Earth orientation parameters: excitation by atmosphere, oceans and geomagnetic jerks

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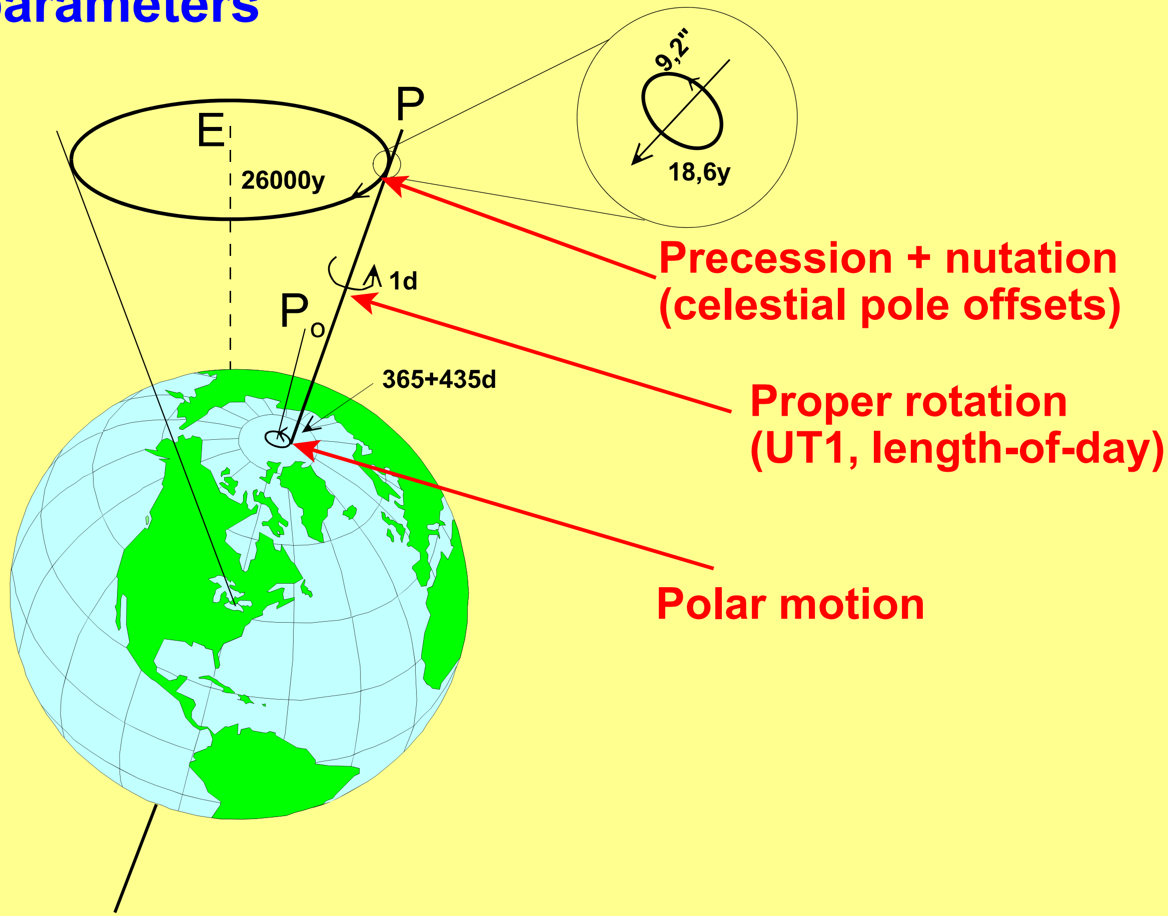
Introduction:

- It was demonstrated earlier that excitations by geophysical fluids play dominant role in polar motion and rotational velocity of the Earth; much smaller effects can be seen also in nutation;
- These effects can be derived by numerical integration of Brzeziński broad-band Liouville equations, using
  - atmospheric & oceanic effective angular momentum functions;
- Sudden changes of amplitude & phase of all Earth Orientation Parameters are correlated with geomagnetic jerks, as recently found:
  - length-of-day (Holme & de Viron 2005, 2013), polar motion (Gibert & le Mouël 2008), nutation (Malkin 2013).
- We discuss these possibilities, using the numerical integration of the excitations and comparing the results with the observed values of EOP.

