3.5 Product Centres

3.5.1 Earth Orientation Centre

This section presents the activities and main results of the Earth Orientation Centre located at Paris Observatory over the year 2012. 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 (DUT1) and leap second announcements. Earth Orientation Parameters (EOP: Polar motion, Universal Time (UT1), Length of Day (LOD) and Celestial pole offsets) are available to a broad community of users in various domains such as astronomy, geodesy, geophysics, space sciences and time.

EOPs are firstly collected in the form of combined solutions derived by the Technique Centers (IGS, IVS, ILRS and IDS). Two main solutions are computed: a long-term solution (IERS C01) since 1846 and the Bulletin B/ C04 given at one-day intervals published monthly with a 30 day delay (Gambis, 2004; Bizouard and Gambis, 2009; Gambis and Luzum, 2011).

An important issue is the maintenance of the consistency between the EOP system and both the terrestrial and celestial reference frames. So far, Earth Orientation Parameters and the terrestrial frame are separately computed. This leads to increasing inconsistencies between both systems. At the end of 2009, these inconsistencies were small but significant for polar motion (negligible for the x-pole component and about 50 microarcseconds for the y-pole component). All IERS reference solutions (C01, Bulletin B, C04 as well as Bulletin A derived by the Rapid Service/ Prediction Center, US Naval Observatory) were recomputed and aligned to the EOP solution associated to the current ITRF2008. Inconsistencies are now limited to about 10 microarcseconds for polar motion and a few microseconds for UT1.

Combined daily series: Bulletin B and C04, statistics over 2011–2012

Tables 1 to 3 present statistics in term of formal errors and Weighted Root Mean Square (WRMS) of the combined technique centres and individual solutions with respect to the combined solution Bulletin B / C04 over the period 2011–2012. Combined solutions derived by the various technique centres (IGS, ILRS, and IVS) are mostly used in the IERS combinations with the additions of some VLBI series for Universal Time (intensive for UT1 and standards for nutation). Statistics concerning individual series are given as a feedback to the analysis centres.

New format of Bulletin B since January 2010

A new presentation is available since January 2010. The new Bulletin B and its content description are available at <ftp://hpiers.obspm.fr/iers/bul/bulb_new/bulletinb.dat> and <ftp://hpiers.obspm.fr/iers/bul/bulb_new/bulletinb.pdf>.

Table 1: Estimated accuracies of individual solutions compared to the combined solutions Bulletin B / C04 over 2011–2012. The satellite techniques provide information on the rate of change of Universal Time contaminated by effects due to non modelled orbit node motion. VLBI-based results have been used to minimize drifts in UT estimates. Solutions contributing to Bulletin B /C04 combined solutions are referred with a star (*).

Individual solutions	Estimated uncertainties				
	Time sampling	Terrestrial Pole µas	UT1 µs	LOD µs	Celestial Pole µas
VLBI – 24 h					
EOP (AUS)	3–4d	340	15.4		200
EOP (BKG)	1–4d	125	10.6		86
EOP (GSFC)	1–4d	120	10.9		75
EOP (IAA)	1–4d	140	12.0		86
EOP (MAO)	1–4d	160	21.6		109
EOP (OPA)	1–4d	154	12.7		82
EOP (USNO)	1–4d	130	9.0		75
EOP(IVS) *	1–4d	125	7.6		47
VLBI – Intensive					
EOP (BKG) *	1–3 d		21.4		
EOP (GSFC) *	1–3 d		22.6		
EOP (PUL) *	1–3 d		21.0		
EOP (USNO) *	1–3 d		20.7		
SLR					
EOP (CGS)	1d	205		53.3	
EOP (IAA)	1d	174		20.2	
EOP (MCC)	1d	180		–	
EOP (ILRS)*	1d	180		36.5	
GPS					
EOP (CODE)	1d	42		13.3	
EOP (EMR)	1d	54		22.0	
EOP (ESOC)	1d	92		13.8	
EOP (GFZ)	1d	50		11.5	
EOP (IAA)	1d	280		53.5	
EOP (JPL)	1d	60		22.0	
EOP (NOAA)	1d	69		9.1	
EOP (SIO)	1d	55		21.6	
EOP (IGR) *	1d	40		7.5	
EOP (IGS) *	1d	28		7.6	

Table 2: Mean and standard deviation in microarcsecond of the differences between various combined techniques solutions entering the combination and Bulletin B/ C04 over 2011–2012

EOP	IGS Comb – IERS 08C04		ILRS Comb – IERS 08C04		IVS Comb – IERS 08C04	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
X (μas)	–7	29	68	173	65	151
Y (μas)	17	26	81	187	99	107
UT1 (μs)					0	7.6
LOD (μs)	–10	8	-5	36		
$D\psi \sin\varepsilon$ (μas)					1	50
$D\psi$(μas)					–20	43

