

3.5 Product Centres

3.5.1 Earth Orientation Centre

This section presents activities and main results concerning the Earth Orientation Centre located in Paris Observatory over 2004. General presentation of the IERS Earth Orientation Parameters (EOP), operational activities and yearly analyses are presented at the web site (<http://hpiers.obspm.fr/eop-pc>). According to the IERS Terms of Reference, the Earth Orientation Centre is responsible for monitoring Earth Orientation Parameters including long term consistency, publications for time dissemination and leap second announcements. It is making available to users different products: long-term and operational series of polar motion, Universal Time (UT1), Length of Day (LOD) and celestial pole offsets.

Determination of EOP is in the form of combined solutions derived by the analysis centres of the different techniques. Various solutions are computed: long-term solution (IERS C01), normal values at five and one-day intervals (IERS C02 and C03) and the operational smoothed solution Bulletin B at one-day intervals published monthly and providing EOP with a delay of 30 days with respect to the date of publication. Bulletin B is updated in an operational mode in the IERS C04 which is computed twice weekly. After the presentation of the new interactive tools implemented on our web site, we will present the different combined EOP solutions available.

Web interactive tools

During the year 2004 we continued the development of interactive tools, mostly written in PHP language and devoted to the EOP time series analyses. Hereafter we present the main new improvements:

- 1) Extension of numerical analyses of EOP series to operational series.
- 2) Implementation of comparison of operational series
- 3) Densification of some EOP series using their associated rates thanks to the approach of “combined smoothing” developed by Vondrák and Cepek (2000).
- 4) Dates converter has been set up in the home page, allowing to easily convert civil date to (Modified) Julian Date or inversely.
- 5) The comparison of EOP changes (1962–2005) with the atmospheric angular momentum can be done in selected frequency ranges by applying Vondrak Filtering.

Combined daily series: Bulletin B and EOP(IERS) C 04

Description of Bulletin B is available in the IERS Explanatory Supplement for Bulletin A and Bulletin B (Gambis and Wooden, 2004). Since formal uncertainties reported by the contributors are often

under-estimated, they are calibrated by statistical assessment using the Allan Variance Analysis in order to reflect the real quality of the data (Gray and Allan, 1974; Gambis, 2002). This procedure leads to an optimal weighting of the individual series entering the combinations (Gambis, 2004). Table 1 gives the estimated accuracy with respect to IERS C04 of these series over 2003–2004 after removal of systematic variations, mainly a bias.

Recently the algorithm and Fortran program allowing to compute C04 series have been considerably improved. Presently under test, this new version, using Vondrák Combined Smoothing (Vondrák and Cepek 2000), will be set up during the year 2005.

Table 1: Estimated accuracies of individual solutions entering the combined solutions in 2004

Individual solutions				Estimated uncertainties				
				Time	Terrestrial Pole 0.001"	UT1 0.0001s	LOD 0.0001s	Celestial Pole 0.001"
VLBI – 24 h								
EOP (AUS)	01	R	01	3-4d	0.12	0.04		0.10
EOP (BKG)	03	R	04	1-4d	0.17	0.06		0.12
EOP (GSFC)	04	R	02	1-4d	0.15	0.06		0.11
EOP (IAA)	03	R	04	1-4d	0.14	0.05		0.08
EOP (MAO)	03	R	01	1-4d	0.15	0.05		0.10
EOP (SPBU)	03	R	03	3-4d	0.14	0.05		0.08
EOP (USNO)	04	R	01	1-4d	0.15	0.05		0.10
VLBI – Intensive								
EOP (BKG)	03	R	02	1-3 d		0.13		
EOP (GSFC)	4	R	01	1-3 d		0.12		
EOP (IAA)	03	R	03	1-3 d		0.13		
EOP (SPBU)	02	R	01	1-3 d		0.16		
EOP (USNO)	5	R	01	1-3 d		0.14		
Satellite Laser Tracking								
EOP (ASI)	03	L	02	1d	0.10		0.24	
EOP (CSR)	95	L	01	3d	0.53	0.30		
EOP (DUT)	98	L	01	3d	0.14	0.40		
EOP (IAA)	02	L	1	1d	0.06	0.02*	0.02	
EOP (MCC)	97	L	01	1d	0.30		0.48	
EOP (ILRS)*	5	L	1	1d	0.30		0.40	
GPS								
EOP (CODE)	98	P	01	1d	0.01		0.25	
EOP (EMR)	96	P	03	1d	0.05		0.20	
EOP (ESOC)	96	P	01	1d	0.02		0.03	
EOP (GFZ)	96	P	02	1d	0.01		0.01	
EOP (IAA)	01	P	01	1d	0.04		0.06	
EOP (JPL)	96	P	03	1d	0.04		0.13	
EOP (NOAA)	96	P	01	1d	0.03		0.04	
EOP (IERS)**	95	P	01	1d	0.02	0.20	0.15	

