COMPUTATION OF THE “GEODETIC” EXCITATION FUNCTION OF NUTATION

S. BOLOTIN[1,2]
[1] Space Research Centre, PAS, Bartycka 18A, 00-716, Warsaw, Poland
[2] Main Astronomical Observatory, NASU, Zabolotnogo Str. 27, 03680, Kiev, Ukraine
e-mail: bolotin@mao.kiev.ua

ABSTRACT. Investigations concerning geophysical excitation of nutation (see Brzeziński and Bolotin, this volume) should be performed in the same way as it has been routinely applied in the polar motion excitation studies: first, compute from the time series of the observed nutation residuals the corresponding “geodetic” excitation, and then compare it to the available geophysical estimates of the excitation.

A simple digital filter for estimation of the geodetic excitation function of nutation was developed by Brzeziński (1994, 2006). A primary purpose of this paper is to assess how important are various simplifications introduced to this filter, what is the influence of the measurement errors and computer round-offs. This is achieved by applying the filter to various synthetic time series of the celestial pole offsets and then comparing its outputs to the assumed input excitations.

1. INTRODUCTION

It is commonly believed that the Free Core Nutation (FCN) and other irregular signals seen in the time series of the celestial pole offsets are mostly driven by the dynamically coupled atmosphere-ocean system.

Recent time domain comparisons of the atmospheric and oceanic excitation functions and the so-called “geodetic” excitation, derived from the nutation time series, showed that the overall correlation between them is low, below 0.3. A sliding window correlation analysis reveals the periods with high correlation, up to 0.8, but also the periods with negative correlation (Brzeziński and Bolotin, this volume).

The aim of this work is to perform numerical tests using the synthetic time series and investigate: 1) how the procedure of evaluation of the “geodetic” excitation function is sensitive to the computer round-offs; 2) how it is affected by the simplifications introduced when developing this procedure; 3) how the evaluated “geodetic” excitation is influenced by the measurements errors in nutation series; and 4) what is the level of correlations which could be expected from real data.

2. COMPUTATIONAL PROCEDURE

The excitation of the FCN by redistribution of mass within the atmosphere and the oceans manifests in offsets of the Celestial Intermediate Pole (CIP) observed by the very long baseline interferometry (VLBI).

The relation between time series of the observed CIP offsets and the celestial effective angular momentum (CEAM) function was studied in details by Brzeziński (1994, 2006). Knowing CEAM functions (mass term $\{\chi^p\}_i$ and motion term $\{\chi^w\}_i$) it is possible to evaluate the changes in nutation series (denoted $\{Nut\}_i$), and, conversely, under the assumption $\chi^w = 0$ it is possible to infer from the time series of nutation the corresponding "geodetic" excitation.

$$(\{\chi^p_{input}\}_i, \{\chi^w_{input}\}_i) \Rightarrow \{Nut\}_i; \quad (\{Nut\}_i) \Rightarrow \{\chi^p_{output}\}_i.$$

Here and below, by the "input" series we will understand a time series of CEAM mass term, synthetic or real, which is used to evaluate the corresponding time series of the CIP offsets – "nutation" series. And the "output" series will mean a time series which is inferred from a corresponding time series of the CIP (under the assumption $\chi^w = 0$).

A time domain comparison of the "input" and "output" series makes it possible to estimate the influence of measurement noise which is added to the synthetic "nutation" series. This comparison is performed using a sliding window analysis of corelation with window length equal to 2 years. Also, two integral characteristics are evaluated, the overall correlation and the relative decrease of variance ΔVar,

$$\Delta Var = \frac{(Var_{input} - Var_{input-output})}{Var_{input}} \times 100\%,$$

where Var_{input} is a variance of the "input" series and $Var_{input-output}$ is a variance of a time series composed from differences of "input" and "output" series.

3. NUMERICAL TESTS

In numerical tests we used the time interval with the available observations of the FCN signal, 1984–2005. In most cases the Gaussian noise with σ_{nut}=0.15 mas was added to nutation series to simulate the measurements errors. This value is about 3 to 4 times larger than mean uncertainties of nutation residuals reported by the VLBI analysis centers for nowadays observations.

The first simple tests were performed using a finite impulse function for the mass term of the CEAM, and zero for the motion term, without adding noise to the derived "nutation". The results show that the computer round-off errors are considerably small, on the level of 10^{-4} mas.

The synthetic time series of the CEAM mass term was then used to investigate the influence of the nutation measurements errors on the evaluating of the "geodetic" excitation function. In the (a) and (b) plots of Fig. 1 are shown the X- and Y-components of this time series. The corresponding "nutation" series derived under assumption that the motion term is zero and after adding the Gaussian noise is shown in Fig. 1, (e) and (f). The evaluated "output" series are compared to the "input" ones in Fig. 1, (c) and (d). The results of a sliding window correlation analysis between the "input" and "output" series are displayed in Fig. 1, (g) and (h). The estimated overall correlation is 0.72 and the relative decrease of variance is found to be 52%. Note, however, that the amplitudes of this synthetic time series are about two times greater than the amplitudes of the CEAM mass term calculated from the EAM functions based on the output of the NCEP-NCAR reanalysis project. Repeating this test for the mass term of the real CEAM data (NCEP-NCAR reanalysis AAM) gives the overall correlation about 0.52 and the relative decrease of variance −25% (negative ΔVar means that the variance of difference of the "input" and "output" series is greater than the variance of the "input" series). Such comparative divergence of "input" and "output" series is caused by decrease of the signal-to-noise ratio.