Table 3: Mean and standard deviation for Pole components and UT1 of the differences between various solutions and Bulletin B/ C04 over 2011–2012

EOP	Unit	Bull A – Bull B		Comb JPL – Bull B	
		Mean	Standard Deviation	Mean	Standard Deviation
X	μas	0	21	0	47
Y	μas	0	17	1	32
UT1	μs	2.0	14.2	–4.1	10.9

The content of Bulletin B is:

1 – DAILY FINAL VALUES AND PRELIMINARY VALUES OF x, y, UT1–UTC, dX, dY
and their respective uncertainties. Angular unit is milliarcsecond (mas), time unit is millisecond (ms).

2 – DAILY SMOOTHED VALUES OF CELESTIAL POLE OFFSETS (dPsi1980, dEps1980)
with respect to IAU 1980 precession-nutation model and their uncertainties.

3 – EARTH ANGULAR VELOCITY: DAILY VALUES OF LOD, OMEGA AT 0hUTC
LOD: Excess of the Length of day – 86400 s TAI
OMEGA: Earth angular velocity

4 – INFORMATION ON TIME SCALES: TAI–UTC, leap second announcements

5 – SUMMARY OF CONTRIBUTED EARTH ORIENTATION PARAMETERS SERIES

Content of Bulletin B / C04

According to the IERS Message 198 (<http://data.iers.org/products/2/14873/orig/message_198.txt>) and starting on 1 December 2011, the EOP C04 series is now delivered with 30-day latency. In other words, only final definitive values are included in it.

Users needing a long-term continuous series extending up to a recent date (including rapid solution over the most recent 30 days) have two possibilities:

1) Getting the C04 solution extending until the date 30 days back and available at

<ftp://hpiers.obspm.fr/iers/eop/eopc04/eopc04_IAU2000.YY>, where YY is current two digit year,

and concatenate it with the Rapid solution (Bulletin A) issued from the Rapid Service/Prediction Center available at: <ftp://maia.usno.navy.mil/ser7/finals2000A.daily>

Due to differences in the delivery times of the two products, users should exercise caution in blending the files to ensure that there is continuity between Bulletin B/ C04 and Bulletin A.

2) Getting the new OPA EOP solution consisting of a continuous series derived from the concatenation of the C04 series and the OPA rapid solution available at:

<ftp://hpiers.obspm.fr/iers/series/opa/eopc04_IAU2000>

Long-term series: C 01 (1846–2013)

EOP(IERS) C 01 is a series of Earth Orientation Parameters given at 0.1 year intervals from 1846 to 1889 (polar motion only) and 0.05 year interval from 1890 until now (polar motion, celestial pole 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 1960's, 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 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.

1962–2013: BIH and IERS solutions (BIH and IERS annual reports).