* Since the beginning of 2005, the official combined ILRS solution derived at ASI is used in the combination, replacing the current quick-look individual solutions;

** The satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to unmodelled orbit node motion. VLBI-based results have been used to minimize drifts in UT estimates.

Predictions Different methods are used for prediction of the Earth Rotation Parameters.

Polar Motion The formalism uses at first a floating period fit (Bevington, 1969) for both the Chandler and annual components estimation over a past time interval of several years. An autoregressive filter is then applied on the short-term residuals series and used for the prediction. The predictions of the celestial pole offsets D_y and D_e are based on an empirical model (McCarthy, 1996).

Universal Time The present formalism used is based on the assumption that the long-term fluctuations (annual and semi-annual) of the preceding year are valid over the next few months. For short-term variations prediction, an autoregressive process is used. Table 2 shows the accuracy of the current EOP solutions and also the skills of the predictions.

Table 2: Uncertainty of the current solution and the estimated accuracies of the predictions for horizons of 5 days to 1 year for 2003

Solutions		Terrestrial Pole 0.001"	UT1 0.0001s	Celestial Pole 0.001"
Analysis daily	1-d	0.10	0.20	0.10
Prediction	1-d	0.50	1.40	0.10
	5-d	3.	10.	0.10
	10d	6.	21.	0.10
	30d	12.	38.	0.10
	90d	40.	45.	0.10
	180d	60.	80.	0.10
	1-yr	50.	120.	0.10

Table 3 present statistics concerning the agreement between official combined solutions derived from the Techniques Centres (IGS, IVS and ILRS), namely biases and standard deviations.

Table 4 gives the agreement and consistencies of the IERS C04 solution with two combined solutions obtained by the IERS Rapid Service at USNO (Bulletin A) and the JPL. These values reflect the mean precision reached, i.e. about 0.05 mas for polar motion and 10 microseconds for UT1. The overall accuracy taking into account the consistency between the terrestrial and celestial frames is in the range of 0.1 mas and 20 microseconds, respectively for polar motion and UT1.

**Long-term series:
C 01 (1846-2003)** EOP(IERS) C 01 is a series of the Earth Orientation Parameters given at 0.1 year interval from 1846 to 1889 (polar motion only) and 0.05 year interval from 1890 until now (polar motion, celestial pole

Table 3: Mean and standard deviation of the differences between various combined techniques solutions and IERS C04 over 2004

EOP	IGS Comb – IERS C04		ILRS Comb – IERS C04		IVS Comb – IERS C04	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
X (μas)	-133	31	-50	246	-190	220
Y (μas)	296	38	255	251	176	112
UT1 (μs)	5	45			4	10
LOD (μs)	2	34	5	71		
$D\psi\text{sin}\epsilon$ (μas)					5	70
$D\epsilon$ (μas)					4	84

Table 4: Mean and standard deviation of the differences between various solutions and IERS C04 over 2004

EOP	Unit	BullA – IERS C04		Comb JPL – IERS C04	
		Mean	Standard deviation	Mean	Standard deviation
X	μas	-115	88	-151	72
Y	μas	70	77	43	66
UT1	μs	4	44	-119	29

offsets; UT1–UTC since 1962). For many decades, the observations were made using mostly visual and photographic zenith telescopes. Since the advent of the space era in the 1960s, new geodetic techniques were used for geodynamics. Now, the global observing activity involves Very Long Baseline Radio Interferometry (VLBI), Lunar (LLR) and Satellite Laser Ranging (SLR), Global Positioning System (GPS) and more recently DORIS.

