3.5 Product Centres
3.5.1 Earth Orientation Centre

This section presents over the year 2014 the activities and main results of the Earth Orientation Centre located at Paris Observatory. According to the IERS Terms of Reference, this component is responsible for monitoring Earth Orientation Parameters including long term consistency, publications for time dissemination (DUT1) and leap second announcements. Earth Orientation Parameters (EOPs: 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 until the end of last year and the Bulletin B / C04 given at one-day intervals and which is 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 lead in the past 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/Predictions Center, US Naval Observatory) were recomputed and aligned to the EOP solution associated to the current ITRF2008. Inconsistencies are now negligible compared to the current accuracies, i.e. limited to about 10 microarcseconds for polar motion and a few microseconds for UT1.

Combined daily series: Bulletin B and C04, statistics over 2013–2014

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 2013–2014. 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 currently given as a feedback to the analysis centres.

Table 1: Estimated accuracies of individual solutions compared to the combined solutions Bulletin B / C04 over 2013–2014. 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	300	15.0		150
EOP (BKG)	1–4d	150	11.0		93
EOP (GSFC)	1–4d	135	11.1		82
EOP (IAA)	1–4d	160	15.4		87
EOP (MAO)	1–4d	140	7.3		88
EOP (OPA)	1–4d	135	9.9		90
EOP (PUL)	1–4d	108	10.8		89
EOP (USNO)	1–4d	85	5.7		50
EOP (IVS) *	1–4d	105	6.7		37
VLBI – Intensive					
EOP (BKG) *	1–3 d		18.0		
EOP (GSFC) *	1–3 d		18.4		
EOP (IAA)	1–3 d		21.3		
EOP (PUL) *	1–3 d		21.0		
EOP (USNO) *	1–3 d		19.7		
SLR					
EOP (CGS)	1d	165		20.3	
EOP (IAA)	1d	300		22.6	
EOP (MCC)	1d	165		–	
EOP (PUL)	1d	110		16.6	
EOP (ILRS)*	1d	135		27.7	
GPS					
EOP (CODE)	1d	31		10.8	
EOP (EMR)	1d	45		9.6	
EOP (ESOC)	1d	40		21.3	
EOP (GFZ)	1d	75		42.2	
EOP (IAA)	1d	43		17.0	
EOP (JPL)	1d	73		8.9	
EOP (NOAA)	1d	65		17.9	
EOP (SIO)	1d	28		8.2	
EOP (IGR) *	1d	34		8.3	
EOP (IGS) *	1d	29		8.2	

Table 2: Mean and standard deviation in microarcsecond of the differences between various combined techniques solutions entering the combination and Bulletin B / C04 over 2013–2014.

EOP	IGS Comb – IERS 08C04		ILRS Comb – IERS 08C04		IVS Comb – IERS 08C04	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
X (μas)	–10	29	91	143	37	83
Y (μas)	10	29	58	131	52	88
UT1 (μs)					6	5.7
LOD (μs)	3	8	7	27		
Dψsinε (μas)					2	56
Dψ (μas)					–32	49

Table 3: Mean and standard deviation for Pole components and UT1 of the differences between combined solutions derives by both the Rapid Service/Prediction Center at USNO, the JPL and Bulletin B / C04 over 2013–2014.

EOP	Unit	Bull A – Bull B		Comb JPL – Bull B	
		Mean	Standard deviation	Mean	Standard deviation
X	μas	0	18	31	32
Y	μas	0	18	-11	18
UT1	μs	2.6	10.7	–1.0	9.9

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>.

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://datacenter.iers.org/eop/-/somos/5Rgv/getTX/2/message_198.txt >) and starting on 1 December 2012, 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>.