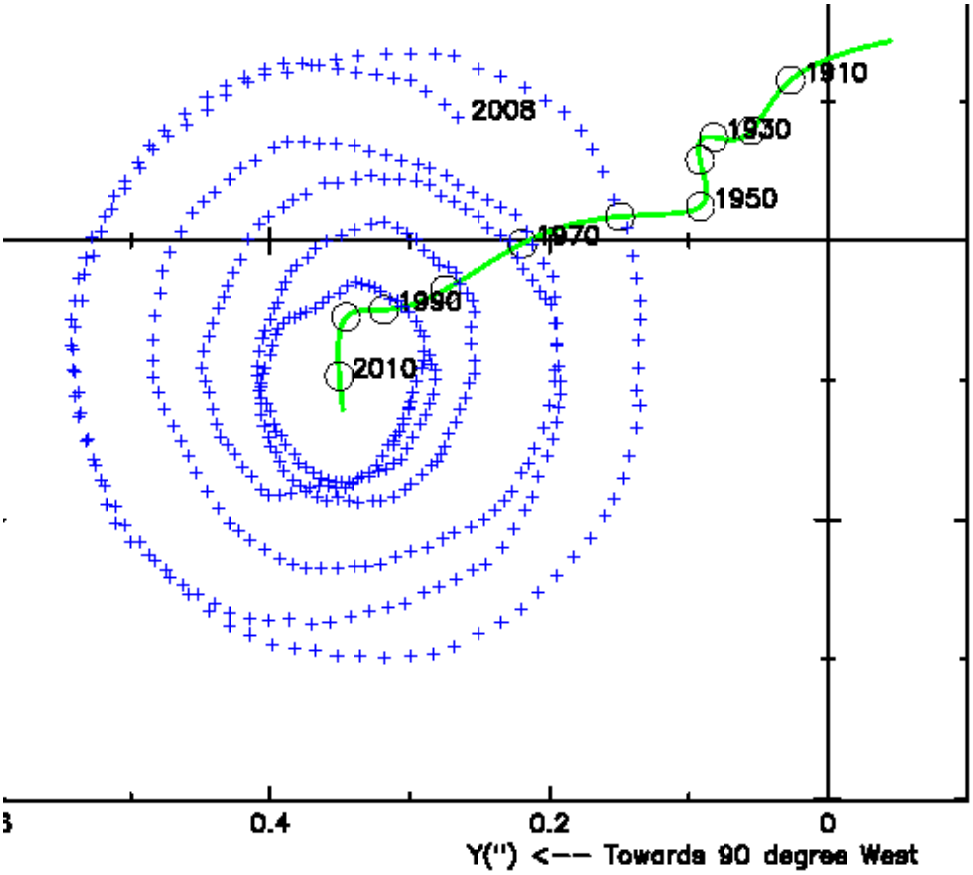


Fig. 1: Mean polar motion (1900–2013) and IERS C04 polhody over 2008–2013

Mean Pole with respect to the IERS reference origin

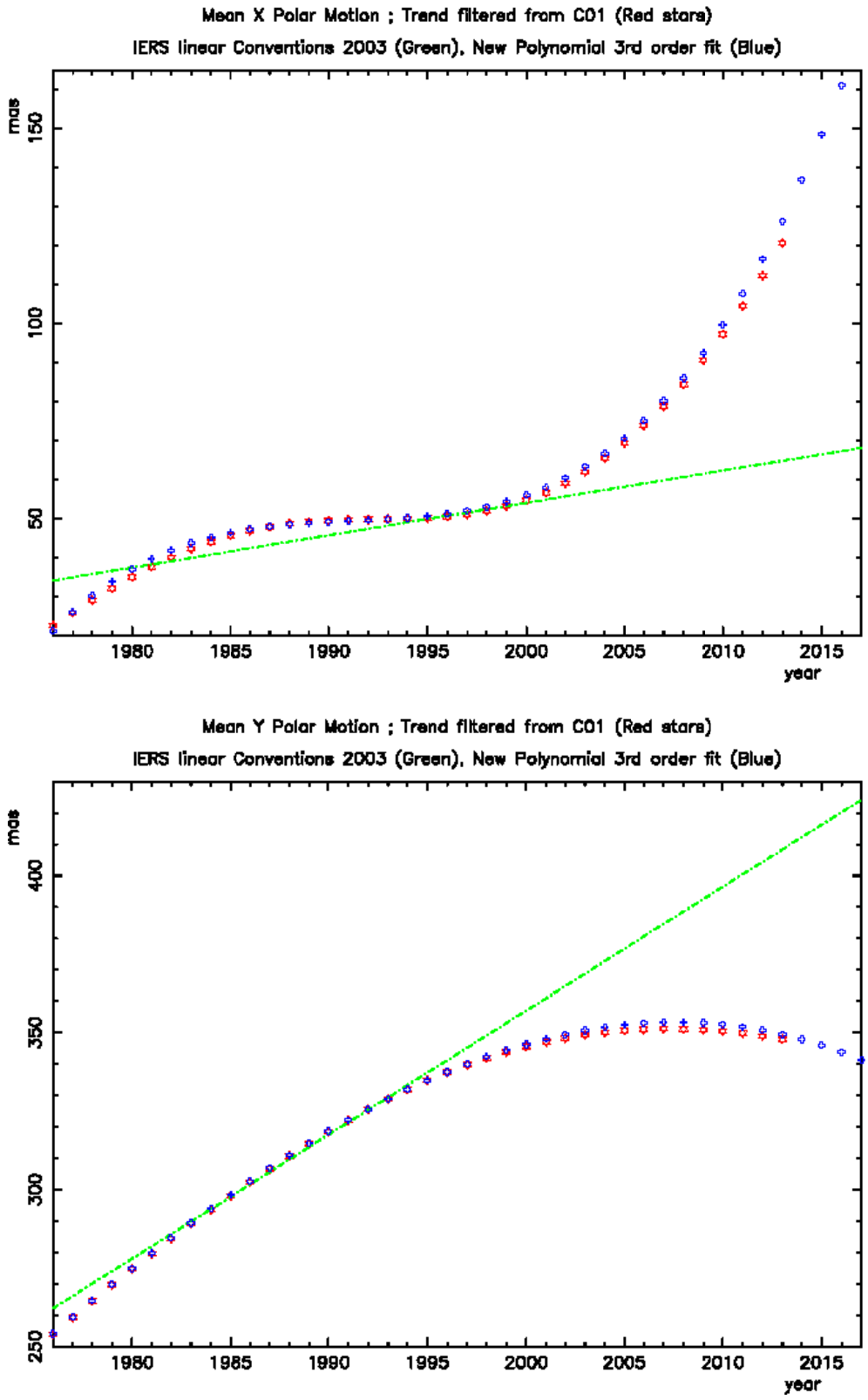
Gravity field models include the tesseral coefficients C21 and S21 coefficients. These terms describe the position of the Earth's figure axis with respect to the Terrestrial Reference Frame. This axis should coincide with the observed position of the rotation pole averaged over the same time period. The mean 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 2012 (Shiskin et al., 1965). Figure 1 represents the polar motion over 2008–2012 and the path of the mean pole since 1900. Until the 2000's the mean polar motion was affected by a long-term drift westward (direction 70.7 degree West, rate: 4.2 mas/yr). It appears clearly that since that epoch, the mean pole is directed to Greenwich direction.

