A search for the free inner core nutation in VLBI data

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1. Introduction

For an elastic Earth in hydrostatic equilibrium with a liquid core and a solid inner core, one can expect a resonance in the nutation due to the inner core (free inner core nutation, FICN) at 475 days in space. Adding a visco-magnetic coupling between the core and the inner core (Mathews et al. 2002, Mathews & Guo 2005, Koot et al. 2010), or including the viscosity of the inner core (Koot & Dumberry 2011), the resonance period can reach the Mathews et al. (2002)'s 1034 days, which were fitted to the observations. However, a stratified liquid core can give birth to a double FICN. The two resonance periods can run from hundreds to thousands of days (Rogister & Valette 2009).
As for the FCN, the FICN could be excited by external fluid layers. Following Dehant et al. (2005), the amplitude of the forced FICN could reach a few tens of mas. It could be detectable observationally as the observation precision is now of this order of magnitude.
During VLBI analysis, mismodeled phenomenon or misadapted parameterization or analysis configuration can lead to significant artifacts in the VLBI series, making them poorly exploitable for geophysics.
In this study we aim at analyzing the interannual prograde band of the nutation in the recent nutation data to point out the significant signal, possibly resulting from the analysis configuration or geophysical phenomena, that should be further investigated.

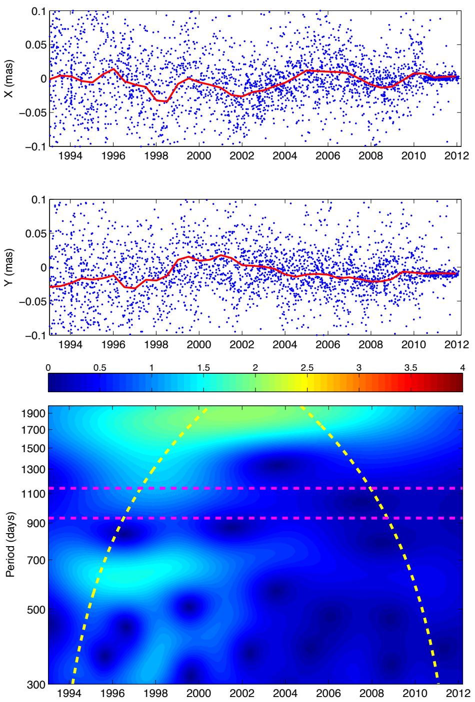

Fig. 3. Nutational signature of the unstable radio sources (top), and prograde band of the wavelet spectrum (bottom). Amplitude unit: μas.

5. Concluding remarks

The prograde band of the nutation series show significant structures at the level of a few tens of μas. These structures are similar for all series analyzed in this work and produced by four distinct analysis centers (that used, however similar observations!)
The instability of the CRF seems to produce an effect much smaller than the observed structures. These structures are likely connected to (i) network effects, i.e., inconsistencies between session-wise TRF and CRF, (ii) atmospheric processes, or other geophysical phenomena including the FICN. More investigations are necessary to separate these effects.

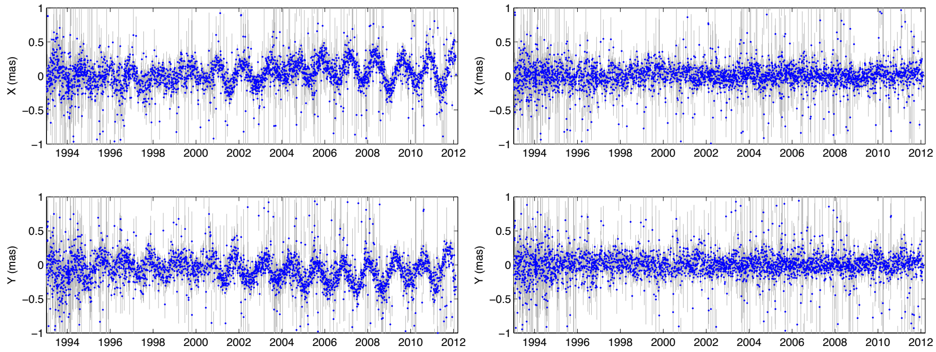

Fig. 1. Nutation offsets after 1993 before (left) and after (right) fitting and removal of the FCN and the tidal terms.

