GEOMAGNETIC EXCITATION OF NUTATION

Cyril Ron, Jan Vondrák

Astronomical Institute AS CR, Prague

Introduction

- Atmospheric and oceanic excitations play dominant role in polar motion and rotational velocity of the Earth.
- Thanks to the precise P/N model IAU2000/2006, small but non-negligible effects can be seen also in the celestial pole offsets (CPO), i.e. in nutation.
- These effects are caused by quasi-diurnal changes of angular momentum functions of the geophysical fluids (atmosphere, oceans,..)

Motivation

- In our previous study we found that atmospheric/oceanic effects do not explain the observed celestial pole offsets (CPO) completely.
- The integrated excitations in CRF in comparison with the observed CPO became out-of-phased after some period.
- We suppose that other excitations have effect. We tested the epochs of strong earthquakes, and geomagnetic jerks (Malkin, 2013),
    - GMJ – rapid changes of the secular variations of geomagnetic field.
- Re-initialization of the integration in the dates of these events was used and
- the best agreement has been found for the GMJ epochs.
- But the re-initialization of integration is not acceptable from the physical point of view.
- Here we present a different approach – adding a continuous excitation near GMJ epochs.

Method used

Broad-band Liouville equations

- The excitations of the Earth rotation in the celestial reference frame (nutation) by atmosphere and ocean were studied using
- Brzezinski's broad-band Liouville equations (1994)

$$\ddot{P} \quad -i(\sigma'_C + \sigma'_f)\dot{P} - \sigma'_C \sigma'_f P = -\sigma_C \left\{ \sigma'_f(\chi'_p + \chi'_w) + \right.$$
$$\left. \sigma'_C(a_p \chi'_p + a_w \chi'_w) + i[(1 + a_p)\dot{\chi}'_p + (1 + a_w)\dot{\chi}'_w] \right\}$$

where

- $P = dX + idY$ is excited motion of Earth's spin axis in celestial frame (CRF),
- σ'_C, σ'_f are the complex Chandler and FCN frequencies in CRF, respectively, σ_C in TRF.
- $a_p = 9.200 \times 10^{-2}$, $a_w = 2.628 \times 10^{-4}$ are dimensionless constants (Koot & de Viron, 2011).
- χ'_p and χ'_w are the angular momentum excitation functions (presure and wind) expressed in CRS

Method used

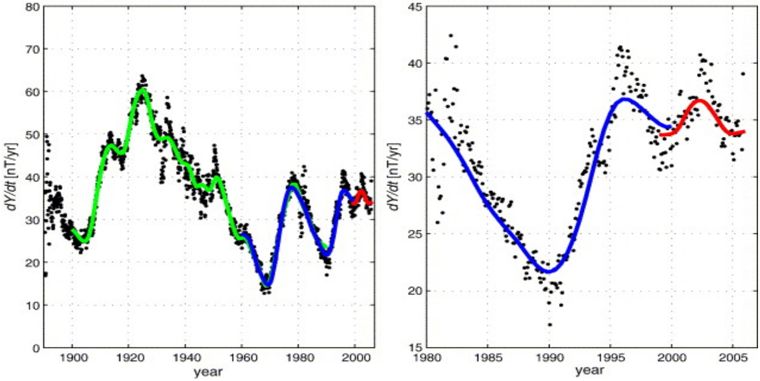
Intial values

- To be able to integrate the system we need initial values P_0, $\dot{P}_0$ constrained so that the free Chandlerian term (with quasi-diurnal period in celestial frame) vanishes.
- The initial values are closely connected to the phase and amplitude of the integrated series.
- The final choice of P_0 was made by repeating integration with different values P_0 to fit the integrated series to VLBI observations so that reaches a minimum rms differences,

Method used

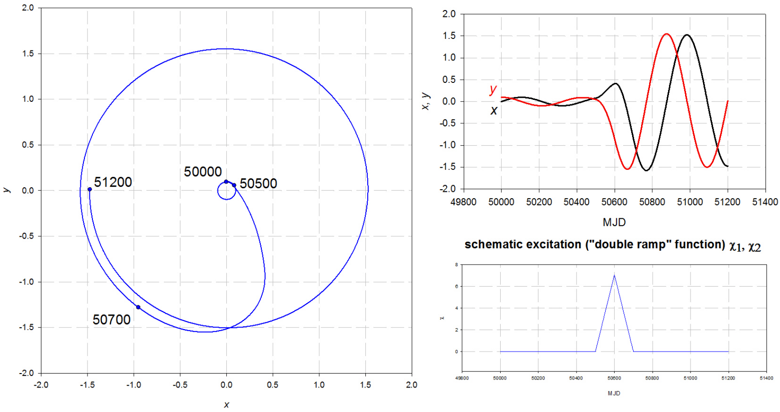
Procedure of searching the additional excitations

