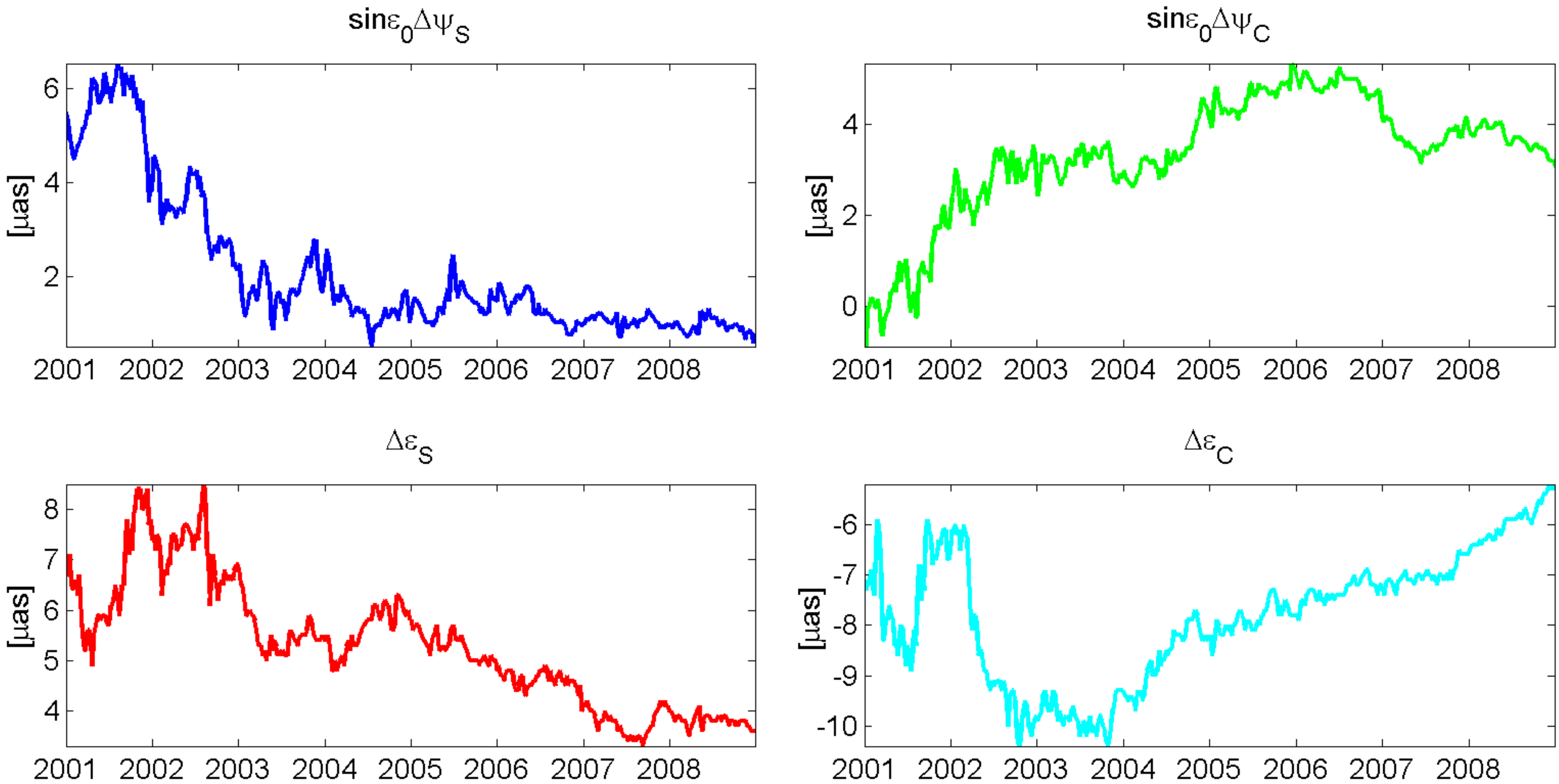


Precision of Nutation Models



Estimation of 8 nutation models from the CO1 series based on 8 years of data shifted by 1 year (time period 1996-2008)

