# Preliminary analysis of the Free Core Nutation from VLBI data

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**Summary:** S everal VLBI EOP series were investigated with goal of determination of parameters of the Free Core Nutation (FCN). Both the amplitude and period of the FCN were studied. Our preliminary analysis reveals a variability of both the amplitude (known also from other investigations) and period of the FCN nutation term. The FCN amplitude varies in the range about 0.1–0.3 mas, and the FCN period — in the range about 415–490 solar days.

## 1 Introduction

In this paper we investigate variability of the FCN parameters. Whereas variations of the FCN amplitude was already investigated (see e.g. *Herring et al., 2002*; *Shirai and Fukushima, 2001*), variations of the FCN period is not been studied yet.

Modern theory of nutation predicts the steady FCN period of 431.2 sidereal days *(Dehant and Defraigne, 1997)*. The FCN period also have been estimated from VLBI observations, and found to be about 430–431 sidereal days or about 429–430 solar days (see, e.g. Table 4 in *Shirai01 and Fukushima, 2001*).

In this paper we analyze four VLBI nutation series available in the IVS data base, sufficiently long and dense to obtain reliable estimates. We consider the differences between observed values of nutation angles and IAU2000A model (which is equivalent to MHB2000 model without FCN contribution). For our purpose, we interpret the unpredicted part of observed nutation series in the FCN frequency band as the FCN contribution.

## 2 Data used in analysis

The series used in our analysis are BKG00003, GSF2002C, IAAO0201, USN2002B. We analyzed both raw (i.e. given on original epochs) and smoothed (equally spaced by 0.05 year) series. For smoothed series we also computed weighted mean one. The parameter of smoothing was chosen in such a way to suppress oscillations with periods less then 1 month. Common time span for all series is 1984.0–2002.8. Figure 1 shows smoothed series used in our analysis.

## 3 Analysis and results

### 3.1 Spectral analysis

For estimation of the power spectral density from both raw (unequally spaced) and smoothed (equally spaced) nutation series we used the Ferraz-Mello's method *(Ferraz-Mello, 1981)* which allows us to process both types of data. For supplement testing, we also compute the power spectral density using the Burg's method *(Marple, 1987)*. Figures 2—4 show the normalized results of spectral estimation, and Table 1 presents the estimates of the FCN period.