Earth orientation parameters



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Data used (in interval 1989.00-2014.25):

- For polar motion and length-of-day changes:
  - IERS C04 solution.
- For the nutation, VLBI-based observations of celestial pole offsets dX, dY:
  - IVS solution ivs14q1X.eops.
- For atmospheric and oceanic excitations - angular momentum functions $\chi_{1,2,3}$ from :
  - NCEP/NCAR (atmosphere with and without IB correction),
  - ECCO (oceans).
- For geomagnetic jerks - impulse-like excitations 200 days long:
  - Epochs 1991.0, 1994.0, 1999.0, 2003.5, 2004.7, 2007.5, 2011; amplitudes estimated from the best fit.

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Brzeziński's broad-band Liouville (complex) equations:

In terrestrial frame (polar motion):

$$\ddot{p} - \mathrm{i}(\sigma_C + \sigma_f)\dot{p} - \sigma_C \sigma_f p =$$

$$= -\sigma_C \left\{ \sigma'_f (\chi_p + \chi_w) + \sigma_C (a_p \chi_p + a_w \chi_w) + \mathrm{i}\left[(1 + a_p)\dot{\chi}_p + (1 + a_w)\chi_w \right] \right\}$$

In celestial frame (nutation):

$$\ddot{P} - \mathrm{i}(\sigma'_C + \sigma'_f)\dot{P} - \sigma'_C \sigma'_f P =$$

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

where

p, P are the motions in terrestrial and celestial system;
σ_C, σ_f are Chandler and FCN frequency in terrestrial frame;
σ'_C, σ'_f are Chandler and FCN frequency in celestial frame;
χ_p, χ_w (χ'_p, χ'_w), are excitations in terrestrial (celestial) frame;
$a_p = 9.200 \times 10^{-2}$, $a_w = 2.628 \times 10^{-4}$ are numerical constants.

Numerical integration of Brzeziński's eqs:

- **We use:**
  - **Complex numerical values of both resonant frequencies, close to observed values (Mathews, Herring, Buffet 2002), and also more recent values of constants a_p, a_w (Koot & de Viron 2011);**
  - **4-order Runge-Kutta procedure (in complex form), with 6-hour step.**
- **The initial conditions (2 complex values) are chosen to assure the best rms fit to observations, and also to suppress unnecessary quasi-diurnal free motions.**

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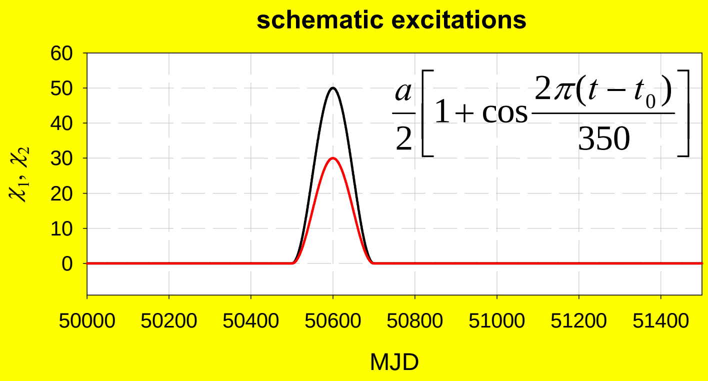
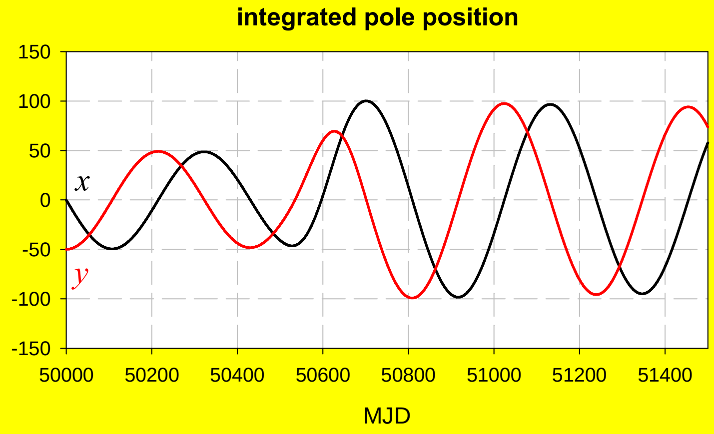
- **Geophysical excitations:**
  - **NCEP/NCAR atmospheric angular momentum functions, both without (equivalent to “frozen” oceans) and with IB correction (equivalent to oceans reacting inversely proportional to atmospheric pressure changes),**
  - **ECCO oceanic angular momentum functions (only PM and LOD),**
  - **Geomagnetic jerks (GMJ - rapid changes of the secular variations of geomagnetic field). The corresponding excitations are modeled as quasi-impulse bell-like function centered at GMJ epochs, 200 days long, amplitudes estimated (yielding the best fit to observations).**