Convergence of Nutation Coefficients

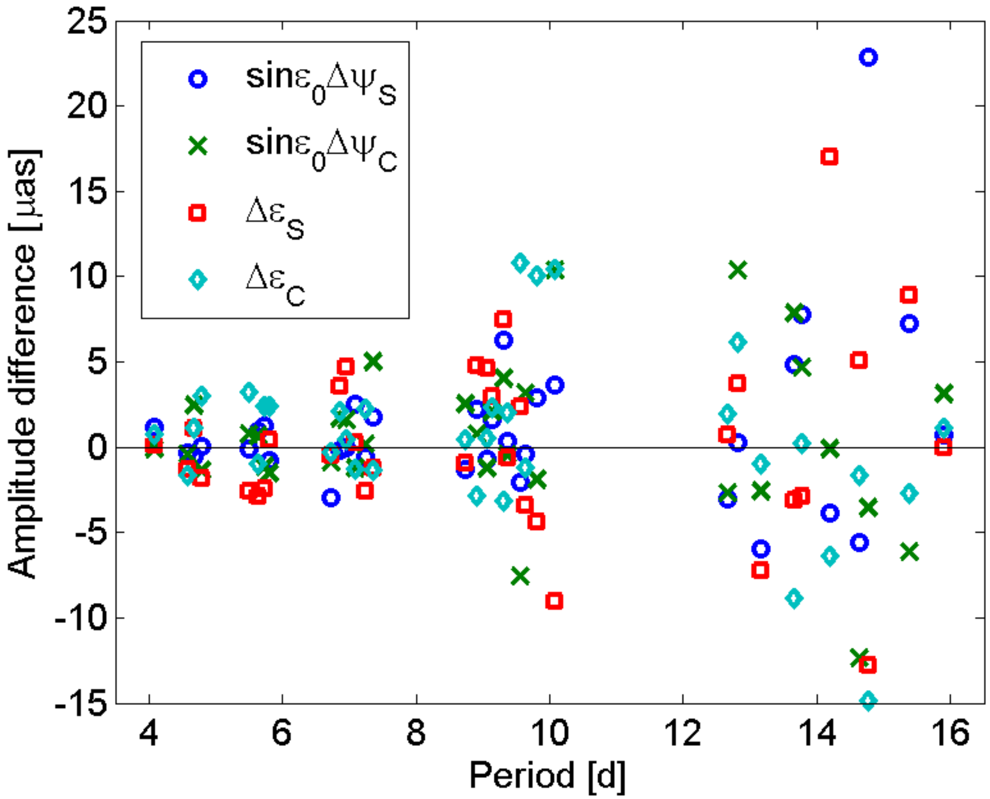


Estimation of nutation models from the CO1 series starting with January 1996 until the time displayed on the *x*-axis, 7.096 d period