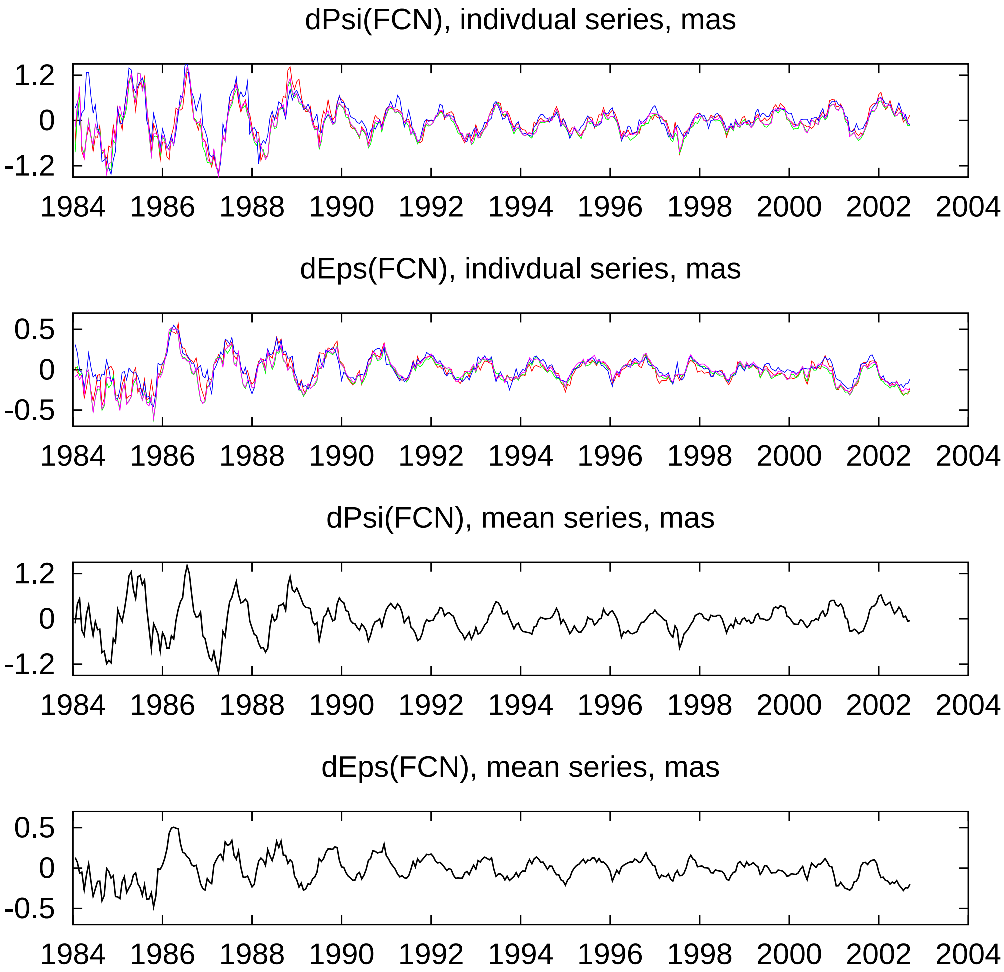


Figure 1: FCN contribution in the individual and mean series.

The average estimated value of the FCN period is of about 434 solar days (about 435 sidereal days). This value is substantially greater than one found in *Shirai and Fukushima (2001)* (431.0±0.6 sidereal days). However, when we used for spectral analysis only nutation series cut at the epoch 2000.2 which corresponds to the data span used in *Shirai and Fukushima (2001)*, we obtain the FCN period of about 432 sidereal days which is close to found in *Shirai and Fukushima (2001)* (see the last line in each section of Table 1).

### 3.2 Wavelet analysis

At the next step we applied wavelet analysis to all the nutation series. For this analysis we used program WWZ, developed by the American Association of Variable Star Observers and available at ([1]). Theoretical background of this method can be found in *Foster (1996)*.

Results of wavelet analysis are presented in Figures 5–9. Figures 5–7 show the skeletons (a period at which the wavelet is maximum). In all these figures the results for the first and the last 2-year periods are not shown since they are affected by the edge effect. All the periods in the figures are given in solar days, and all amplitudes computed from the smoothed values are to be multiplied by 1.01 to recover the smoothing effect.

[1] http://www.aavso.org/cdata/wwz.shtml

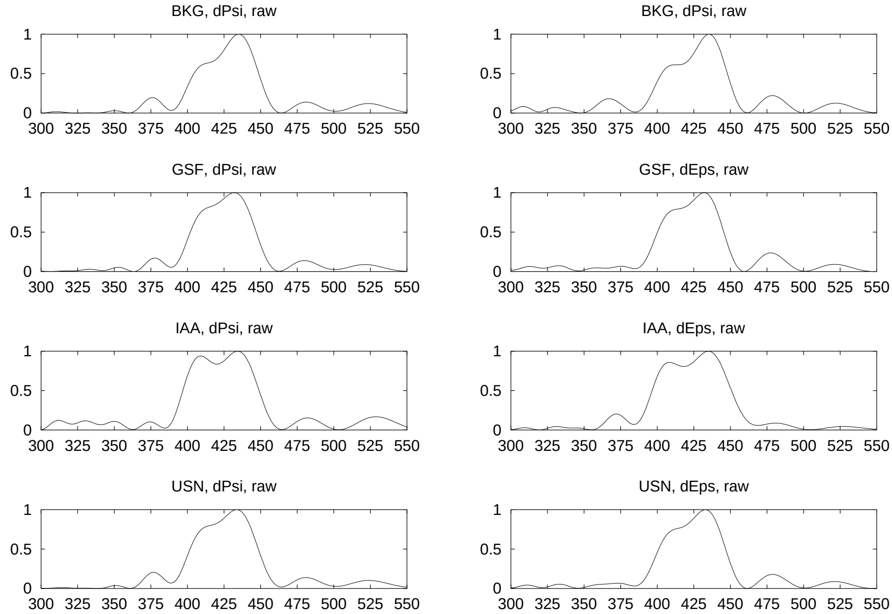


Figure 2: Spectra of raw data, Ferraz-Mello's method, solar days.