GMJ simulated effect





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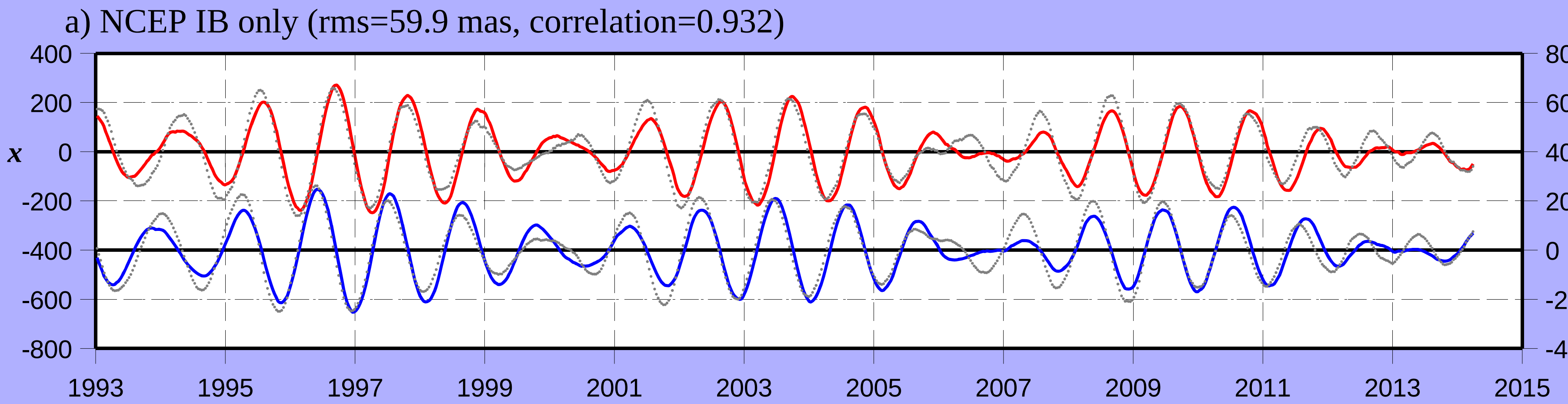
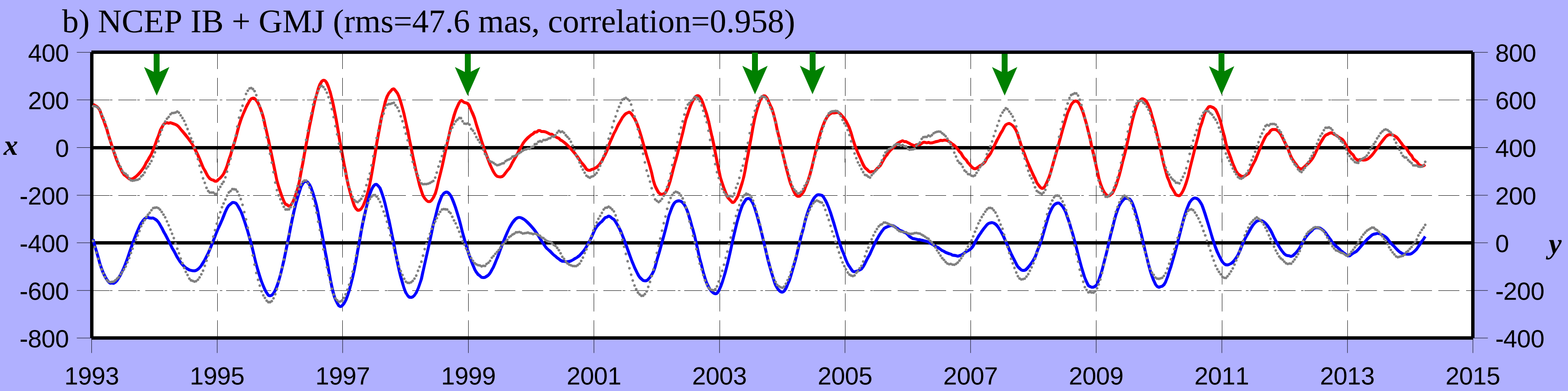
Results for polar motion (long-periodic part removed)
AAM IB (+GMJ)





