GEOPHYSICAL EXCITATION OF LOD/UT1 ESTIMATED FROM THE OUTPUT OF THE GLOBAL CIRCULATION MODELS OF THE ATMOSPHERE - ERA-40 REANALYSIS AND OF THE OCEAN - OMCT

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ABSTRACT. We use new estimates of the global atmospheric and oceanic angular momenta (AAM, OAM) to study the influence on LOD/UT1. The AAM series was calculated from the output fields of the atmospheric general circulation model ERA-40 reanalysis. The OAM series is an outcome of global ocean model OMCT simulation driven by global fields of the atmospheric parameters from the ERA-40 reanalysis. The excitation data cover the period between 1963 and 2001. Our calculations concern atmospheric and oceanic effects in LOD/UT1 over the periods between 20 days and decades. Results are compared to those derived from the alternative AAM/OAM data sets.

1. INTRODUCTION

The axial component of Earth rotation which is expressed by the length of day (LOD) or universal time (UT1), is subject to changes with periods ranging from a fraction of a day to decades. According to the principle of conservation of angular momentum, changes in the LOD are excited by mass redistributions and angular momentum exchanges between the solid Earth and geophysical fluids: atmosphere, oceans, land hydrosphere and fluid core. It has been proven that variations with decadal and longer periods are excited mainly by the interactions between the core and the mantle (Gross et al., 2005). Changes with shorter periods are driven mostly by the dynamically coupled system atmosphere-oceans.

Our earlier investigations of excitation of the equatorial components of Earth rotation (Korbacz et al., 2007) revealed significant differences between the effective angular momentum functions derived from the ERA-40 reanalysis and nontidal OMCT (Ocean Model for Circulation and Tides) and from other atmospheric and oceanic models. These differences were found smaller at shorter periods while increasing towards the longer periods. Current research is an extension of the previous work by considering the axial component of rotation expressed as changes of the length of day (LOD). The combination ERA-40 + OMCT will be compared to other available models of the atmospheric and oceanic excitation and to the observations of the LOD over a broad band of frequencies: from decadal through interannual and seasonal, up to intraseasonal. Comparison between geophysical excitation data and geodetic observations of LOD is much simpler than in case of polar motion because there is a linear relationship between the χ_3 component of the atmospheric and oceanic angular momenta (AAM, OAM) and LOD.

2. DATA DESCRIPTION AND ANALYSIS

We used in our analysis two atmospheric angular momentum time series. The first one, estimated from the NCEP/NCAR reanalysis model, is available from the website of the IERS Special Bureau for Atmosphere. The second one was estimated from output fields of the ERA-40 reanalysis model (Uppala et al., 2005). Both series have the same temporal resolution of 6 hours and long, but slightly different data spans. In our combinations we used the standard AAM series and that with the "inverted barometer" correction, denoted AAMIB. The AAM series is based on the full variability of the pressure fields, while AAMIB assumes an isostatic ocean response to the atmospheric pressure fluctuations and thus only include effects of variability in the average atmospheric pressure over the ocean.

The description of the oceanic angular momentum time series used in our analysis is shown in Table 1. Each data set is designated by the code containing 3 characters. The first character is an abbreviation of

OAM code	description	ocean model	forcing atmosphere model	temporal resolution	data span
T06	Thomas et al., 2001	OMCT	ERA-40	30 min.	1963-2001
P01	Ponte, 2001	MOM + assimil.	COADS/NCEP	1 month	1950-2000
G05	Gross et al., 2005	ECCO-MITgcm	NCEP	10 days	1949-2002
G03	Gross et al., 2004	ECCO-JPL	NCEP	1 day	1980.0-2002.2
Pas	Ponte et al., 2001	ECCO-Scripps + assim.	NCEP	1 day	1992.8-1998.0

Table 1: Oceanic angular momentum time series.

the name of the author, who computed or described the series, the last two characters express the year of publication and "as" means data assimilation. Besides the new T06 series, we use four different OAM estimates. In computations, the T06 OAM series will be combined with the ERA-40 AAM, while all other OAM series with the NCEP/NCAR reanalysis AAMIB. The difference between AAM and AAMIB is important when considering the influence on polar motion, but in case of the axial component of rotation the difference is negligible, because the atmospheric pressure term plays only a minor role in the excitation of the LOD.

The time series of OAM: P01 and G05 cover long data span, but have lower temporal resolution. They are capable for investigation of the seasonal and longer variations. The next two time series G03 and Pas are with diurnal sampling, but are significantly shorter, therefore cannot be applied for investigation of long periods. The new data set T06 has a high temporal resolution and covers a long time span enabling estimation over the entire band of frequencies considered in this work.

We use for comparison the LOD time series COMB2002 (Gross, 2000), which is combined solution derived by the Kalman filter. This series is denoted here **obs**.