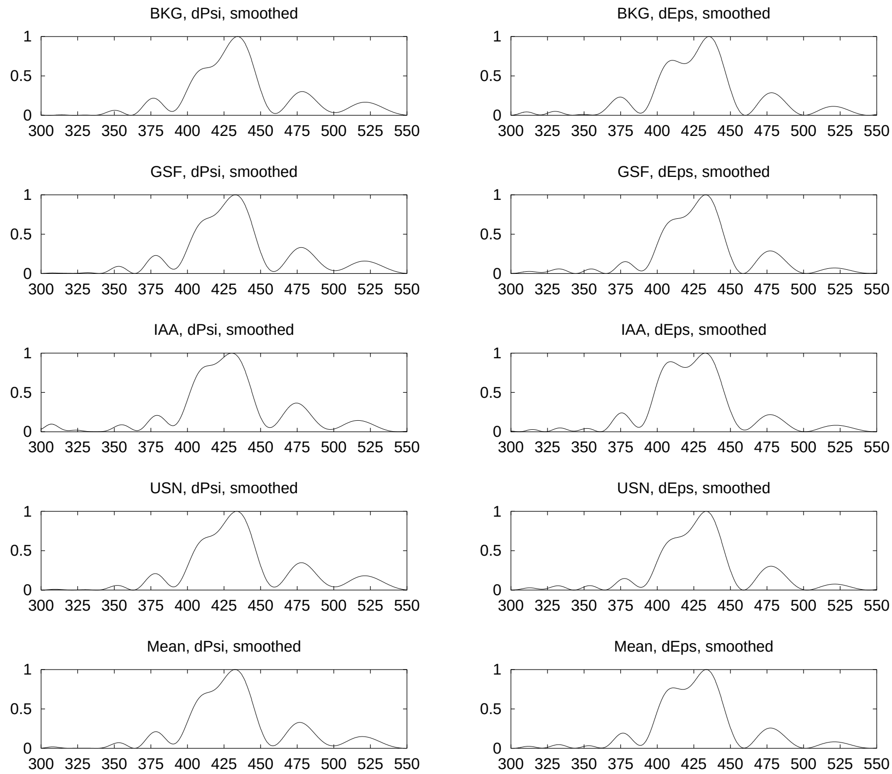


Figure 3: Spectra of smoothed data, Ferraz-Mello's method, solar days.

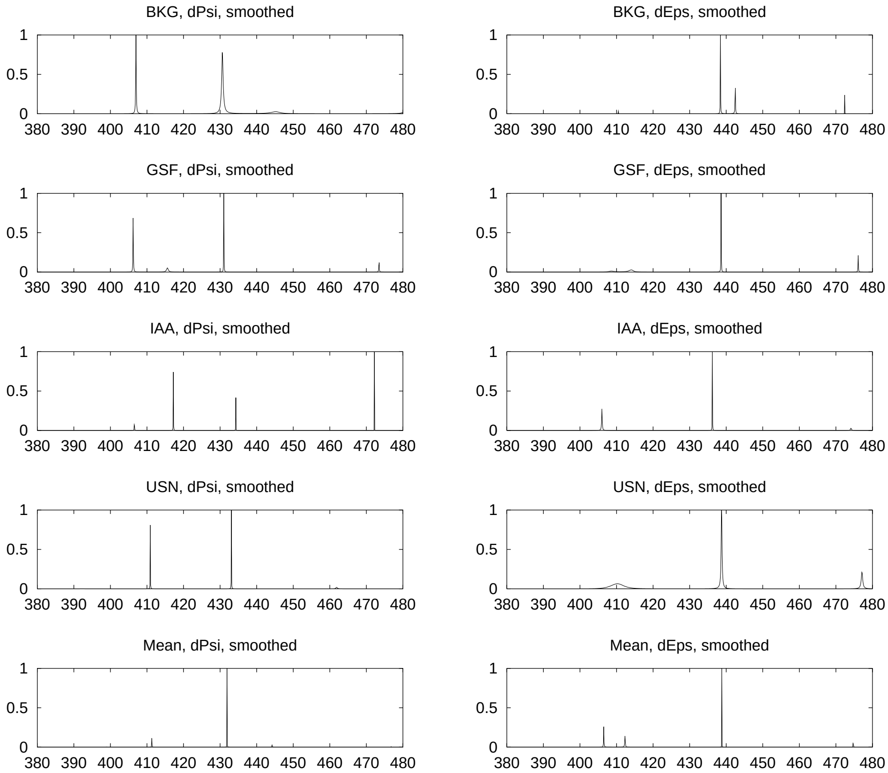


Figure 4: Spectra of smoothed data, Burg's method, solar days.