The C 01 series was recomputed in the course of 2004. It is a composite series based on following temporal solutions:

1846–1899: Fedorov et al. (1972) polar motion solution derived from three series of absolute declination programs (Pulkovo, Greenwich, Washington).

1900–1961: Vondrak et al. (1995) solution derived from optical astrometry analyses based on the Hipparcos reference frame. The series gives polar motion, celestial pole offsets and Universal Time (since 1956).

1962–2004: BIH and IERS solutions (BIH and IERS annual reports).

Mean Pole with respect to the IERS reference origin

The analyses of the observations of space geodesy require to perform the transformation between both terrestrial and celestial frames via the Earth Orientation Parameters. Gravity fields models include the tesseral coefficients C21 and S21. These terms describe the

3.5.1 Earth Orientation Centre

position of the Earth's figure axis with respect to the Terrestrial Reference Frame. This axis should coincide with the observed position of the rotation pole averaged over the same time period.

The mean polar motion is affected by a long-term drift westward (direction: 70.7 deg West, rate: 4.2 mas/yr). The mean rotation axis with respect to the IERS Terrestrial Reference Frame can be considered as the long-term trend obtained after filtering out the Chandler and seasonal terms, every year from 1900 to 2000 (Shiskin et al. 1965). Figure 1 represents the polar motion over 2001–2003 and the path of the mean pole since 1900. The table is available in IERS Conventions (2003) (McCarthy and Petit 2004) and at the following address: <<http://hpiers.obspm.fr/eop-pc/>>.

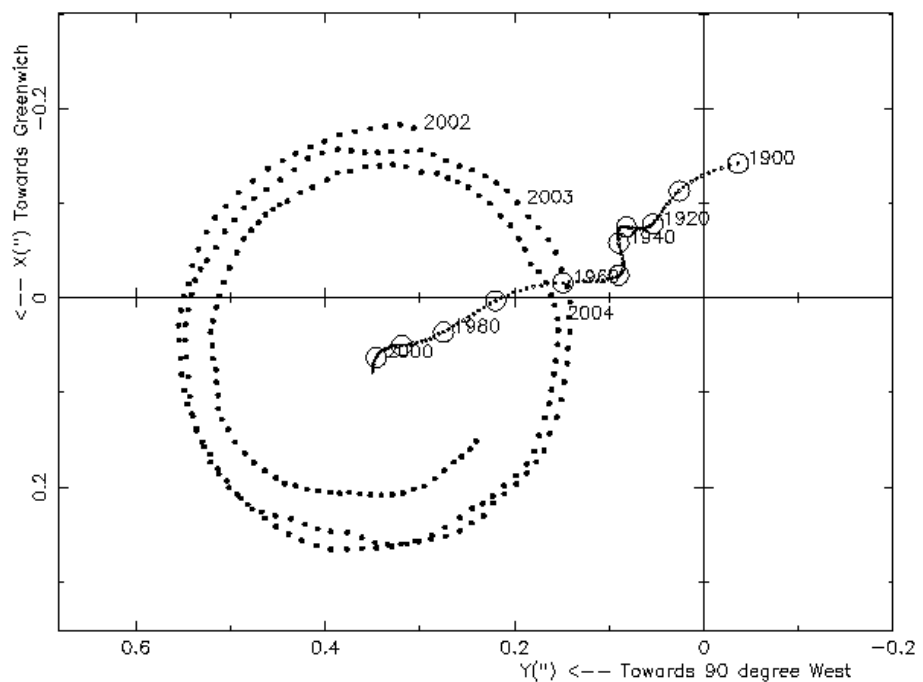


Fig. 1: Mean polar motion (1900–2003) and IERS C04 polhody over 2002–2004.

