GEOPHYSICAL EXCITATION OF DIURNAL PROGRADE POLAR MOTION DERIVED FROM DIFFERENT OAM AND AAM DATA

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ABSTRACT. Short period variations in polar motion are mostly caused by the system atmosphere-ocean impact. In this work we compare the geodetic and geophysical excitation. Geodetic excitation have been estimated on the basis of polar motion series with sub-diurnal temporal resolution obtained from VLBI observations. For our comparison we used two sets of geophysical data: first one is that of atmospheric and oceanic angular momenta (AAM, OAM) calculated during ERA-40 reanalysis project; second one contains AAM series derived from NCEP/NCAR reanalysis project and corresponding OAM series from the barotropic OGCM (Oceanic Global Circulation Model) model. Our analysis covers prograde diurnal frequency band.

1. GEODETIC EXCITATION OF POLAR MOTION DERIVED FROM VLBI OBSERVATIONS

VLBI observations obtained in the period from 1989 till 2004 have been used for estimating of polar motion by the least square collocation method (LSCM) as it is realized in OCCAM 6.1 software. The distinctive feature of this method is that the Earth rotation parameters (ERP) are estimated as stochastic process with known covariance matrix. Elements of this matrix (q_{ERP}) are calculated in according to the following formula (see Titov,2000):

$$q_{ERP}(\tau) = \frac{\sigma^2_{ERP}}{\cos(\varphi)} e^{-\alpha|\tau|} \cos(\omega\tau + \varphi), \tag{1}$$

where σ^2_{ERP} is a priori variance of stochastic process, τ — time shift (in parts of day) $0 \leq \tau \leq 1$; $\alpha = 50\, day^{-1}$ — damping parameter, $\omega = 1$ cpd — cyclic frequency; $\varphi = 0.3$ rad — initial phase. All these parameters except a priori variance of ERP can be estimated from VLBI observations during iterative process. The value of σ^2_{ERP} should be derived from some a priori information on process. We obtain two solutions under different values of a priori variance: series SPU_1 ($\sigma^2_{ERP} = 4.4 cm^2$) and series SPU_2 ($\sigma^2_{ERP} = 0.44 cm^2$).

Note that in both of this series the model of the diurnal and sub-diurnal variations in polar motion due to oceanic tides has already been taken into account (corresponding model is provided by the International Earth Rotation Service (IERS) Conventions 2003). Based on this series we calculated the geodetic excitation.

The resulting geodetic excitation series are unevenly sampled with time resolution 3-5 min within one 24-hours session. The method of complex demodulation has been applied in order to extract from the series mentioned above a signal in the prograde diurnal frequency band. It have been shown by Brzezinski et al. (2002), Kudryashova and Petrov (2005) that an application of complex demodulation method for such a series yields meaningful results. This procedure can be described by the following equation:

$$\chi' = -\chi e^{-in\phi},$$

where $\phi \approx \Omega(t - t_0) + \phi_0$ is the Greenwich mean sidereal time, χ, χ' are the initial and demodulated excitation series, and $n\Omega$ — frequency of demodulation (which equals $+\Omega$ in this study). In the frequency domain such a transformation just shifts spectrum of the initial series along the frequency axis in such a way that $n\Omega$ becomes 0. This procedure was followed by Gaussian filtering.

After applying the complex demodulation, frequencies of those diurnal tides which play the main role in AAM and OAM (S1, P1, π1, K1), have been changed for $\nu_1 = -1$ cycle per year (cpy) (annual retrograde), $\nu_2 = -2$ cpy (semiannual retrograde), $\nu_3 = -3$ cpy (terannual retrograde) and $\nu_0 = 0$ (constant term), respectively.

As a next step we estimated the best least square fit of the model, which contains first-order polynomial and sum of complex sinusoids:

$$f = a + bt + \sum_{k=1}^{3}(A_k \exp^{(i2\pi t\nu_k)} + B_k \exp^{(-i2\pi t\nu_k)}) \quad (2)$$

Components of this model either correspond to the thermal tide S1 or are caused by its seasonal modulation.

2. GEOPHYSICAL EXCITATION OF POLAR MOTION

In the subsequent analysis two sets of geophysical excitation, provided us by R. Ponte and M. Thomas, have been used. Let us briefly describe theses data.

R. Ponte

Atmospheric excitation is expressed by the AAM estimates calculated on the basis of the NCEP/NCAR (U.S. National Center for Environmental Prediction/National Center for Atmospheric Research) reanalysis project results (see for details Kalnay E., et al., 1996). The series is now available from the web-site of the IERS Special Bureau for the Atmosphere. This series is sampled four-times daily and covers the period from 1948.0 till now.

The oceanic excitation series OAM used in the present study are based on the barotropic ocean model by Ponte and Ali (2002). The model is driven by the atmospheric surface wind and pressure fields from the NCEP/NCAR reanalysis project. The series spans the period from 1993.0 till 2000.5 and has one-hour temporal resolution.

M. Thomas

Atmospheric excitation is expressed by AAM estimates calculated on the basis of atmospheric global circulation model. These estimates have been obtained during data reanalysis project ERA-40 carried out in European Center for Medium-Range Weather Forecast (ECMWF).

For consistency oceanic excitation has been estimated on the basis of the Ocean Model for Circulation and Tides(OMCT), driven by the ERA-40 wind and surface pressure fields (Seitz et.al., 2004).

Procedure of the complex demodulation with subsequent Gaussian filtration have been applied to both sets of geophysical data, as well as estimation of coefficients of the model (2). Comparison of demodulated data revealed that matter terms of OAM and AAM, as well as motion terms of OAM from both sets are comparable. However, AAM motion term from ERA-40 estimations is about twice more powerful then that one from NCEP/NCAR estimations.