Table 1: Periods of the FCN contribution, solar days.

| Series | Method | BKG | GSF | IAA | USN | Mean |
|---|---|---|---|---|---|---|
| | | | **dPsi** | | | |
| Raw | Ferraz-Mello | 435.0 | 432.2 | 434.4 | 433.7 | — |
| Smoothed | Ferraz-Mello | 434.2 | 432.7 | 430.3 | 433.7 | 432.5 |
| Smoothed | Burg | 430.6 | 431.0 | 434.3 | 433.1 | 431.9 |
| Smoothed | Burg (–2000.2) | 433.4 | 430.0 | 428.5 | 433.4 | 431.9 |
| | | | **dEps** | | | |
| Raw | Ferraz-Mello | 435.4 | 432.2 | 435.0 | 432.9 | — |
| Smoothed | Ferraz-Mello | 435.4 | 433.1 | 432.9 | 433.5 | 433.5 |
| Smoothed | Burg | 438.4 | 438.6 | 436.2 | 438.7 | 438.8 |
| Smoothed | Burg (–2000.2) | 431.7 | 428.5 | 429.5 | 430.1 | 429.9 |
| | | | **Mean of dPsi and dEps** | | | |
| Raw | Ferraz-Mello | 435.2 | 432.2 | 434.7 | 433.3 | — |
| Smoothed | Ferraz-Mello | 434.8 | 432.9 | 431.6 | 433.6 | 433.0 |
| Smoothed | Burg | 434.5 | 434.8 | 435.2 | 435.9 | 435.4 |
| Smoothed | Burg (–2000.2) | 432.6 | 429.2 | 429.0 | 431.8 | 430.9 |

Figure 9 presents the final results of the present investigation. It should be mentioned that based on comparison of FCN amplitudes found here and previous investigations *(Malkin, 2002)*, we consider the results obtained before 1990 as not very reliable.

Of course, an important question arising from the obtained result is whether the variations of the period found from our analysis is an actual geophysical signal or an artifact caused by inadequate computational procedures. One can see that large increasing of the FCN period after ≈1998 corresponds to relatively low amplitude of the FCN oscillation. We have performed some tests to estimate how result of wavelet analysis depend on variable amplitude of input signal. Our conclusion is that found variations of the FCN period cannot be explained by computational errors. Besides, results of spectral analysis made for different subset of data also corroborate our conclusion.

## 4 Discussion and conclusions

The results of our investigations allow us to make some preliminary conclusions.

The FCN period most likely varies with time. Probably, change in the period is physically connected with change in amplitude. On the other hand, one can see that the variations of the FCN period show clear periodicity with a period about 5 years, whereas variations of the FCN amplitude does not show such an effect.

Another reason of the observed behavior of the FCN period maybe a jump(s) in the FCN phase. Analogous effect was found also at the Chandler frequency *(Vondrak, 1988)*, for which dependence of the period on amplitude, and the phase jump occurred during the period of the lowest amplitude were also found.

It is interesting, that the Chandler wobble period also decreased in ≈1986–1988, and increased in ≈1989–1996 (see *Höpfner, 2003*, *Schuh et al., 2001*). Unfortunately, Polar Motion series studied in those papers are much shorter than one analyzed here to perform a reliable comparison.

Variations of FCN amplitudes show several possible epochs of the excitation of the FCN, most of them are close to ones detected in *Shirai and Fukushima (2001)*.

Some tests we performed allow us to make a conclusion that investigated nutation series really contain such a signal with variable amplitude and period, however it's not clear if this corresponds to a known geophysical process(es). As stated above, we interpret the differences between observed nutation and the IAU2000A model as FCN contribution, which may be too strong assumption.

We plan to continue our analysis to detect and investigate more carefully the complex observed signal and possible geophysical interpretation.