A similar analysis after taking into account the motion term (calculated from the effective angular atmospheric functions, NCEP-NCAR reanalysis project) is illustrated in Fig. 2. For this test the overall correlation falls down to 0.45, and the relative decrease of variance is −44%.

The last test was repeated with different values of σ_{nut} to see how the overall correlation and decrease of variances depend on the measurement noise. The results are presented in Table 1.

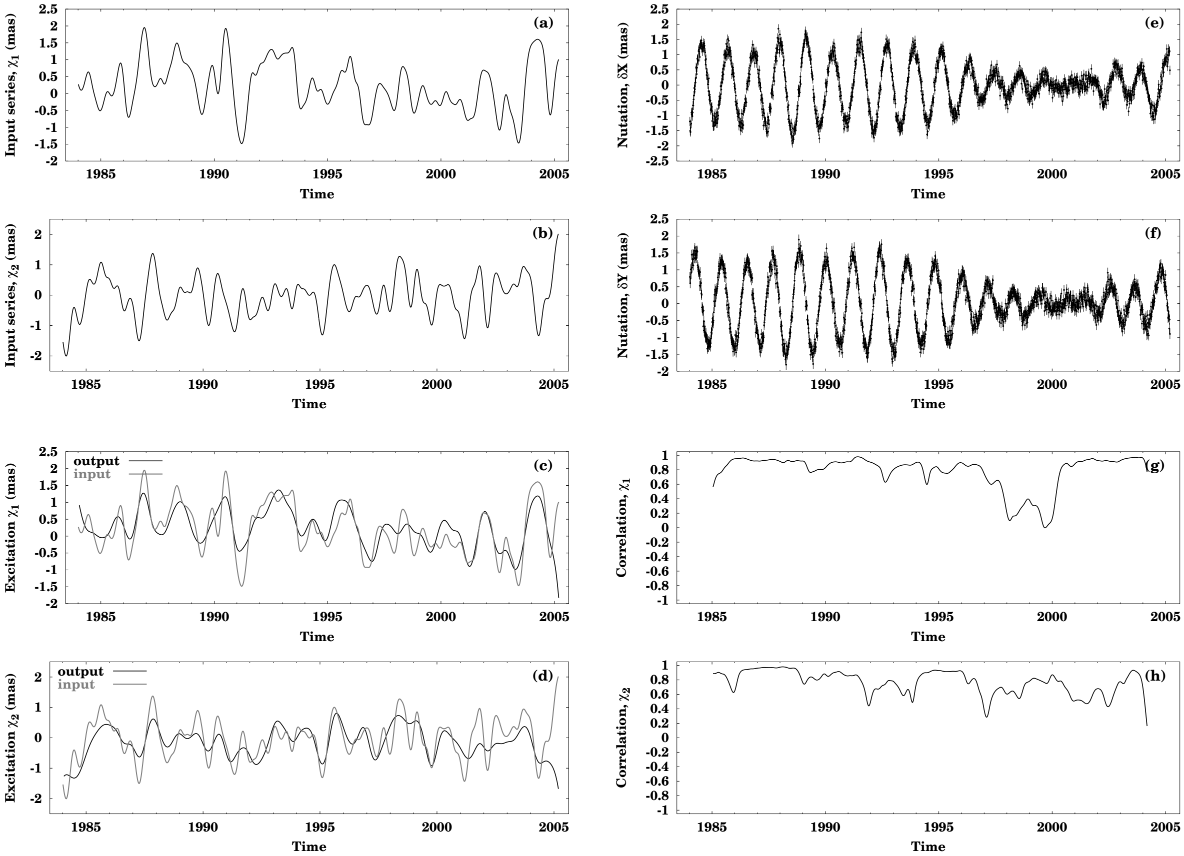

Figure 1: Artificial "input" time series. The "input" series (a) and (b), the resulting "nutation" series (e) and (f), the evaluated "output" series (c) and (d) and a sliding window correlations between the "input" and "output" series (g) and (h).

In these tests the case $\sigma_{nut} = 0$ shows how much the resulting "output" series is distorted by the assumption that the motion term has a small influence on the FCN and can be neglected.