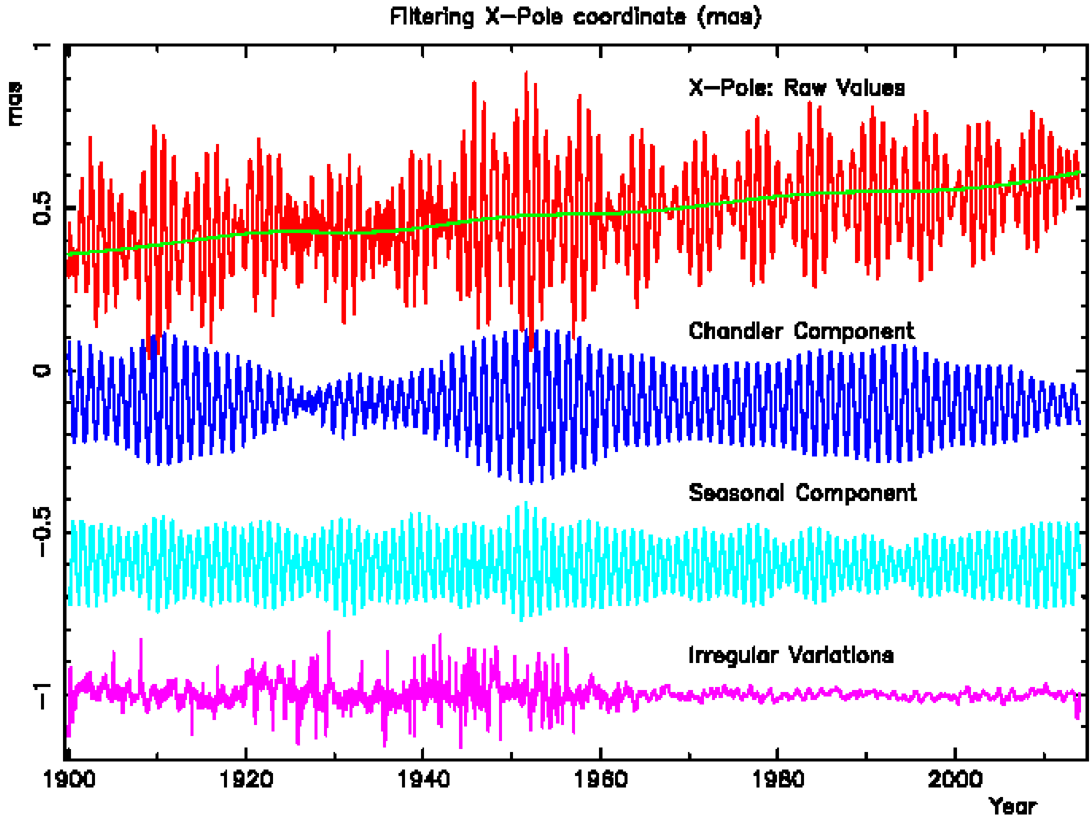
Long-term series: C 01 (1846–2014)

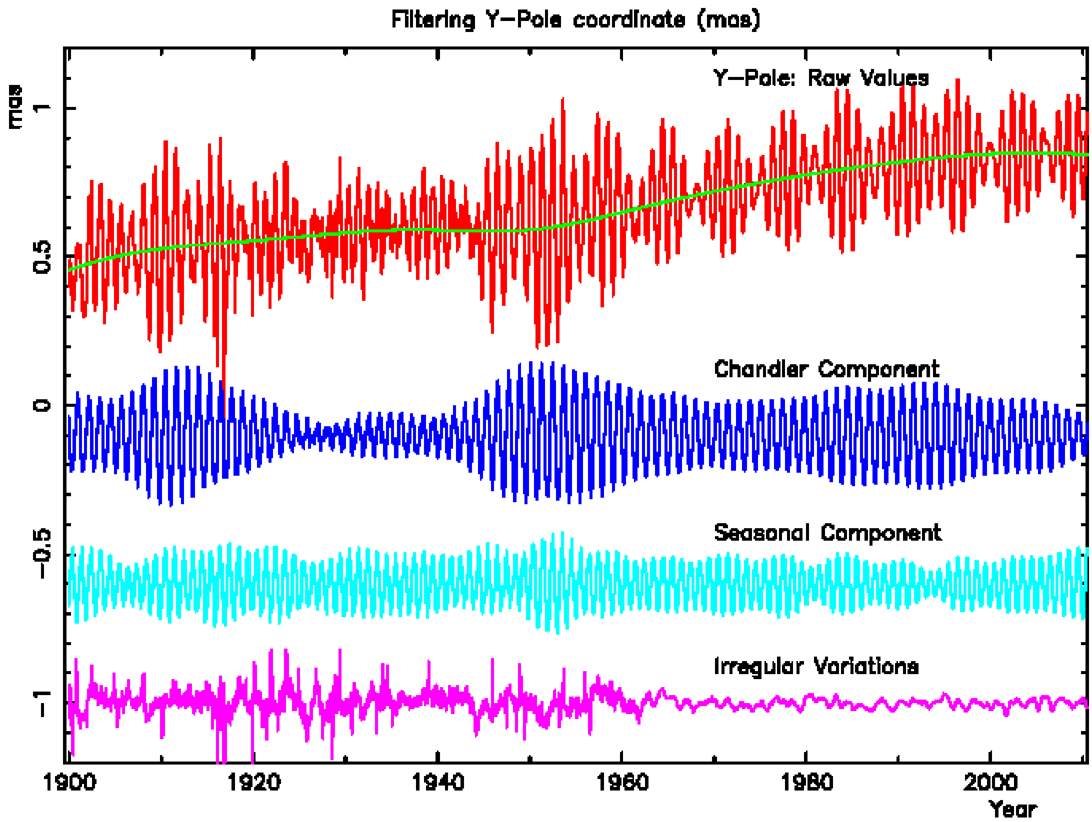
EOP(IERS) C01 is a series of Earth Orientation Parameters given at 0.1 year intervals from 1846 to 1889 (polar motion only) and 0.05 year interval from 1890 until now (polar motion, celestial pole offsets, UT1–UTC since 1962). For many decades, the observations were made using mostly visual and photographic 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 C01 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.