The mean pole is described by a third order polynomial. Its coefficients are published in IERS Conventions 2010 (Petit and Luzum, 2010). The corresponding table is also available at the following address: <http://hpiers.obspm.fr/eop-pc/>.

After two years, it was interesting to match the extrapolated polynomial values and the updated mean pole time series. Table 4 and Figures 2a and 2b thereafter give the IERS mean pole components compared to the fitted polynomial and their differences which appear to remain roughly limited to a couple of mas over the extrapolated period 2010–2013 .

Table 4: IERS mean pole components compared to the fitted polynomial and their differences which remain limited to a couple of mas over the extrapolated period.

Year	X-Pole (mas)			Y-Pole (mas)		
	IERS data	Polynomial	diff(X-pole)	IERS data	Polynomial	diff(Y-pole)
1976	22.494	21.157	1.337	253.915	254.139	-0.224
1977	25.835	25.966	-0.131	259.294	259.467	-0.173
1978	29.050	30.173	-1.123	264.564	264.706	-0.142
1979	32.106	33.822	-1.716	269.720	269.850	-0.130
1980	34.973	36.954	-1.981	274.756	274.894	-0.138
1981	37.622	39.611	-1.989	279.668	279.832	-0.164
1982	40.028	41.836	-1.808	284.455	284.660	-0.205
1983	42.169	43.671	-1.502	289.118	289.370	-0.252
1984	44.032	45.157	-1.125	293.661	293.959	-0.298
1985	45.606	46.337	-0.731	298.088	298.420	-0.332
1986	46.891	47.254	-0.363	302.404	302.749	-0.345
1987	47.898	47.948	-0.050	306.607	306.939	-0.332
1988	48.646	48.463	0.183	310.694	310.985	-0.291
1989	49.164	48.841	0.323	314.653	314.882	-0.229
1990	49.491	49.123	0.368	318.470	318.625	-0.155
1991	49.674	49.352	0.322	322.128	322.207	-0.079
1992	49.768	49.570	0.198	325.608	325.624	-0.016
1993	49.833	49.819	0.014	328.892	328.870	0.022
1994	49.931	50.141	-0.210	331.964	331.940	0.024
1995	50.128	50.579	-0.451	334.813	334.827	-0.014
1996	50.486	51.175	-0.689	337.431	337.527	-0.096
1997	51.067	51.970	-0.903	339.814	340.035	-0.221
1998	51.926	53.006	-1.080	341.964	342.344	-0.380
1999	53.114	54.327	-1.213	343.883	344.450	-0.567
2000	54.677	55.974	-1.297	345.574	346.346	-0.772
2001	56.655	57.989	-1.334	347.042	348.028	-0.986
2002	59.083	60.415	-1.332	348.290	349.490	-1.200
2003	61.990	63.293	-1.303	349.319	350.726	-1.407
2004	65.402	66.666	-1.264	350.130	351.731	-1.601
2005	69.337	70.575	-1.238	350.724	352.500	-1.776
2006	73.812	75.064	-1.252	351.102	353.027	-1.925
2007	78.836	80.174	-1.338	351.266	353.307	-2.041
2008	84.416	85.947	-1.531	351.219	353.335	-2.116
2009	90.553	92.425	-1.872	350.966	353.104	-2.138
2010	97.247	99.651	-2.404	350.510	352.609	-2.099
2011	104.497	107.667	-3.170	349.855	351.845	-1.990
2012	112.304	116.514	-4.210	349.002	350.807	-1.805
2013	120.666	126.236	-5.570	347.953	349.489	-1.536



Figs. 2a and 2b: Plots showing the good agreement between the data and the fitted polynomial. Their differences remain limited to a couple of mas over the extrapolated period 2010–2013.