The first step of data analysis consists in converting the time series AAM and OAM into the effective angular momentum function χ_3 and then into LOD using a linear transformation (Gross et al., 2004). Then we split up all the LOD series into the model comprising the first order polynomial and seasonal harmonics with periods 1, 1/2 and 1/3 year, and the residuals, that is the difference between the original series and the model. These two components of the LOD are treated separately. First we estimate amplitudes and phases of the seasonal harmonics and compare them in the phasor diagrams. Then we apply the band-pass filter to split up the residual series into four components: decadal ($T > 8$ years), interannual ($2 < T < 8$ years), seasonal ($1/2 < T < 2$ years) and intraseasonal (20 days $< T < 1/2$ year). Finally we compare the estimated oceanic and atmospheric LOD to the observed one in each of the selected spectral bands.

Figure 1 shows the atmospheric LOD calculated from the ERA-40 reanalysis data, wind term and pressure term, and the corresponding oceanic LOD from the OMCT model, currents and mass term. All plots are shown in the same scale. It can be seen that the dominant part of LOD is that due to the zonal winds. The oceanic contribution to LOD is almost negligible. The annual signal is clearly visible in all components. Significant part of the power disappear from data after subtracting the seasonal harmonic model.

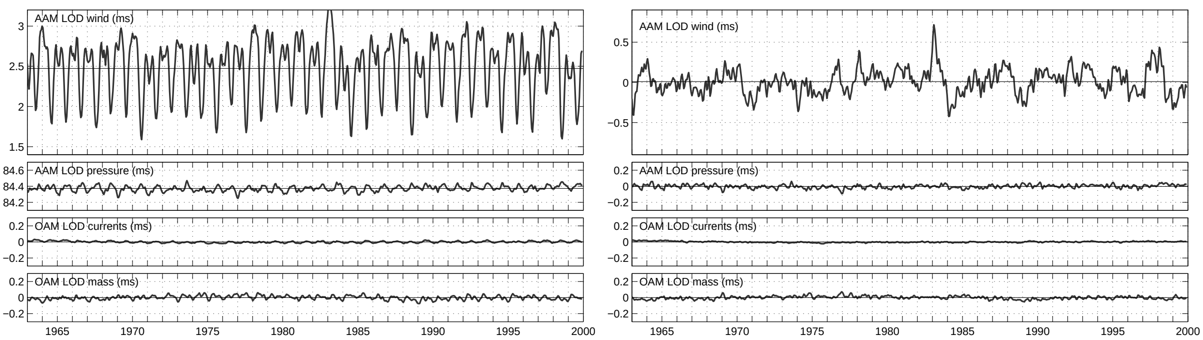


Figure 1: Atmospheric and oceanic LOD from ERA-40 and OMCT. Variations with period $T < 20$ days have been removed by smoothing. The right panel shows the data after subtracting the model.

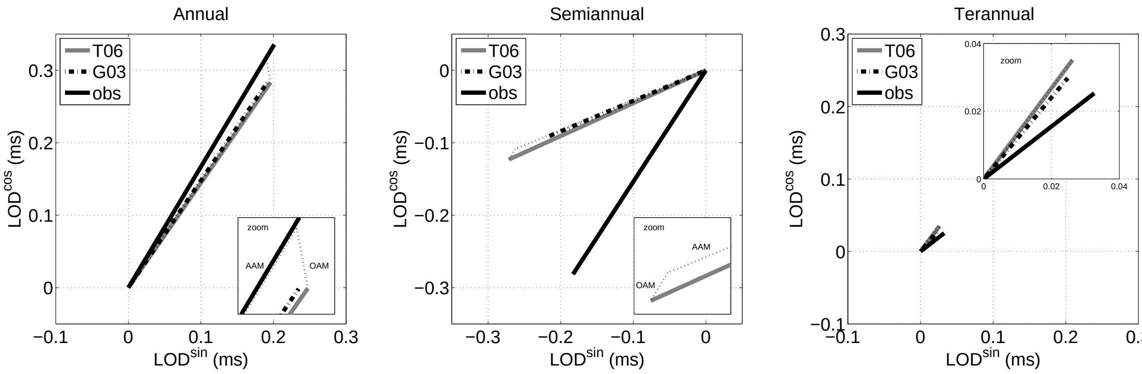


Figure 2: Comparison of the seasonal harmonics estimated from the series T06, G03 and **obs**.

