The Annual Retrograde Nutation Variability

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Abstract : *Very Long Baseline Interferometry is the only technique that can estimate Earth nutations with an accuracy under the milliarcsecond level. With 35 years of geodetic VLBI observations, the principal nutation terms caused by luni-solar tides and geophysical response have been estimated. We focus on the variability. Two of them present very significant amplitude and phase variations : the retrograde Free Core Nutation (FCN) at around 430 days period and the Annual Retrograde Nutation (ARN). Despite progresses achieved in global circulation models, the atmospheric and ocean excitation cannot account for that. In particular the ARN shows an amplitude modulation of approximately 6 years, reminding the 6-year geomagnetic oscillation in Length of Day (LOD). As the latter, we suggest that the nutation term variability may have deep Earth causes, and estimate an order of magnitude of Earth internal structure parameters to explain this variability.*

Nutation Comparison between Operationnal IVS analysis center

We carried out a comparison of several nutation time series provided by different analysis centers of the IVS :

- Geoscience Australie (AUS00007, Australia)
- Bundesamt für Kartographie und Geodäsie (BKG00014, Germany)
- Centro di Geodesia Spaziale (CGS2014A, Italy)
- Goddard Space Flight Center (GSF2014A, USA)
- Institue of Applied Astronomy (IAA2007A, Russia)
- Observatoire de Paris (OPA2015A, France)
- Astronomical Institute of St.-Petersburg University (SPU00004, Russia)
- U.S. Naval Observatory (USN2015A, USA)
- Vienna University of Technologie (VIEEOP13, Austria)
- the IVS combined solution (IVS14Q2X) which is computed with the transformed and weighted normal equations of several operationnal analysis center solutions [1].

The nutation time series used in this study are offsets according to IAU2000A/2006 precession-nutation model [9, 5] in dX, dY parametrization. Despite the divergence between nutation time series, analysis center products are **in agreement on Free Core Nutation (FCN) and Annual Retrograde Nutation (ARN) products at the level of about 30 μas**.