- Geomagnetic jerks (or secular geomagnetic variation impulse) is a relatively sudden change in the second derivative of the Earth's magnetic field with respect to time. (Olsen & Mandea, 2007).



Method used

Integration with simulated schematic excitation



Method used

Procedure of searching the additional excitations

- We fix the the central epochs of additional excitations around GMJ epochs:
  - 1991.0, 1994.0, 1999.0, 2003.5, 2004.7, and 2007.5.
- GMJs last typically several months.
- The length of excitation was fixed to 200 days.
- The complex amplitudes of the excitations were estimated to lead to the best rms fit to observed CPO.
- In our previous studies we also tested if the excitations is preceeding, delaying or corresponding to the GMJ epochs
- The best agreement was found for the epochs of GMJ.

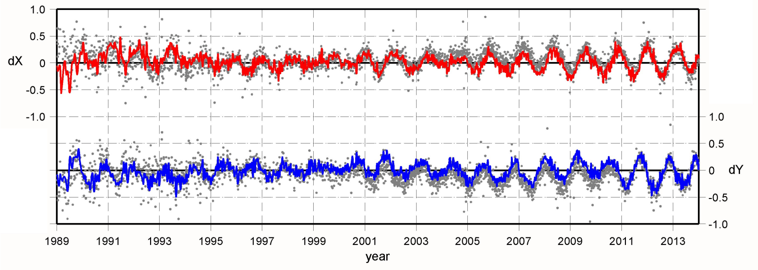
Data used

Celestial pole offsets

- Celestial pole offsets
  - The last IVS combined solution `ivs14X1q.eoxy` covering the interval 1989.0-2014.0. dX and dY are given in unequally spaced intervals.
  - then the empirical Sun-synchronous correction of IAU2000 nutation model has been added in order to be the observed CPO comparable with the atmospheric contribution.
  - than the series were filtered to retain only periods between 60 and 6000 days and interpolated at regular 10-day intervals and.

IVS Celestial pole offsets

Observed and filtered (60<P<6000d)



Data used

Atmospheric angular momentum

- There are two sources of Atmospheric angular momentum data
  - European Centre for Medium-Range Weather Forecasts (ECMWF), ERA40
  - Atmospheric and Environmental Research, USA, NCEP/NCAR reanalysis
- Our previous study based on AAM/OAM function of European meteorological Center ECMWF ERA40 and on the ocean model OMCT showed not so good agreement in comparison with the NCEP/NCAR series.
- No model of oceanic angular momentum driven by NCEP atmosphere is available for the whole period
- The pressure term with IB correction - a simple model of oceanic response on the pressure changes.

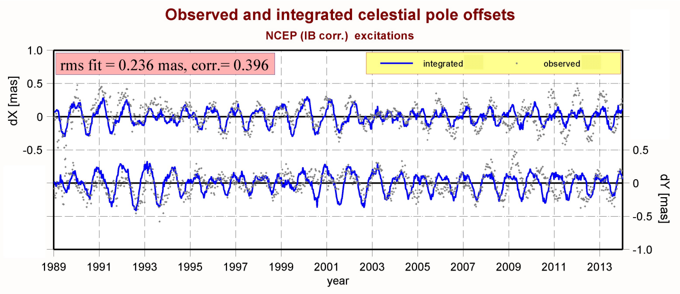
Data used

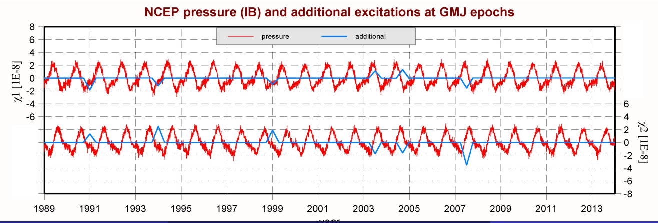
Atmospheric angular momentum

- The time series of AAM χ (complex values) were transformed from the terrestrial frame to the celestial frame by using the complex decomposition at retrograde diurnal frequency $\chi' = -\chi e^{i\Phi}$, Φ is the Greenwich sidereal time.
- Because we are interested in the long-periodic motion (comparable with nutation), we applied the smoothing to remove periods shorter than 10 days and calculated their time derivatives needed for integration.