Impact of Different Processing Options

A priori radiation pressure model

- CO1: empirical CODE model
- PD1: physical ROCK model

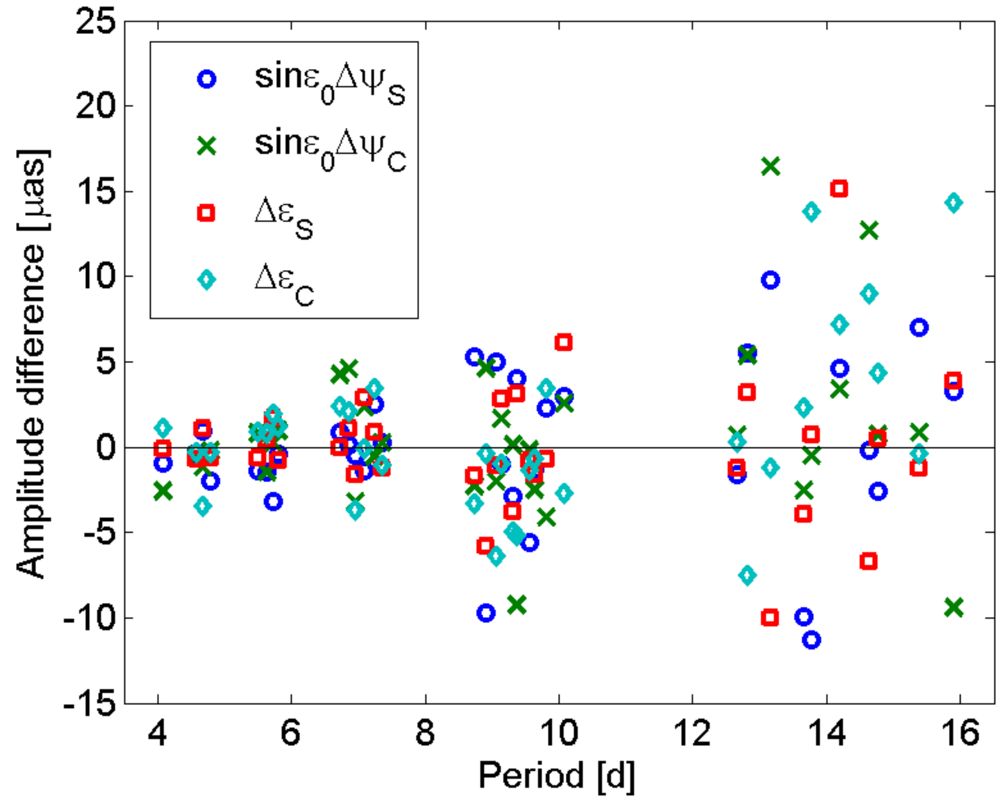


$$\overline{\Delta}_{C,S} = 4.9\,\mu as$$

GPS vs. GPS/GLONASS

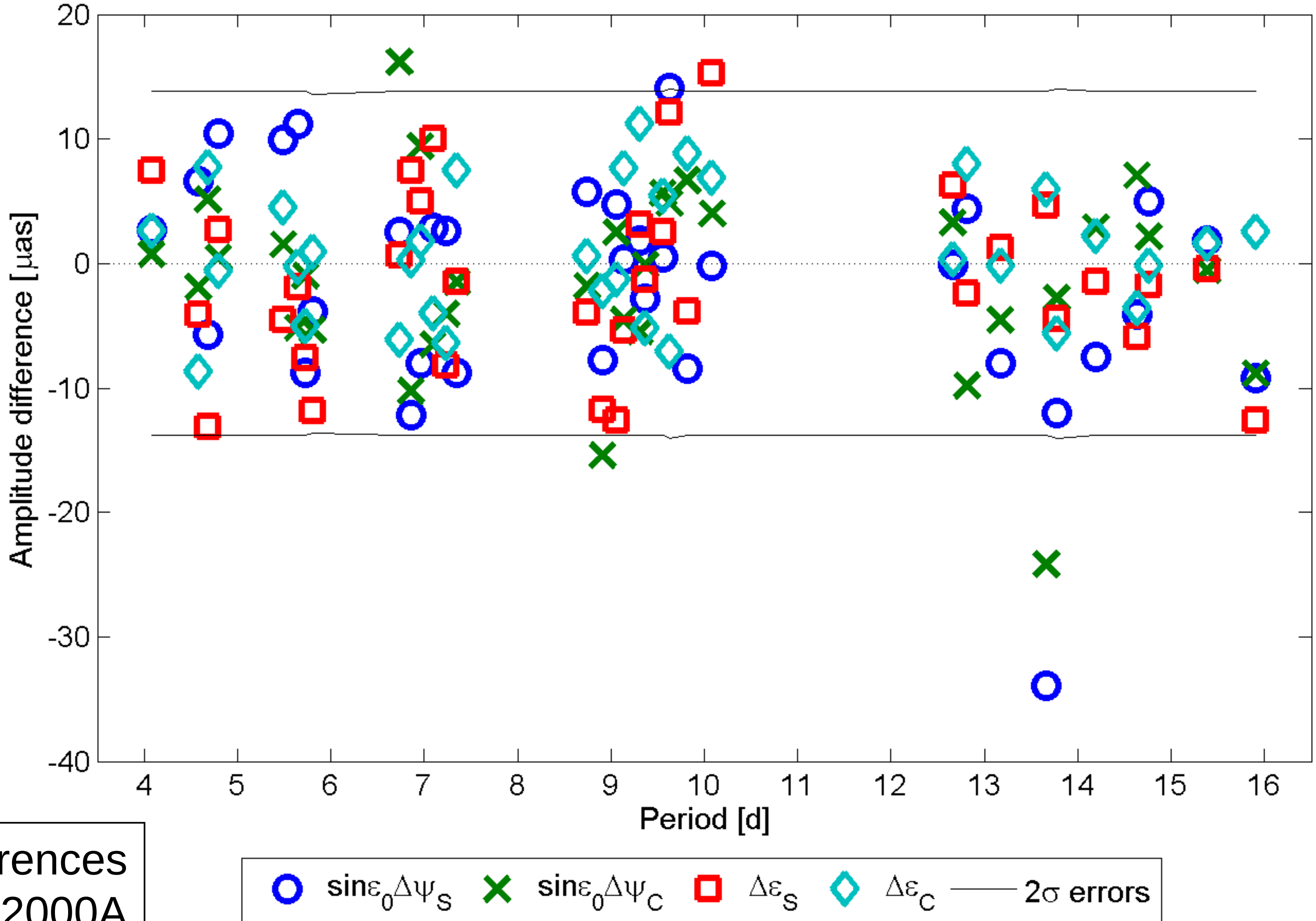
limited time interval 321/2005-366/2008

- COD: GPS+GLONASS
- CO1: GPS-only



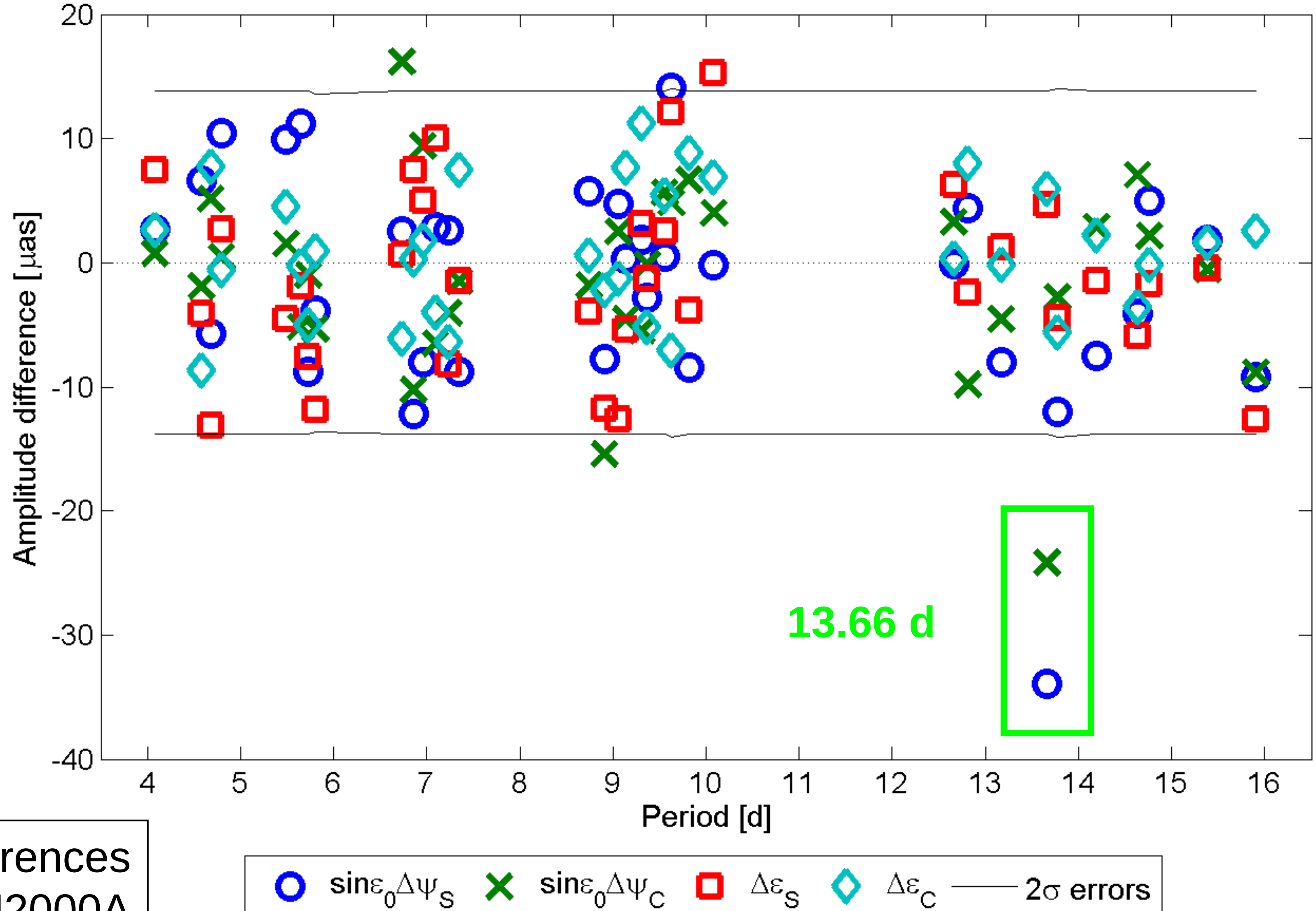
$$\overline{\Delta}_{C,S} = 4.6\,\mu as$$

GSFC VLBI Nutation Model



Differences to IAU2000A

GSFC VLBI Nutation Model



Differences to IAU2000A

Comparison of Nutation Models