2. The nutation offsets

The IAU 2000A nutation model is not perfect. One expects therefore the nutation offsets to contain a non negligible signal arising from unmodeled or mismodeled tidal terms (e.g., at 18.6-year or semi-annual periods) or other geophysical contribution including the atmosphere (Bizouard et al. 1998, Yseboodt et al. 2002, Dehant et al. 2003, Vondrák et al. 2005, Lambert 2006). The amplitude- and phase-variable retrograde free core nutation (FCN) was not included in IAU 2000A and is therefore also left in the nutation offsets. A better, but empirical, modeling of the nutation can be achieved by (i) adjusting a retrograde, 430-day period signal with variable amplitude and phase (on, e.g., a 2-year sliding window) to account for the FCN, and (ii) fitting a number of tidal terms of fixed period and phase to the nutation offsets. A list of 42 tidal terms is provided in Herring et al. (2002). The atmospheric contribution to the nutation remains unpredictable due to strong inconsistencies in the global circulation models at diurnal frequencies (de Viron et al. 2005) and will therefore not be considered here.
The tidal term and time-variable FCN amplitudes and phases were fitted by weighted least-squares to the whole data set (i.e., since 1979). The solution is shown in Fig. 1 before (left) and after (right) fitting. A slight variation over few years shows up in both X and Y (e.g., around 2000) of amplitude likely below 100 μas.

3. Residual signal in the prograde band

The nutation offsets after 1993 were analyzed by wavelets (Morlet) using Torrence & Compo's MATLAB routines, for nutation series released by various IVS operational analysis centers (Fig. 2). For the purpose of the wavelet algorithms, the series were regularized by a moving average every 10 days. Some significant features show up in every spectra: strong power in the early years above 1000 days, increasing power in the FICN band after 2008 (probably a side effect), and some power around 2004 at about 600 days.

4. Signature of the unstable radio sources

Nutation are especially sensitive to the realization of the celestial reference frame (CRF). For instance, Feissel-Vernier et al. (2005) showed that some power in the FICN band was associated with an intense activity of the radio sources that result in significant displacements of their radio centers. The CRF is materialized by the coordinates of more than 4,000 quasars that are estimated during the analysis. Generally, most of the quasars' coordinates are estimated as global parameters. Nevertheless, since some quasars are very unstable, the analyst can decide to downgrade those coordinates to session parameters. Especially, during the ICRF2 work, we isolated 39 very unstable quasars having a large observational history (observed in more than 1,000 sessions).
To check whether the signal present in the wavelet spectrum is due to the celestial reference frame instability, we ran two solutions: one wherein 39 unstable radio source coordinates are estimated as global parameters, and another one where these source coordinates are estimated as session parameters (i.e., identical to the solution shown in Fig. 2). The difference of the nutation series and the spectrum are displayed in Fig. 3. A significant variation shows up in both X and Y at the level of a few tens of μas. However, the wavelet spectrum shows that these variations do not explain those observed in the nutation series.

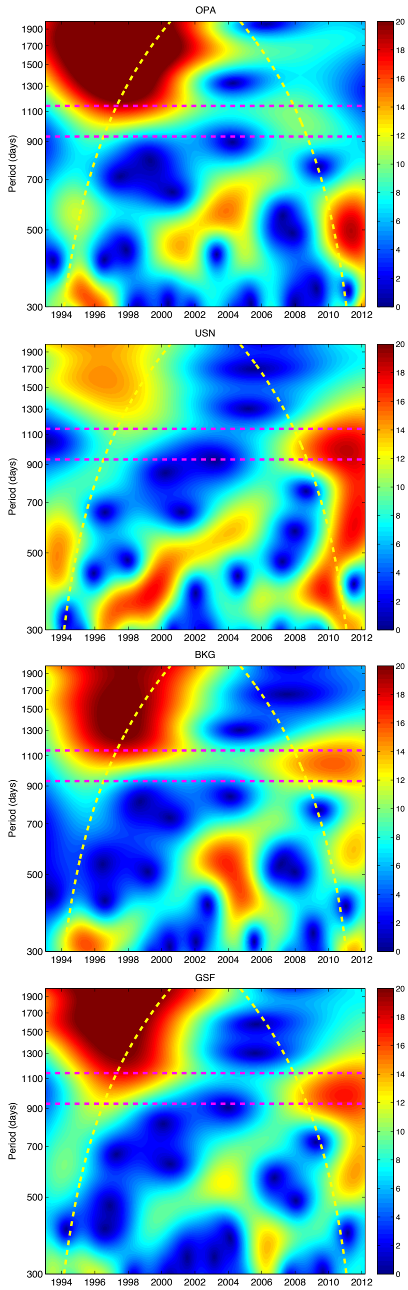

Fig. 2. Wavelet spectra of four operational nutation series. The horizontal dotted lines show the FICN frequency band following Mathews et al. (2002). Amplitude unit: μas.