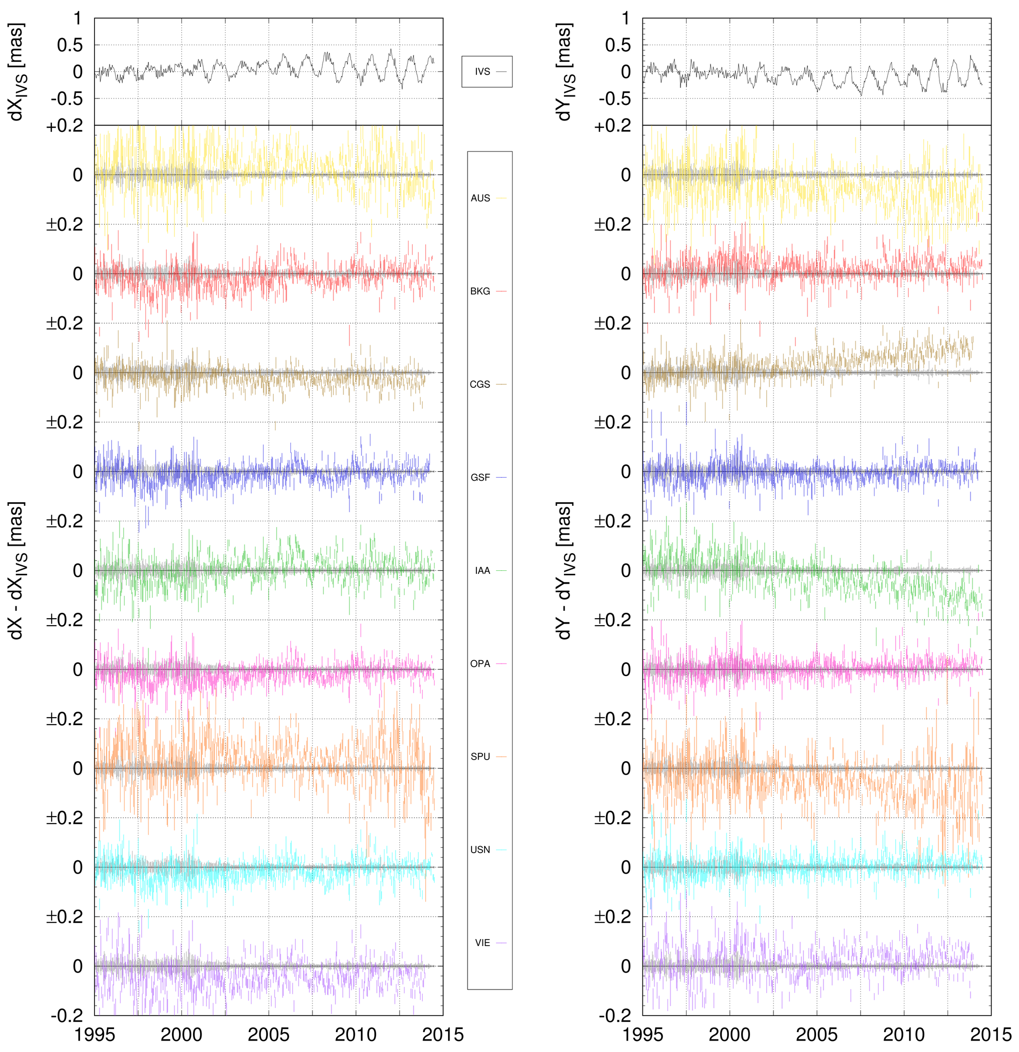

Fig. 1: Comparison on dX,dY of several analysis center with respect to the IVS combination

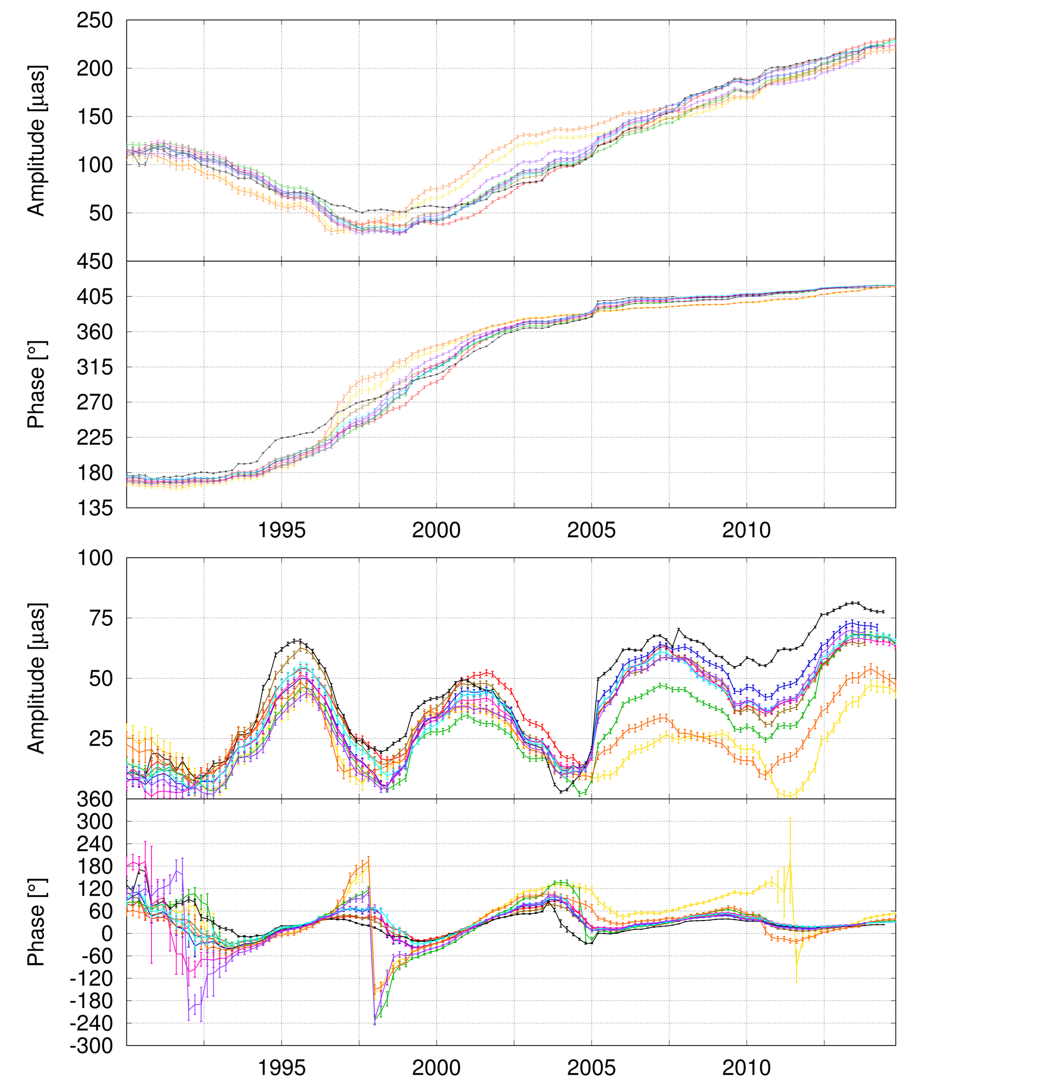

Fig. 2: Free Core Nutation and Annual Retrograde Nutation simultaneous adjustments by mean of a 7-year sliding window least square