Table 1: The changes of the overall correlation and the decrease of variances with the parameter of the Gaussian noise

σ_{nut}, mas	0.0	0.02	0.04	0.06	0.08	0.10	0.12	0.15	0.18	0.22	0.25	0.30	0.40
correlation	0.91	0.84	0.76	0.69	0.63	0.57	0.49	0.45	0.38	0.33	0.30	0.28	0.23
ΔVar, %	82	71	54	37	24	-2	-22	-60	-106	-189	-263	-383	-742

4. SUMMARY AND CONCLUSIONS

The motion term of the CEAM function has a small contribution to the excitation of the FCN; the assumption $\chi^w = 0$ in calculation of the "geodetic" excitation function does not alter the results significantly.

Calculation of the "geodetic" excitation function is also not sensitive to the computer round-offs. But, our tests show that the calculation is strongly depends on the noise contents in nutation series.

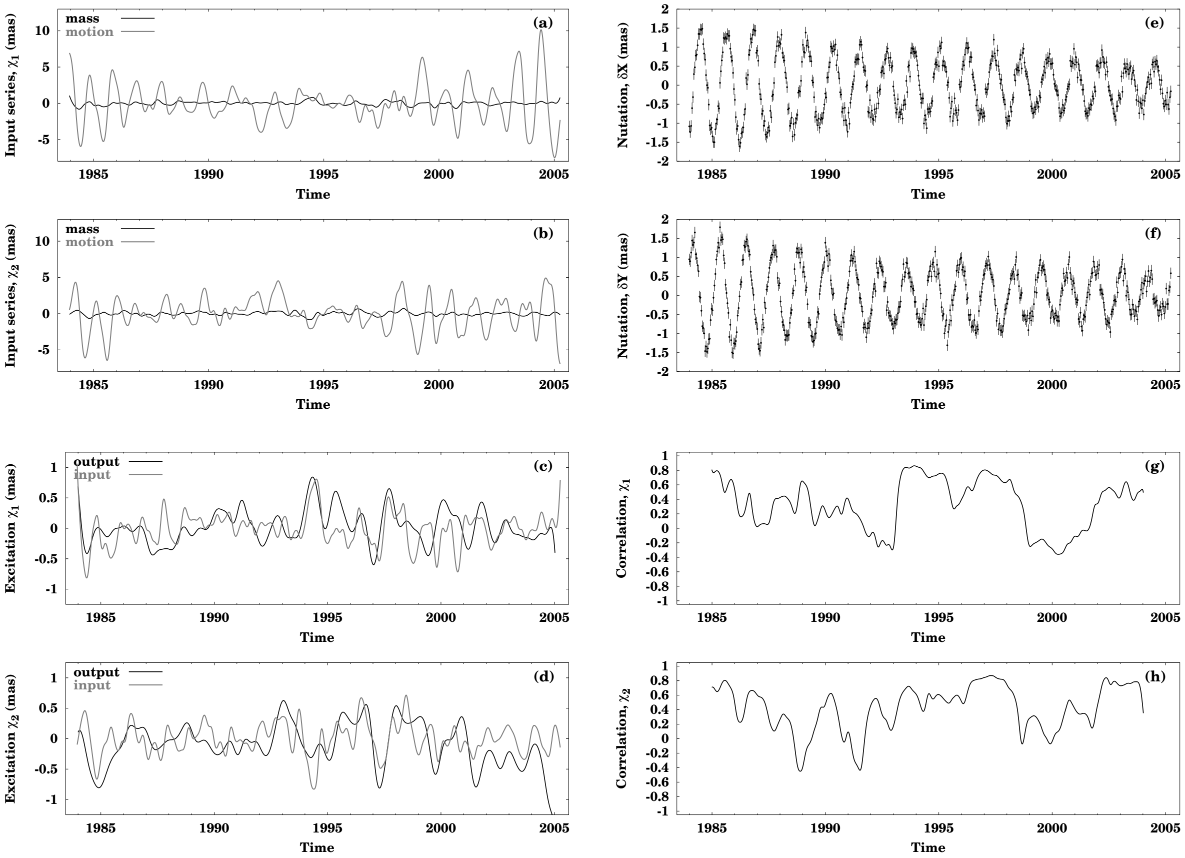

Figure 2: Mass and motion terms (from the NCEP-NCAR reanalysis project). The layout is the same as in Figure 1.

When assuming the standard deviations of the VLBI nutation series at the level of 0.15 mas or better, we can expect a reliable calculation of the “geodetic” excitation function.

Acknowledgments. This work was financed by a post-doc visiting grant in a frame of the “Descartes-Nutation” project. It was partially performed at the Space Research Centre, Polish Academy of Sciences. Author is very thankful to the collective of the Centre for cordial reception and hospitality.

This research has made use of the effective angular atmospheric functions based on results of the NCEP-NCAR reanalysis project provided by the IERS SBAAM.

REFERENCES

Brzeziński, A., 1994, Polar motion excitation by variations of the effective angular momentum function, II: Extended model, Manuscr. Geod., 19, pp. 157–171.

Brzeziński, A., 2006, A digital filter for the geophysical excitation of nutation, Journal of Geodesy, Special VLBI Issue, in press.