3. RESULTS

The seasonal harmonics estimated from the G03 and T06 series are compared to each other and to observations, in phasor diagrams of Figure 2. In case of T06 shown are additionally separate contributions from AAM and OAM (dotted line). For each component there is a very good agreement in phase between the geophysical models, and slightly worse in amplitude. In case of the annual harmonic the AAM+OAM combination based on the T06 model yields good agreement in phase and amplitude with the observations. However, from the decomposition into the atmospheric and oceanic contributions it can be seen that atmosphere alone gives better agreement in amplitude and phase. In case of the semiannual oscillation we detected phase difference about 30^o between geophysical models and observations, which is probably caused by land hydrology which is not taken into account in this comparison. It appears that adding the ocean OMCT to the ERA-40 makes the amplitude and phase a little closer to the observed. The terannual oscillation is very weak in comparison to other terms considered, nevertheless the zoom shows quite good agreement between geophysical models and observations.

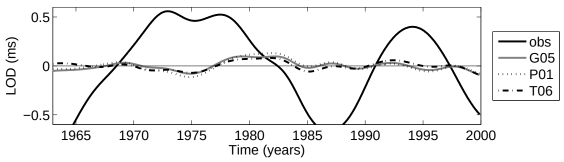
Figure 3 illustrates the analysis of the residual part. On the left-hand side there are plots showing decadal, interannual, seasonal and intraseasonal components of LOD computed from geophysical and observed time series. The tables on the right show the correlation coefficient between the modeled and observed LOD and the reduction of variance when subtracting the modeled excitation from the observed one. The reduction is negative when the variance increases after this operation. The last part of table contains standard deviations of each excitation series (wind, pressure, current and mass terms), giving the measure of their contribution to the observed LOD.

For each component of residual part there is a very good agreement of T06 series with other AAM+OAM estimates. Standard deviation shows that atmospheric winds are the most important in the excitation of LOD.

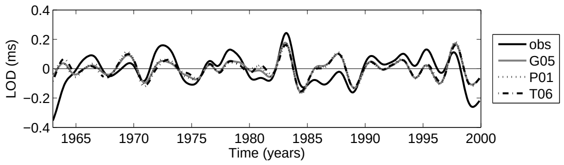
In case of decadal component changes in observed LOD are not significantly influenced by the atmosphere and the ocean, as could be expected. For the interannual component of LOD there is much better agreement between geophysical models and observations than for decadal band. The correlation coefficients are about 0.6 for each series, the reduction of variance is always positive and has similar value. The analysis of the seasonal component of LOD shows almost perfect agreement between the AAM+OAM series and observations. In case of the intraseasonal component the correlation coefficients are still high, but lower than in the seasonal band.

4. CONCLUSIONS

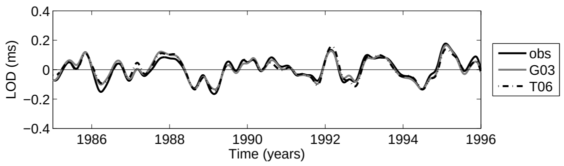
Unlike equatorial component of Earth rotation, the axial component of T06 combination AAM+OAM does not differ significantly from other geophysical models. In case of annual and terannual harmonics in LOD there is an excellent agreement in amplitude and phase between models and observations. For semiannual oscillation there is a high agreement in amplitude, but a large phase difference ($\sim 30^o$) occurs. An obvious candidate to explain this difference is the land hydrology. At decadal periods, the AAM and OAM are much smaller than the observed LOD, as could be expected from earlier works. For periods shorter than 8 years the atmospheric/oceanic excitation plays an important role with the highest



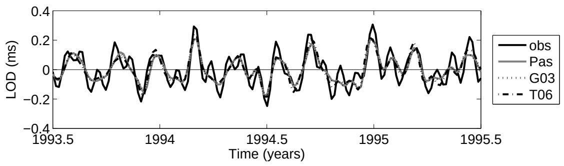
	Corr. with **obs**	Var. reduct. (%)	Standard deviation (μs)			
Series	(1963.0→1999.9)		wind	pres.	curr.	mass
P01	-0.104	-4.970	40	8	2	1
G05	0.151	2.144	40	8	2	1
T06	0.071	0.423	41	7	6	11
				obs	413	



Series	(1963.0→1999.9)		wind	pres.	curr.	mass
P01	0.588	34.038	61	6	2	2
G05	0.631	39.854	61	6	2	2
T06	0.608	37.002	60	5	1	4
				obs	102	



Series	(1980.0→2001.9)		wind	pres.	curr.	mass
G03	0.958	91.733	81	8	3	3
T06	0.963	92.538	84	9	3	7
				obs	84	



Series	(1992.9→1997.9)		wind	pres.	curr.	mass
Pas	0.858	73.059	96	15		6
G03	0.858	73.028	96	15	6	6
T06	0.870	75.174	100	20	6	17
				obs	195	

Figure 3: Comparison of data after removal of the seasonal model and trend. From up to down shown are the results for decadal, interannual, seasonal and intraseasonal bands.

agreement with observations in the seasonal band. The dominating contribution to the excitation of LOD at periods shorter than 8 years comes from zonal winds. Variations of the atmospheric pressure and the ocean play a minor role.

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