6-year variability of the Annual Retrograde Nutation (ARN)

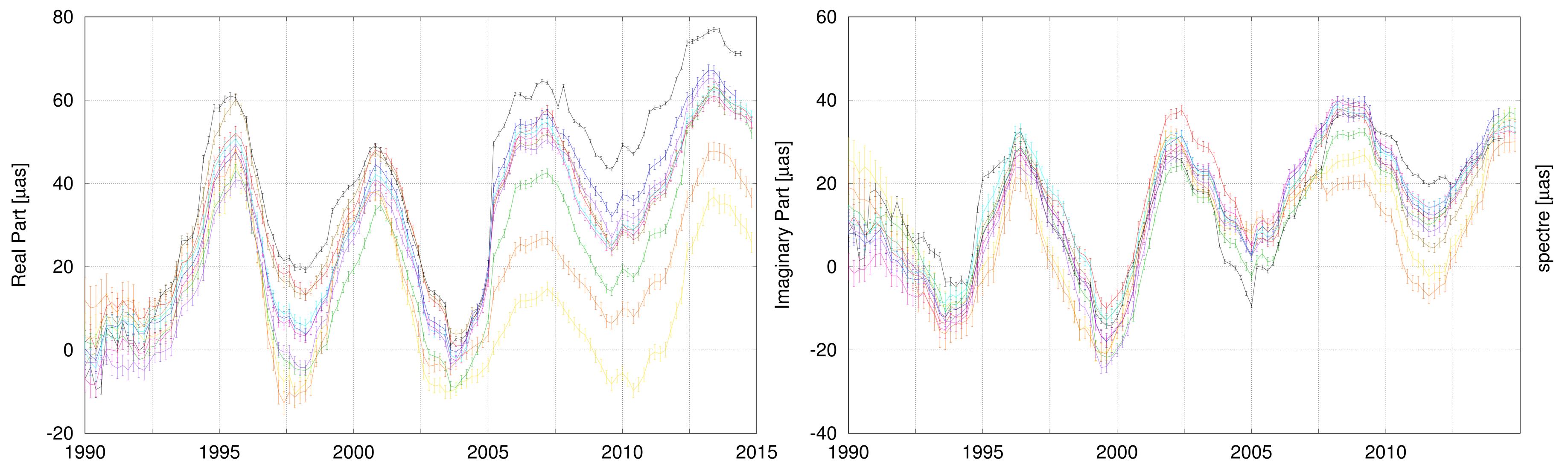

Fig. 3: Annual Retrograde Nutation in Real/Imaginary form

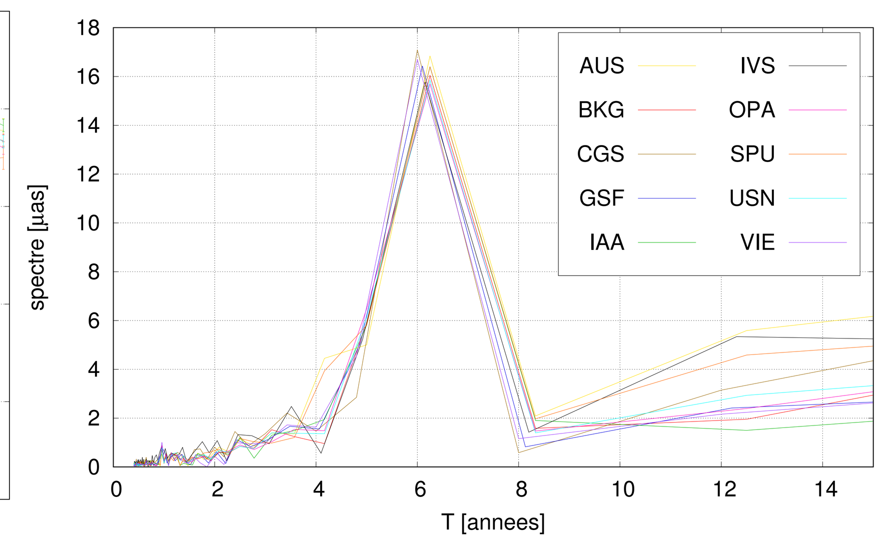

Fig. 4: Spectrum of the Annual Retrograde Nutation

The ARN is of luni-solar origin. Rigid Earth model [13] predicts an amplitude of 24 mas, amplified by a factor ≈ 1.3 in the non-rigid Earth model [9]. The Analysis of ARN products from each IVS analysis centres clearly **show a periodical modulation of period around 6-year and of about 20 μas of intensity**.
Can this variability be an artefact from our analysis ? Indeed, the sum of two periodic signal, one at the ARN period, the other at the FCN period lead to a single modulated signal at 6.62 year-period of modulation. In the spectral domain, if the ARN is truly modulated in amplitude by a 6-year period, the spectrum should present two symmetric peaks around the ARN frequency, one at the right place of the FCN, so invisible because of the dominance of the latter, one