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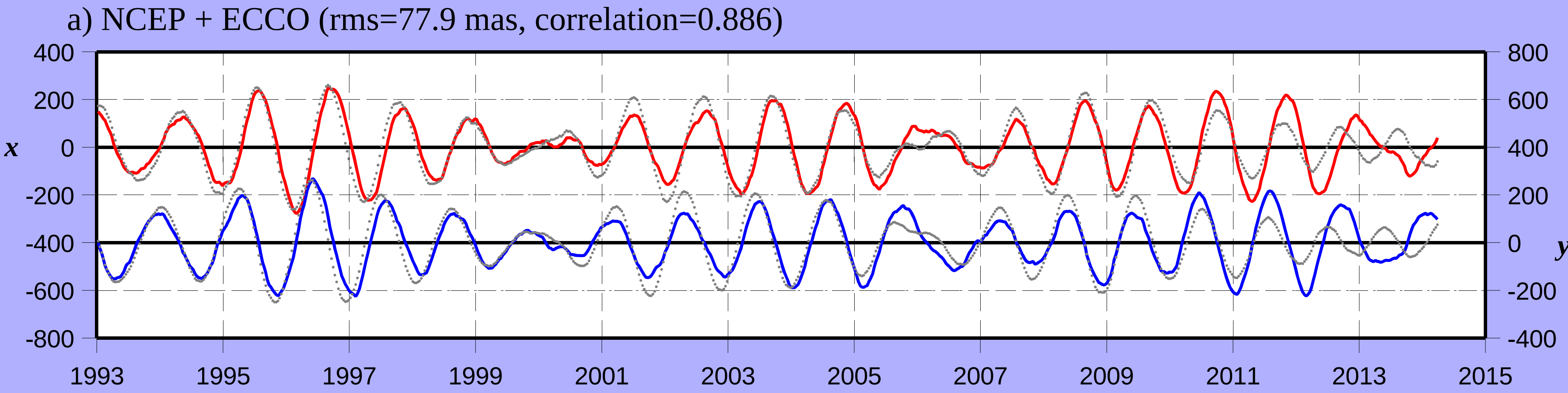
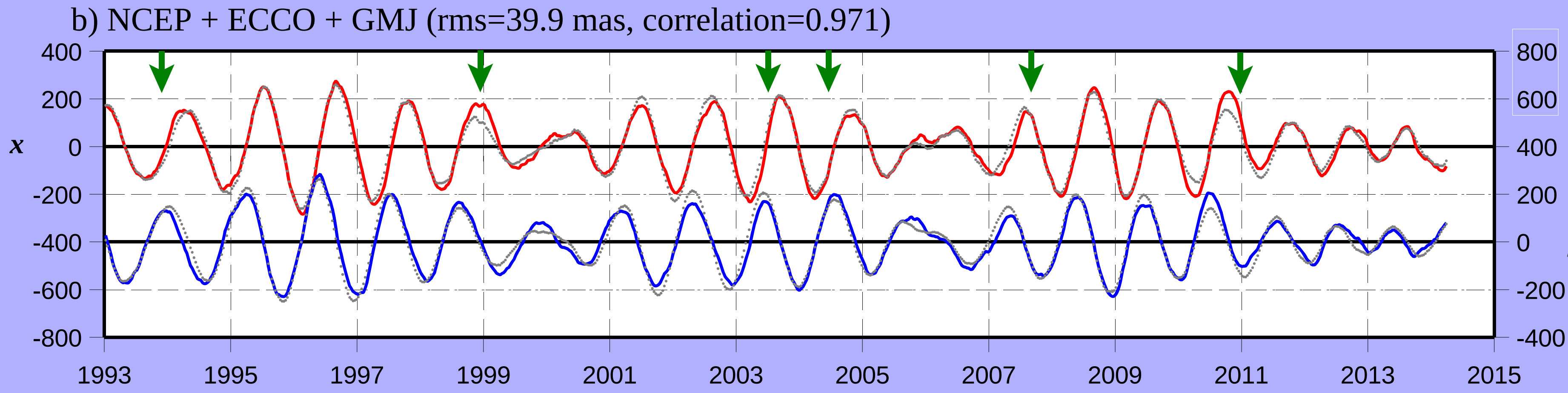
Results for polar motion (long-periodic part removed)
AAM NIB + OAM (+GMJ)