Long term UT1/LOD (EOP C02: 1830–now)

For geophysical study, we propose a new product: a long term UT1/LOD series (with the label EOP C02). This series is extending from 1830 until now and is monthly updated.

This series is composite and is available at <http://hpiers.obspm.fr/eoppc/series/longterm/eopc02.1830-now>; it is composed of the following series series:

1) 1830–1955: Delta T = TE – UT = TE – TAI – (UT – TAI) from Jordi et al. (1994), and obtained from the analysis of lunar occultations – mean sampling time of 120 days.

2) 1955–1962: from Vondrak et al. (1995) UT1 time series from optical astrometry.

3) 1962–now: Combined C04 time series free from short term zonal tides (< 2 years).

The characteristics of the combination are:

- For optical astrometric data (Jordi et al., AICAS), prior to 1962, UT–TE / UT1–TAI series are smoothed by gaussian filter with 365 day interpolation step.
- C04 series are smoothed using a gaussian filter with a 200 day interpolation step.
- After filtering the total series, composed of UT–TE (prior to 1958) and UT1–TAI (after 1958), are interpolated by cubic spline at 100 days step.
- Variation of the length of day LOD, given by LOD / D = –dUT1/dt where D = 86400 s is the duration of the day, is then obtained from a two point time derivative of the 100 day UT1 time series.

Dissemination of UT1–UTC through the use of virtual observatory

Information concerning UT1–UTC and the occurrence of the leap seconds are currently made available via IERS Bulletin D and C. However, this old-fashioned procedure does not satisfy automatic systems. We have investigated the way to develop a new service based on the concept of Virtual Observatory (VO). This concept, provided by the International Virtual Observatory Alliance (IVOA), allows scientists and the public to access and retrieve UT1–UTC information using on-line distributed computational resources. We derived the concept, using the XML-based VO Table format to build this UT1–UTC dedicated new service (Deleflie et al., 2011).

The scientific community working in different field and requiring in particular UT1–UTC on a regular and reliable basis can benefit from the VO concept. The concept of metadata allows making available a single file with a description. Such tools can enhance the visibility of earth orientation parameters as well as UT1–UTC derived by the IERS.

Staff

Daniel Gambis	Astronomer, Head
Christian Bizouard	Astronomer
Teddy Carlucci	Engineer
Jean Yves Richard	Engineer
Olivier Becker	Engineer
Pascale Baudoin	Secretary

References

Bizouard, C. and D. Gambis, 2009, the combined solution C04 for Earth Orientation Parameters, recent improvements, Springer Verlag series, Series International Association of Geodesy Symposia, Vol. 134, Drewes, Hermann (Ed.), pp. 265–270, DOI 10.1007/978-3-642-00860-3

Deleflie F., D. Gambis, C. Barache, J. Berthier, 2011, Dissemination of UT1–UTC through the use of virtual observatory VO, in AAS proc., AAS 11-680

Fedorov, E.P., Korsun, A.A., Mayor, S.P., Pantscheenko, N.I., Tarady, V.K., Yatskiv, YA. S., 1972: *Dvizhenie polyusa Zemli s 1890.0 po 1969.0.* Naukova dumka, Kiev (English translation of the text available).

Gambis, D., 2004: Monitoring Earth Orientation at the IERS using space-geodetic observations. *J. of Geodesy* 78, pp. 295–303.

Gambis, D. and Luzum, B., 2011, Earth rotation monitoring, UT1 determination and prediction, Metrologia 48 (2011) S165–S170

Jordi, C., L. V. Morrison, R. D. Rosen, D. A. Salstein, and G. Rosello, Fluctuations in the earth's rotation since 1830 from high-resolution astronomical data, Geophys. J. Int., 117, 811–818, 1994.

Petit, G. and B. Luzum (eds.), 2010: *IERS Conventions (2010)*, BKG, Frankfurt am Main (*IERS TN* 36; Website: <http://www.iers.org/TN36>).

Shiskin, J., Young, A.H., Musgrave J.C., 1965: *The X-11 variant of the Census Method II seasonal adjustment program*, U.S. Dept. of Commerce, Bureau of the Census *(Technical Paper No 15).*

Vondrak J., Ron C., Pesek I., Cepek A., 1995: New global solution of Earth orientation parameters from optical astrometry in 1900–1990, *Astron. Astrophys*. 297, 899–906.

Daniel Gambis and Christian Bizouard