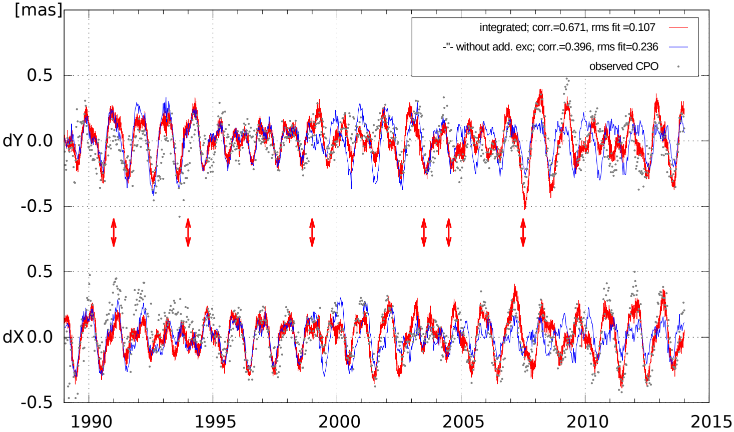
Results

pressure term with IB correction



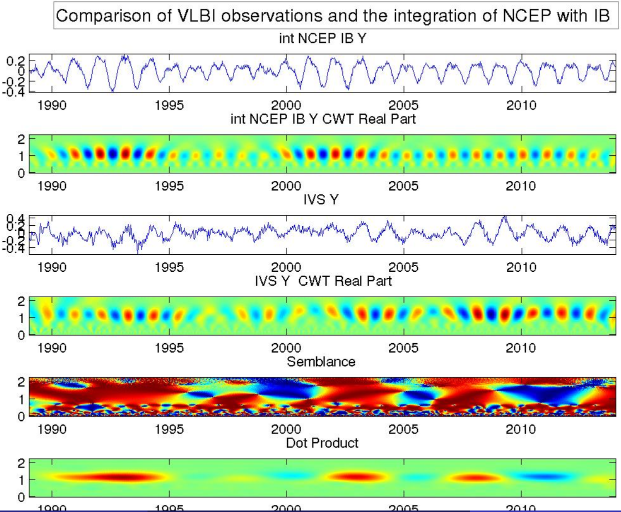


Comparison of integrated series with the observed celestial pole offsets.

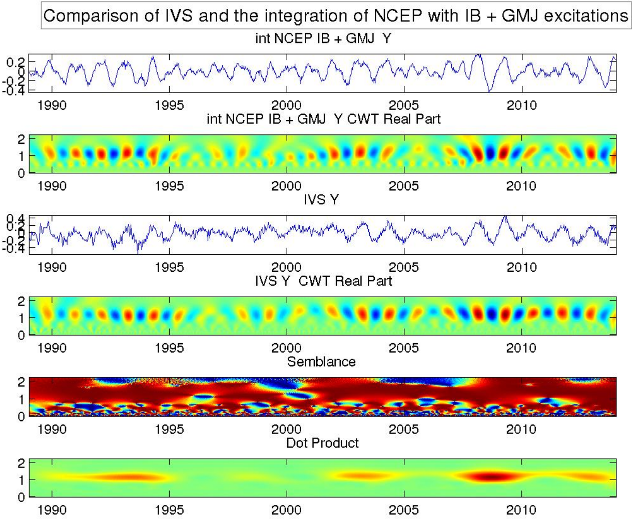


Wavelet based semblance analysis

Cooper & Cowan, 2008



Wavelet based semblance analysis



Conclusions

- Geophysical excitations can yield significant contribution to nutation, of the order of 0.1mas;
- NCEP solution with the inverted barometer correction leads to better agreement than ERA solution
- The application of schematic additional excitations at GMJ epochs improves the agreement of integrated pole position with VLBI observations.
- The interpretation of the physical nature of the GMJ effect on nutation requires more study in future.