3. RESULTS AND CONCLUSIONS

Figures 1 and 2 show a comparison of the geodetic and geophysical excitation of diurnal polar motion, assuming different models of the ocean response to atmospheric forcing:

- the non-IB model which assumes rigid ocean, with excitation expressed by AAM;
- the IB model which implies static ocean response, with excitation expressed by AAMIB;
- the dynamic model of ocean response with excitation expressed by the sum of AAMIB+OAM.

Comparison of Figure 1 and 2 shows that the best agreement between geodetic and geophysical excitation is achieved when estimation of the ERP is performed with an a priori dispersion $\sigma = 0.44\,cm^2$. From Table 1 it could be seen that amplitude and phase of the S1 term as they seen from SPU1 solution and AAM (matter term) reveal very good agreement. Moreover, the agreement became better after 1996. This is the case for both sets of geophysical data.

In case of estimation of the ERP with a larger a priori dispersion ($\sigma = 4.4\,cm^2$), geodetic excitation is highly overestimated with respect to geophysical excitation (Figure 2). However, comparison (Kudryashova M. et. al., 2007) of VLBI series obtained in Astronomical Institute of St. Petersburg University and that one calculated in GSFC reveals that these series are in better agreement if the former series is calculated with a larger a priori dispersion ($\sigma = 4.4\,cm^2$).

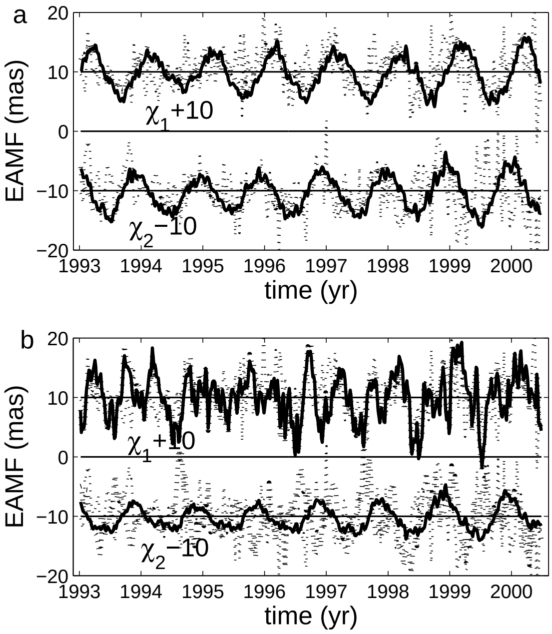

Figure 1: Comparison of the geodetic (SPU1) and geophysical excitation of diurnal polar motion: a — AAM and OAM from data, provided by R. Ponte; b — AAM and OAM from data, provided by M. Thomas. Geodetic excitation is denoted by dotted grey line; rigid ocean responce — dotted black line; dynamic model of ocean response — solid black line.

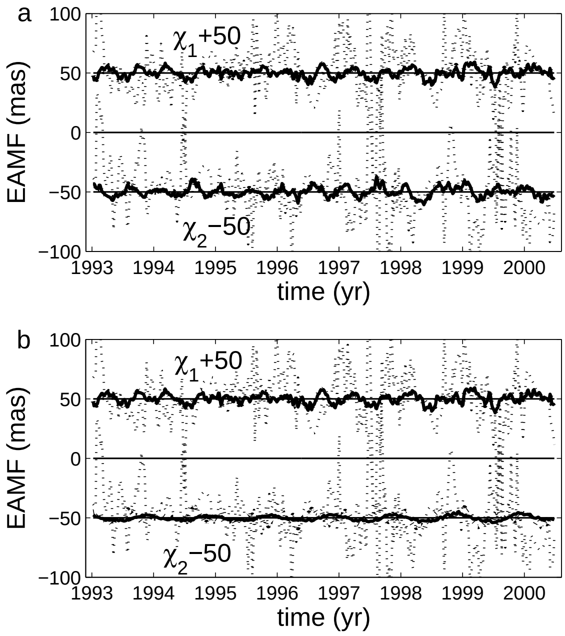

Figure 2: Comparison of the geodetic (SPU2) and geophysical excitation of diurnal polar motion: a — AAM and OAM from data, provided by R. Ponte; b — AAM and OAM from data, provided by M. Thomas. Geodetic excitation is denoted by dotted grey line; rigid ocean responce — dotted black line; dynamic model of ocean response — solid black line.

term	EAMF		polar motion	
	ampl.(mas)	phase[°]	ampl.(μas)	phase[°]
data provided by R. Ponte				
geodetic excit.(SPU2)	14.1	16.3	33.3	−163.7
geodetic excit.(SPU1)	2.04	12.8	4.8	−167.2
AAM(matter)	2.03	12.6	4.9	−169.7
AAM(motion)	2.24	90.8	5.2	−91.5
AAMIB(motion)	1.58	−8.9	3.8	168.8
OAM(mater)	3.28	66.6	7.9	−115.8
OAM(motion)	2.26	−137.7	5.2	40.0
data provided by M. Thomas				
geodetic excit.(SPU2)	14.1	16.3	33.3	−163.7
geodetic excit.(SPU1)	2.04	12.8	4.8	−167.2
AAM(matter)	2.1	17.7	5.0	−162.3
AAM(motion)	1.2	−87.9	2.8	92.1
OAM(matter)	1.4	59.1	3.3	−120.9
OAM(motion)	0.8	−175.3	1.9	5.0

Table 1: Parameters of S1 component derived from atmospheric and nontidal oceanic contribution as well as from different VLBI solution (SPU1 and SPU2).

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