## Acknowledgments

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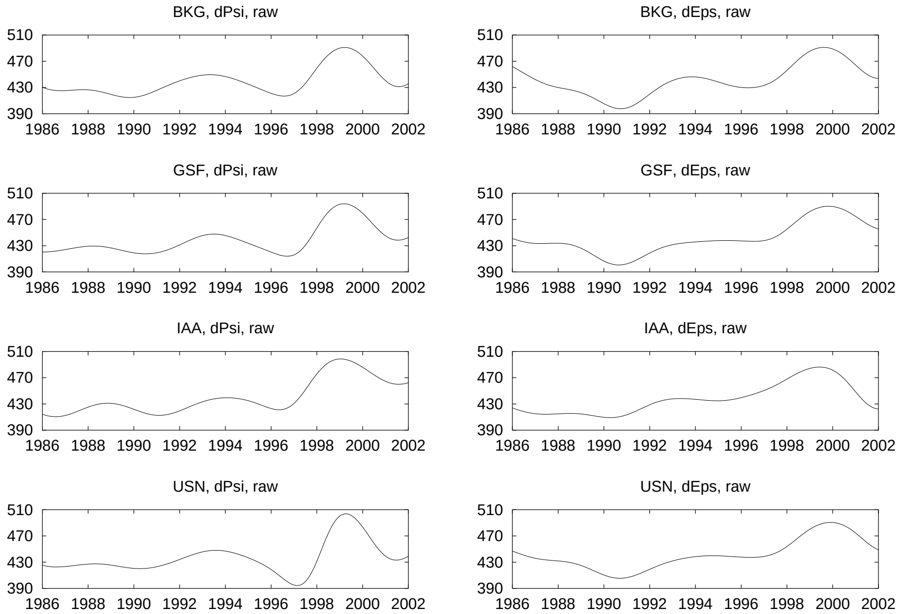


Figure 5: Variations of the FCN period with time, raw data, solar days.

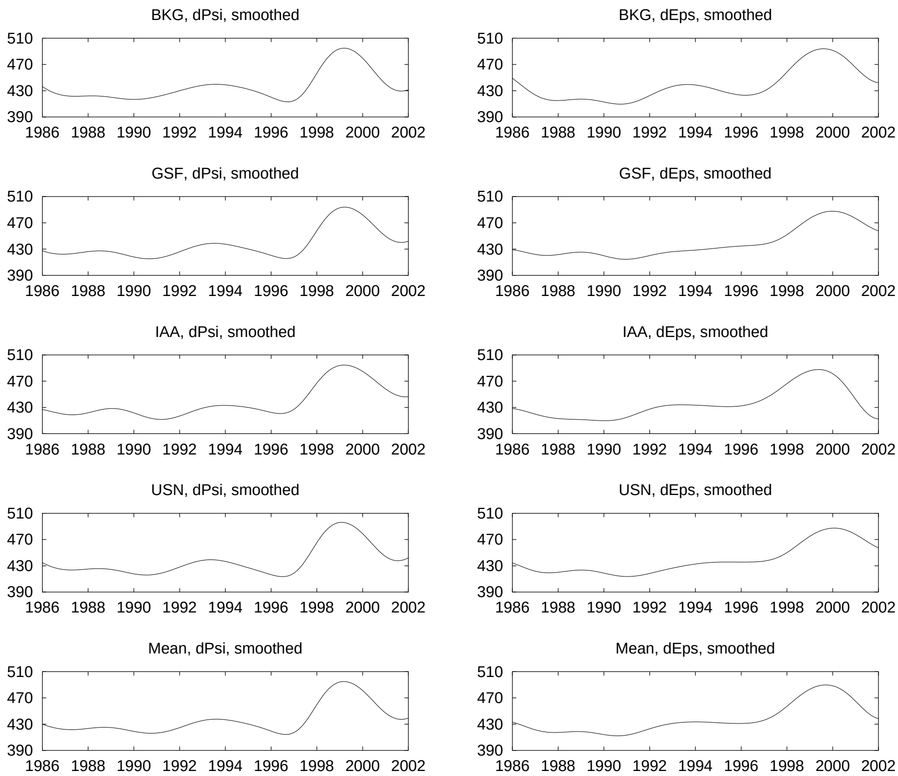


Figure 6: Variations of the FCN period with time, smoothed data, solar days.