on the other side. By studying the spectrum of several IVS solutions, we see no evidence of such a second peak around 313 days. But the surroundings also show that fluctuations is also at the level of 20 μas.
We are still working on the understanding of our analysis system, especially by a test on a fully controlled artificial signal simulating a combination of a non-variable FCN and a 6-year variable ARN. Our ability to recover or not the two artificial nutations and the variability of the ARN will help us to conclude on the modulated observed ARN

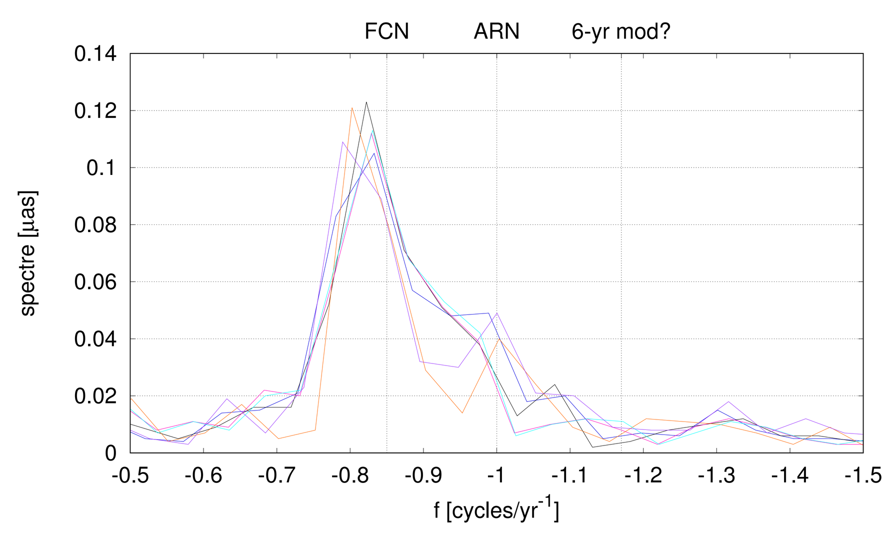

Fig. 5: Spectrum of nutations around the retrograde annual frequency

6-year in the LOD

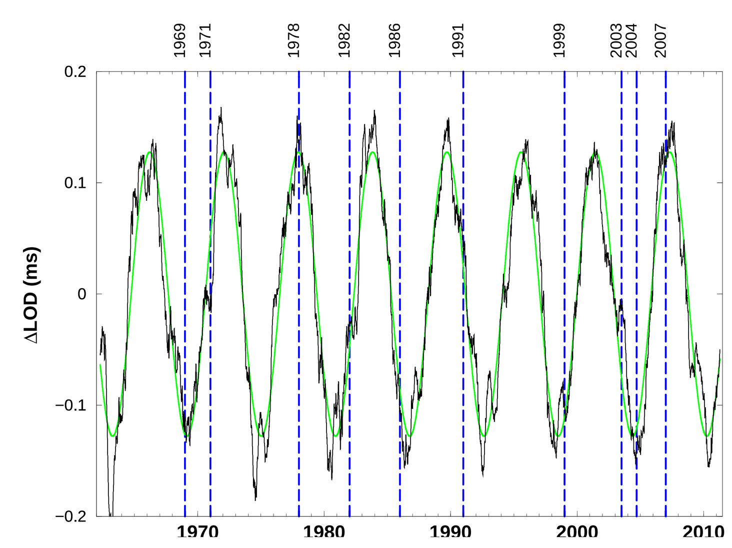

Fig. 7: 6-year term in the Length of Day (courtesy of Holme) [7]

Recently, a 6-yr oscillation detected in the length-of-day (LOD) was possibly accounted for by a internal mechanisms [10], while Holme & de Viron [7] suggested that observed jumps in the LOD were direct signatures of geomagnetic jerks.