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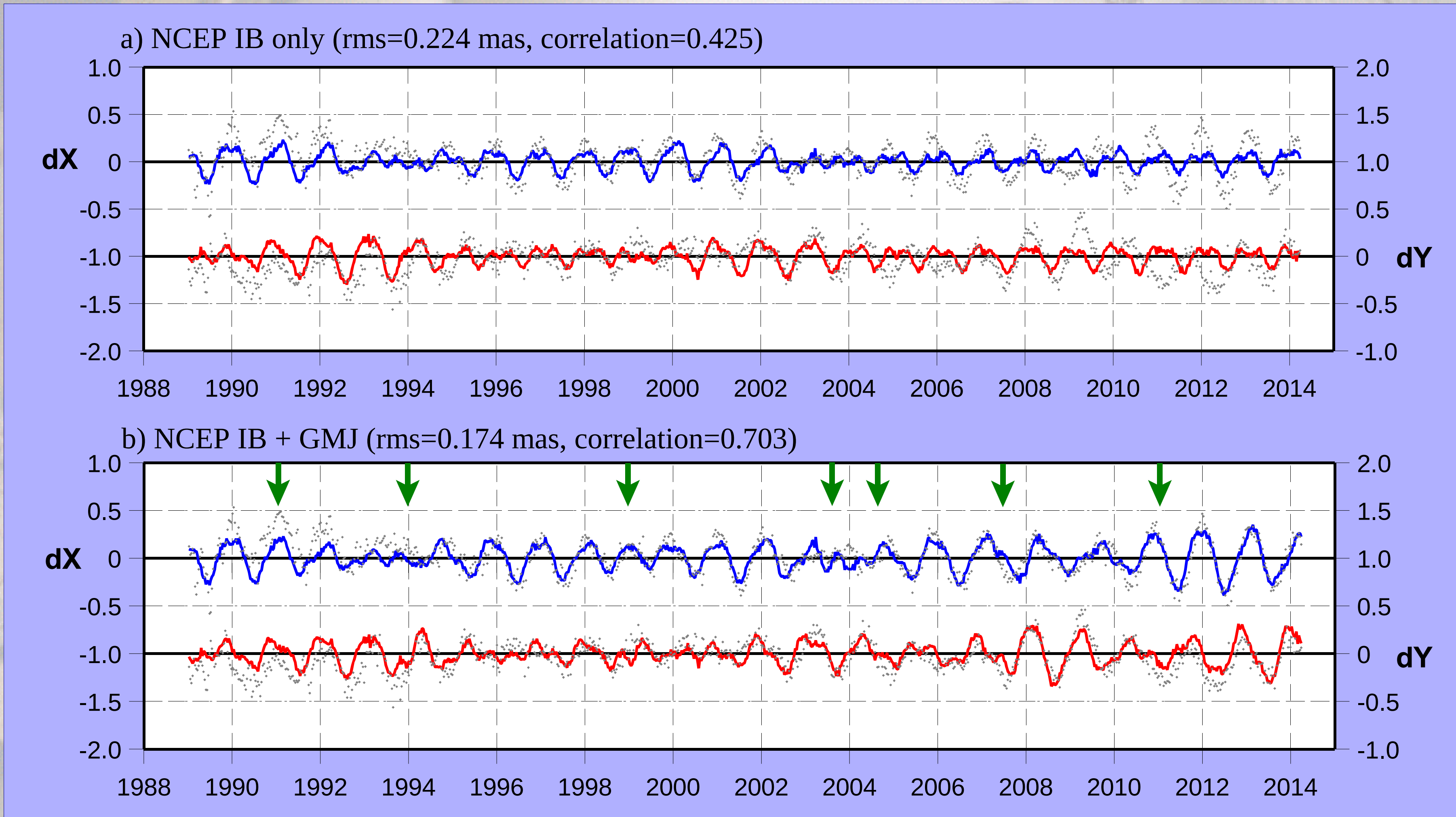
Results for celestial pole offsets
AAM IB (+GMJ)