Differences between the coefficients of model 1 and model 2 in μas:

$$\overline{\Delta}_{C,S} = \sqrt{\left[\sum_{i=1}^{n}(\Delta\psi_1^i - \Delta\psi_2^i)^2 \cdot \sin\epsilon_0^2 + \sum_{i=1}^{n}(\Delta\epsilon_1^i - \Delta\epsilon_2^i)^2\right] \cdot \frac{1}{4n}}$$

Model	GPS			VLBI			
	COD	CO1	PD1	DGF	GSF	GIC	IAU
COD	--	20.1	20.1	22.8	21.0	22.2	20.4
CO1		--	4.9	10.0	9.1	10.3	7.0
PD1			--	9.1	8.4	14.2	6.7
DGF				--	5.9	3.9	8.2
GSF					--	5.8	8.4
GIC						--	8.4

Conclusions

- **Homogeneously reprocessed** long-time series of nutation rates are a **prerequisite** for the determination of nutation with GNSS
- Still **systematic effects** from **deficiencies** of the **orbit modeling** at longer periods but **good agreement** with IAU2000A at **short periods**
- Pronounced differences between **VLBI** and **IAU2000A** for the **13.66 d period**
- GNSS and VLBI **intra-technique comparisons** agree on the level of **5 μas**
- Direct comparison of **GNSS** and **VLBI** is a **factor of two worse**
- **GNSS** and **VLBI** agree with **IAU2000A** on the level of **7 – 8 μas**
- **Improvement** of GNSS **orbit modeling** (e.g., albedo) should result in more precise and more accurate nutation rates