Normal Point Solutions: C 02 (1962-2003), C 03 (1993-2003)

Other series, based on normal points solutions given at various time intervals, are also proposed to users, i.e. C 02 (5-day intervals, polar motion, UT1–UTC, $\delta\psi$, $\delta\epsilon$), C 03 (one-day intervals, polar motion, UT1–UTC) (Gambis 1997; Eisop and Gambis 1997). These series are respectively consistent one to another. They use the full correlation matrix when available. Recently there were new developments in the normal point series C 02 and C 03 in which the estimation of the solution given at the central dates of the n-day interval is made using a least-square fit for all EOP components. Although the L2 estimation has been extensively used for data analysis, it has some drawbacks linked to problems of ill-conditioning and in the non-detection of outliers. Alternative methods based on

robust estimators like M-Huber can be used. These estimators are a generalization of both the L1 and L2 class. They have been implemented in our analyses and are now currently used (Bougeard et al. 2000). Table 5 reflects the evolution of the mean uncertainties of C02 solution since 1962.

Table 5: EOP(IERS) C 02 : Evolution of the mean uncertainty of the normal point solution given at five-day intervals

YEARS -- Unit	$\sigma(X)$ -- 0.001"	$\sigma(Y)$ -- 0.001"	$\sigma(UT1)$ -- 0.0001s	$\sigma(\delta\psi)$ -- 0.001"	$\sigma(\delta\epsilon)$ -- 0.001"
1962–1967	30	30	20	–	–
1968–1971	25	25	17	–	–
1972–1979	11	11	10	–	–
1980–1983	2	2	3	2	1
1984–1989	.40	.40	.20	.5	.2
1990–2000	.20	.20	.20	.3	.1
2001–2005	.15	.15	.1	.3	.1

Evaluation of EOP derived from a simultaneous combination of TRF and EOPs

Although the current determination of reference frames and EOP temporal series are derived from the same software, rigorous approaches for simultaneously determining reference frames and EOP are not currently applied. This is however a more satisfactory approach to ensure a better consistency. Different approaches are currently being developed within the IERS (Altamimi et al. 2005). The first approach is based on combination at the observation-equation level. Anderson (1995) has developed a software package, called GEOSAT, for the combined analysis of VLBI, GPS, SLR and other types of satellite tracking data (e.g., GLONASS, DORIS, Precise Range And Range-rate Estimation (PRARE) and satellite radar altimetry). Here, the observations are combined at the observation-equation level with a consistent model and consistent analysis strategies. In another project (Yaya 2001; Biancale et al. 2002), the observations of the different techniques (VLBI, SLR, LLR, DORIS and GPS) are processed separately by the same single software package, called GINS/DYNAMO, which has been developed at the GRGS (Groupe de Recherches de Géodésie Spatiale) since 1962. Here, the normal matrices are stacked to derive both the terrestrial frame and EOP. In these approaches, it is essential that the results be optimal for the different techniques before a global solution can be performed.

In order to study the feasibility of such a project, an analysis is performed on an operational basis starting from January 2005. For each individual technique, the processing of data is performed at different locations. GPS at Noveltis, Toulouse (S. Loyer), Doris at CLS, Toulouse (L. Soudarin), SLR at Cerga, Grasse (D. Coulot, P.

3.5.1 Earth Orientation Centre

Bério), LLR at CNES, Toulouse (R. Biancale) and et l'Observatoire de Paris (G. Francou), VLBI at CNES, Toulouse (R. Biancale) and Observatoire de Bordeaux (P. Charlot). The final combination as well as the validation and various analyses are performed at the Observatoire de Paris starting in January 2005 (T. Carlucci, D. Gambis, G. Francou, N. Capitaine, P. Sillard).

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3.5.1 Earth Orientation Centre

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