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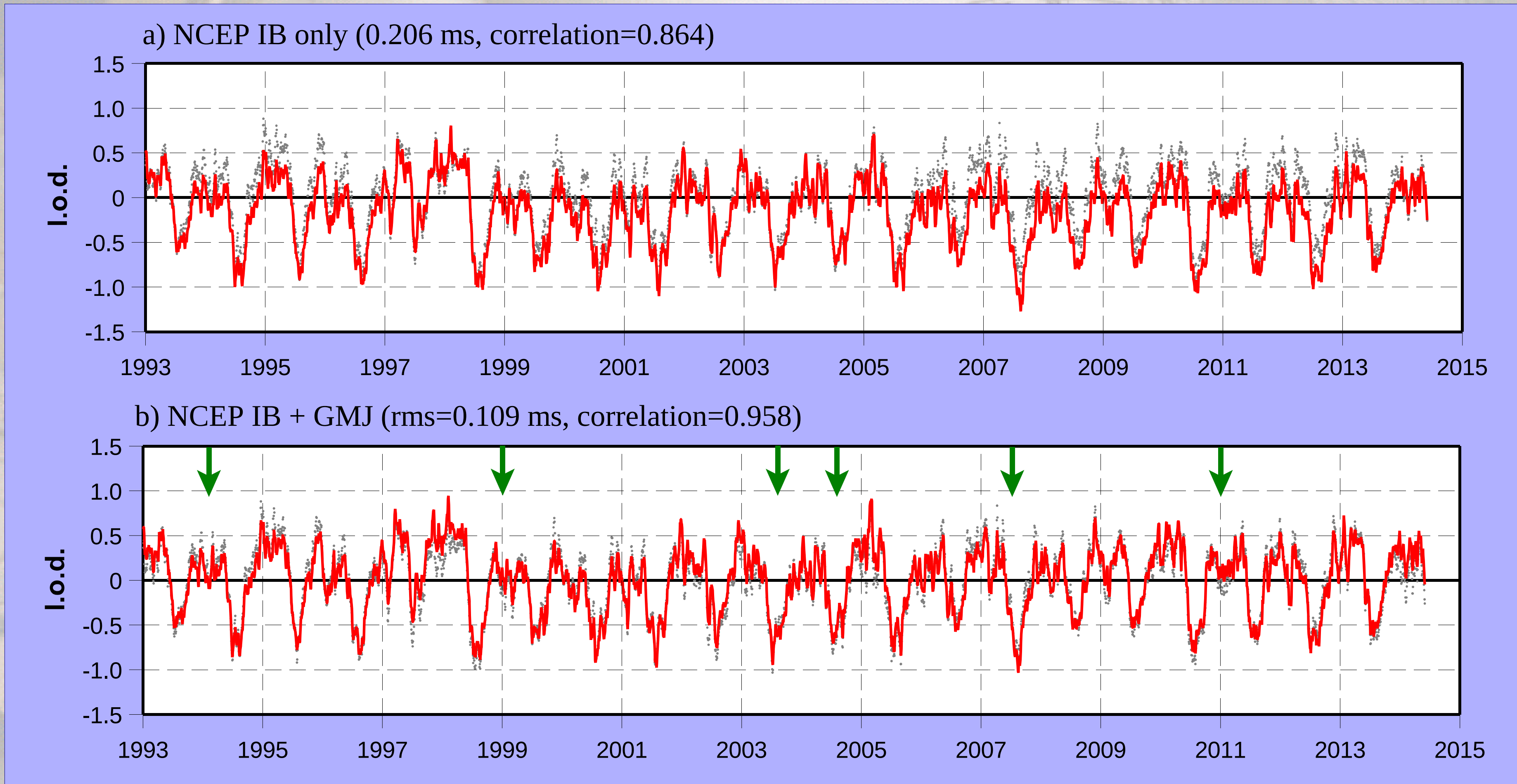
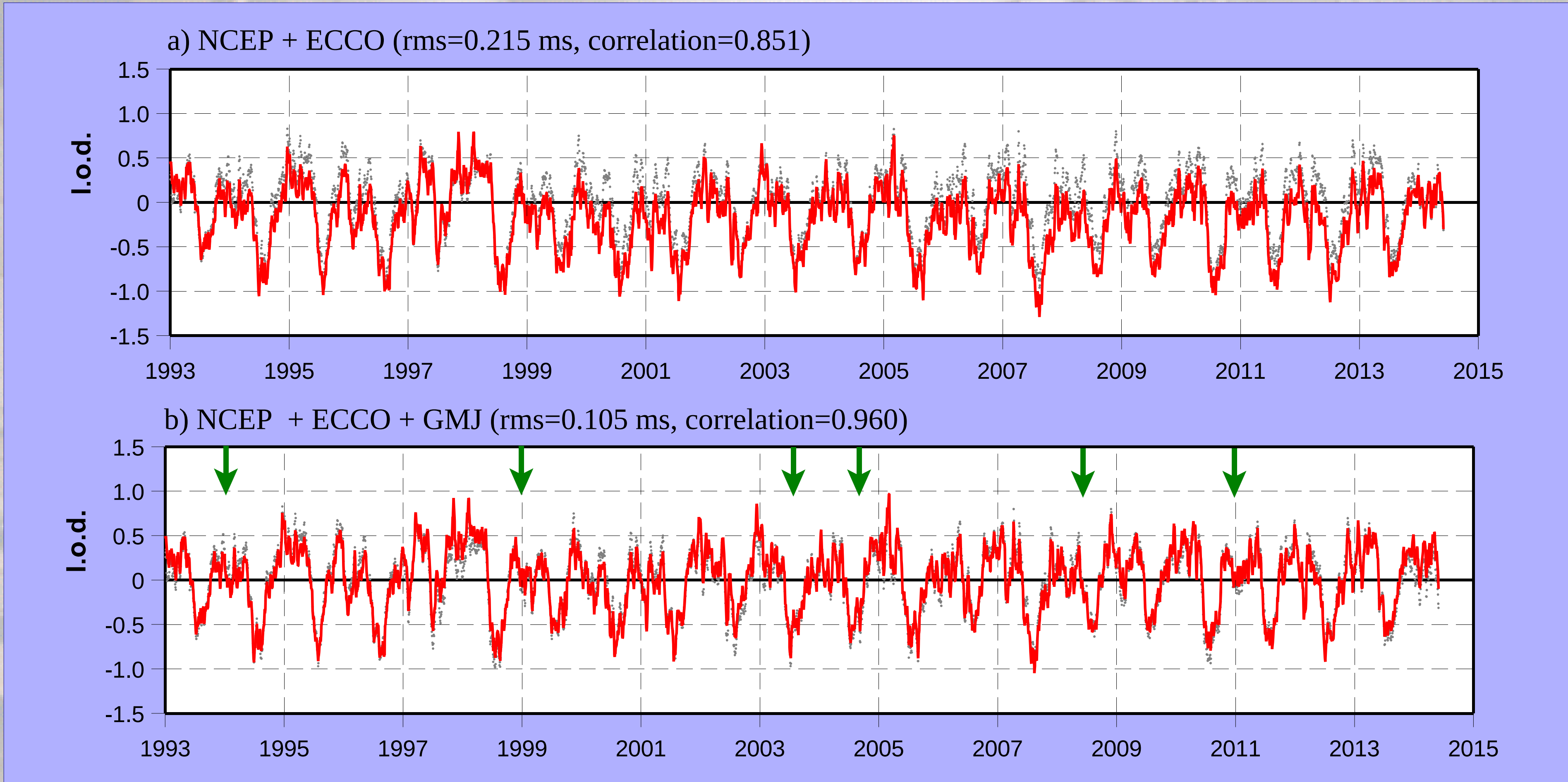
Results for LOD (long-periodic & tidal part removed)

AAM IB (+GMJ)



Results for LOD (long-periodic & tidal part removed)
AAM NIB + OAM (+GMJ)



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Conclusions

- Geophysical excitations are capable of yielding significant contribution to Earth orientation parameters, but the comparison of the results based on these excitations with the observations does not provide fully satisfactory agreement;
- Additional impulse-like excitations applied at the epochs of geomagnetic jerks improves the agreement substantially in all Earth orientation parameters:
  - The amplitudes of GMJ excitations are comparable to the ones by geophysical fluids;
  - Best agreement for PM & CPO is obtained if NCEP atmospheric + ECCO oceanic excitation is combined with GMJ effects;
  - In case of LOD, the effect of the oceans is marginal, but adding GMJ also improves the agreement substantially.

THANK YOU FOR YOUR ATTENTION!

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