Geophysical consequence

Variability of the ARN may have consequences on our **understanding of the Earth's deep interior**. Mechanisms responsible would be searched at the surface or deeper. Inside the Earth, the main source of excitation is the tidally- or electromagnetically-driven core flow interacting at the core-mantle boundary (CMB) and the inner core boundary (ICB). The core flow is tied to the walls by viscous, topographic, or electromagnetic couplings. The former occur when, e.g., the fluid is trapped in incursions of the CMB in the mantle. The latter comes up if there is a thin metallic layer at the base of the mantle that can be permeated by the toroidal magnetic field [11, 2, 4]. Another source of excitation is the gravitational coupling between the inner-core and the mantle [3, 4, 10]. It is difficult to conclude about superficial fluid layer contribution in absence of reliable data set [6, 8] and recent results on LOD lead us to study ARN variability in term of internal dynamics consequences.

ARN is mainly governed by the FCN resonance :

$$\sigma_{\mathrm{FCN}} = -\Omega - \Omega \frac{A}{A_{\mathrm{m}}} \left(e_{\mathrm{f}} - \beta + K_{\mathrm{CMB}} + \frac{A_{\mathrm{s}}}{A_{\mathrm{f}}} K_{\mathrm{ICB}} \right), \quad (1)$$

which A, $A_{\mathrm{m,f,s}}$ the mean moment of inertia of the whole Earth, mantle, outer core, and inner core, respectively ; e_{f} the core flattening ; β expressing the deformation at the surface when a pressure is applied to the CMB ; and $K_{\mathrm{CMB,ICB}}$ coupling constants at the CMB and the ICB [9]. Note that K_{CMB} is directly proportional to the radial component of the magnetic field at the CMB. We used the transfer function in [9] to constrain a possible departure of the global constant $K_{\mathrm{CMB}} + A_{\mathrm{s}}/A_{\mathrm{f}} K_{\mathrm{ICB}}$ with respect to the model, and allowing the observed variability of the ARN. The coupling constant remains within $\sim 10^{-6}$, so at the order of the uncertainty on $\mathrm{Im}K_{\mathrm{CMB}}$ and smaller than the one on K_{ICB} [9]. the FCN period would change by few hours, not detectable by direct observation of the free motion or indirect determination of the resonance through VLBI or superconducting gravimeter data [12].

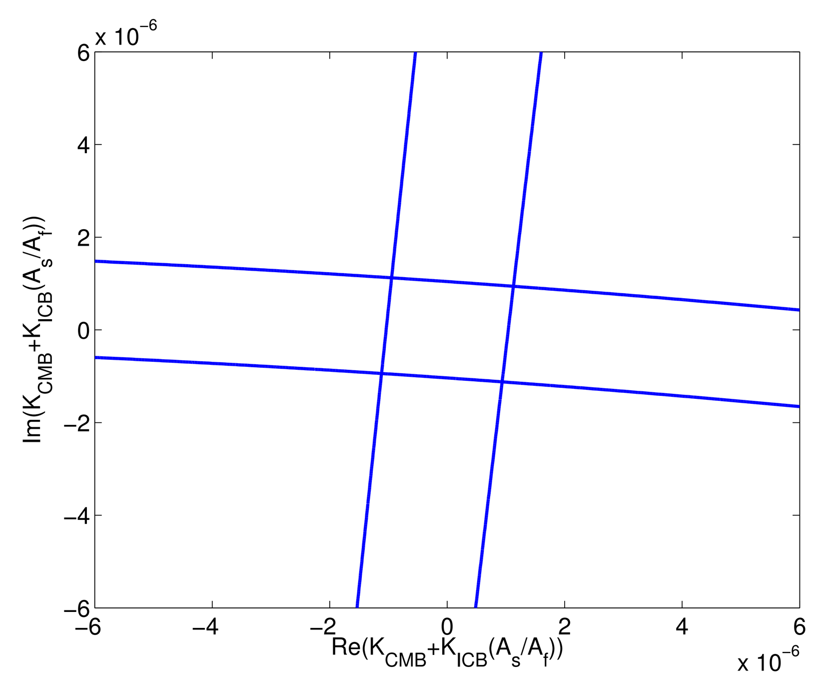

Fig. 6: The region where the global coupling constant $K_{\mathrm{CMB}} + A_{\mathrm{s}}/A_{\mathrm{f}} K_{\mathrm{ICB}}$ can vary to account for the observed variability of the retrograde annual nutation.

Références

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