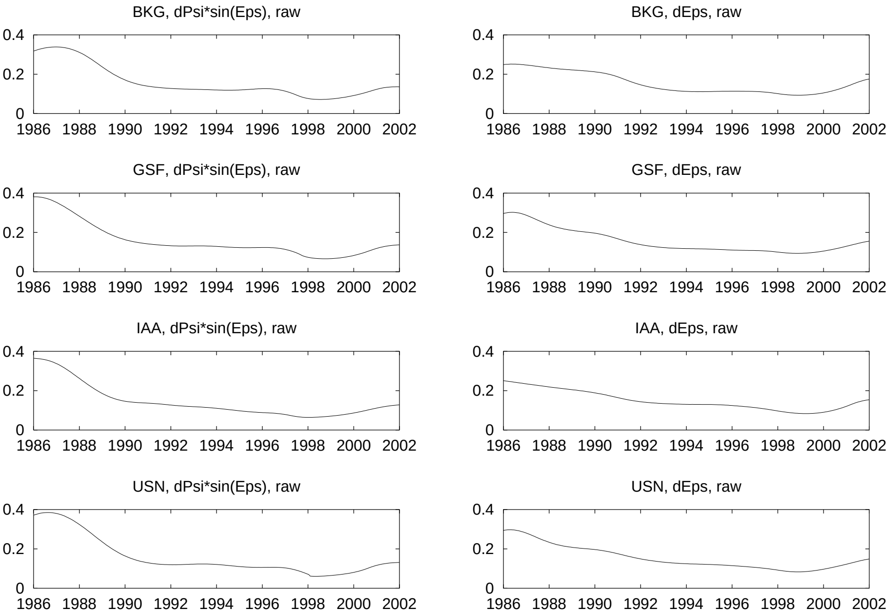


Figure 7: Variations of the FCN amplitude with time, raw data.

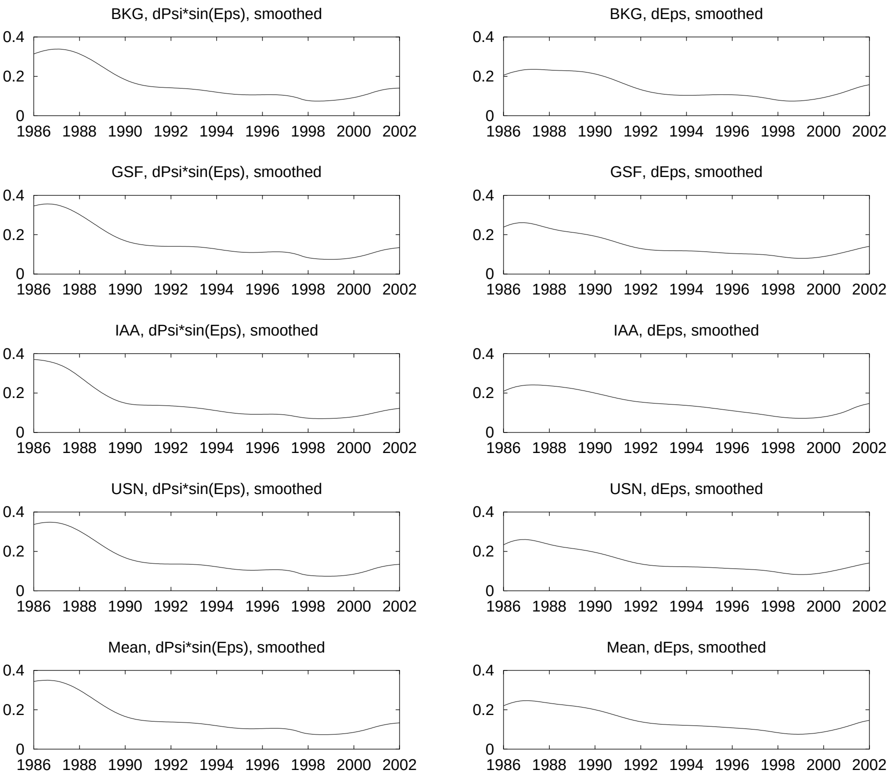


Figure 8: Variations of the FCN amplitude with time, smoothed data.

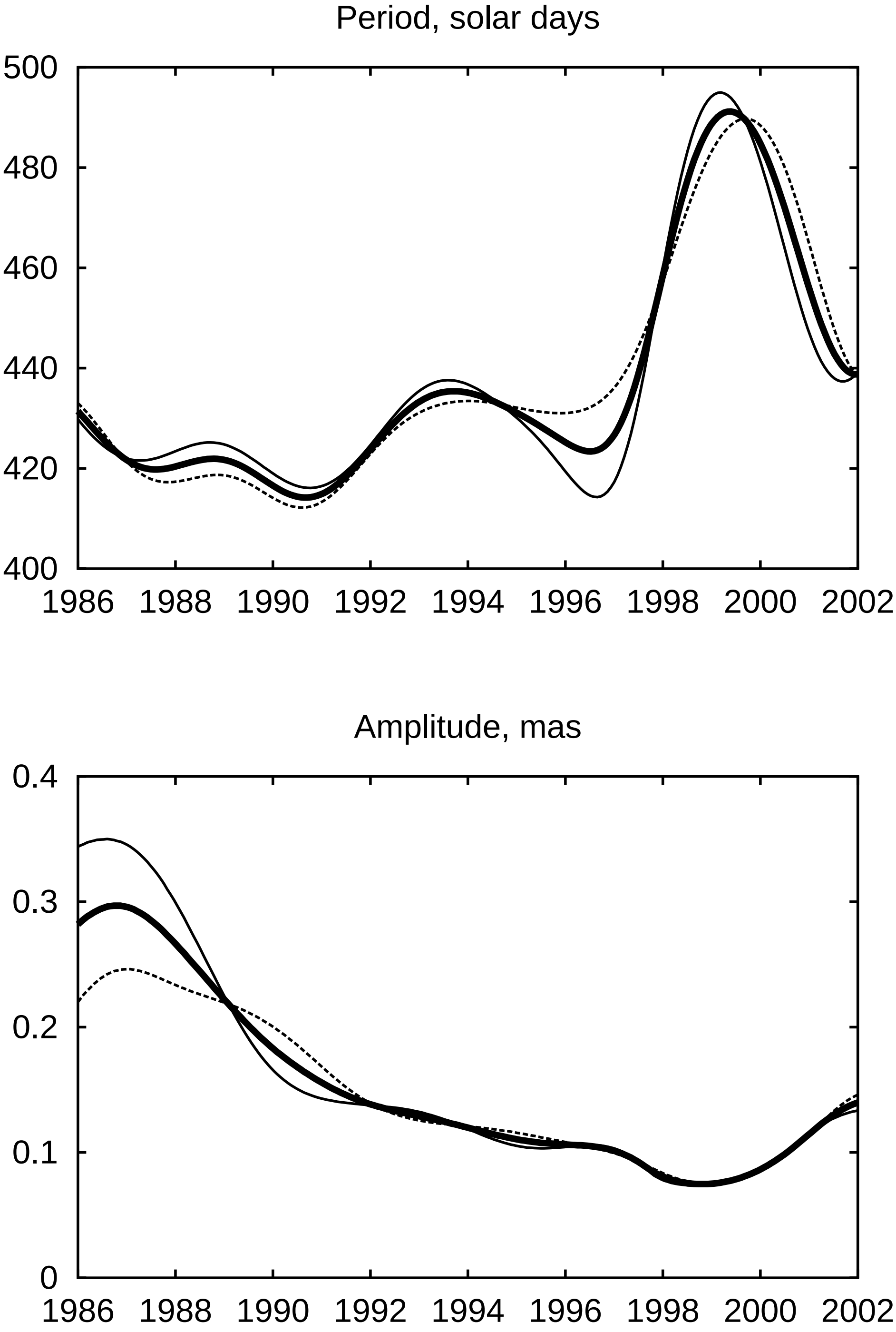


Figure 9: Variations of the FCN period and amplitude with time; $\Delta\psi * \sin(\varepsilon)$ (solid line), $\Delta\varepsilon$ (dashed line), and mean of $\Delta\psi$ and $\Delta\varepsilon$ (bold line).

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