Figs. 1a and 1b: Filtering of pole coordinates in various components.

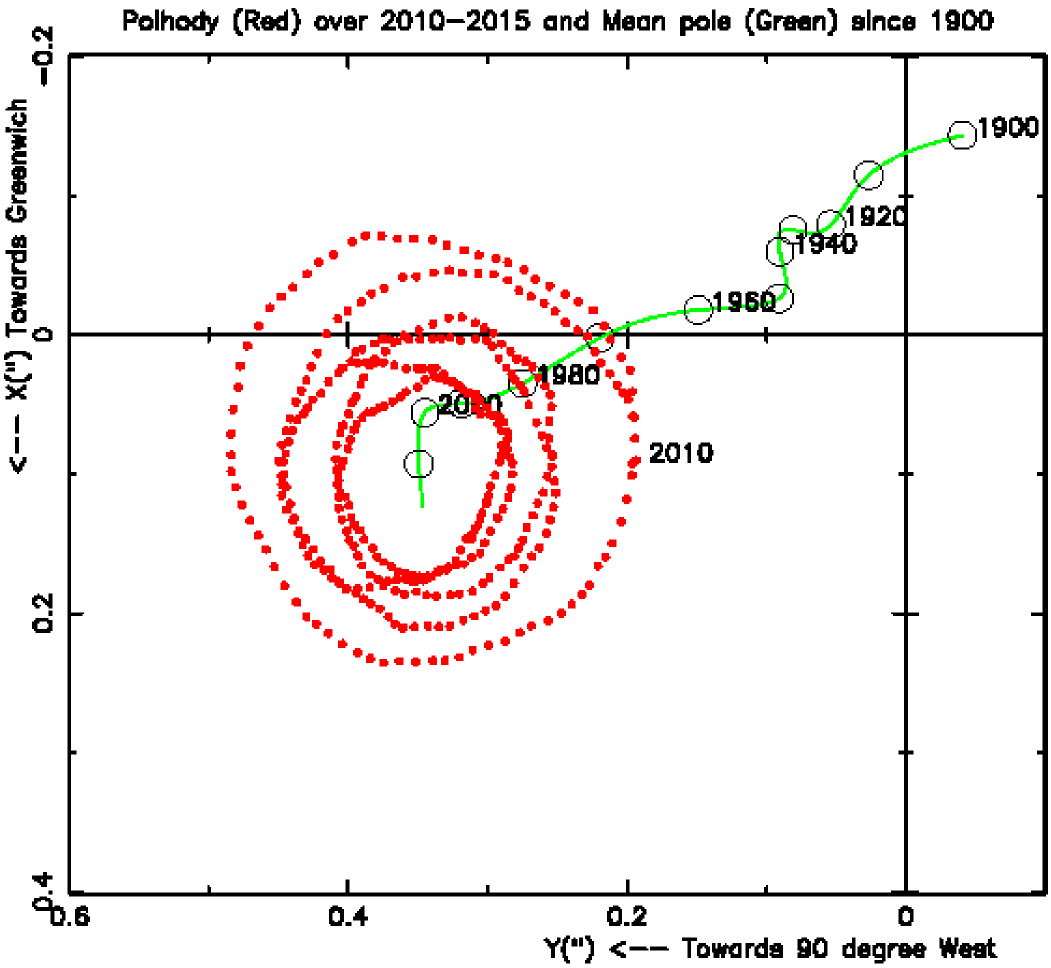


Fig. 2: Mean polar motion (1900–2015.0) and IERS C04 polhody over 2008–2015.0.

1962–2015: BIH and IERS solutions (BIH and IERS annual reports).

Figures 1a and 1b show the filtering of both pole coordinates since 1890 expressed in various components, i.e. the trend, the seasonal term and the Chandler wobble using the X-census filter (Shiskin et al., 1965).

Figure 2 shows the mean polar motion over 1900–2014 as well as the C04 polhody over 2008–2014. The change of direction of the mean pole since the beginning of the 2000s is apparent. The origin can be attributed to a change in the Earth inertia momentum probably due to the ice cap melting effect.

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 2015.0 (Shiskin et al., 1965). Figure 2 represents the polar motion over 2008–2014 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 direction has changed and is directed to Greenwich meridian. Table 4 gives the IERS mean pole components.

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 is available at <http://hpiers.obspm.fr/eoppc/series/longterm/eopc02.1830-now>. It is composed of the following 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).

Table 4: IERS mean pole components over 2000–2015.0.

Year	mean X-pole (")	mean Y-pole (")
2000.	0.055981	0.345218
2001.	0.058022	0.346532
2002.	0.060436	0.347619
2003.	0.063229	0.348490
2004.	0.066403	0.349153
2005.	0.069953	0.349618
2006.	0.073868	0.349899
2007.	0.078133	0.350008
2008.	0.082731	0.349963
2009.	0.087643	0.349779
2010.	0.092851	0.349474
2011.	0.098339	0.349062
2012.	0.104098	0.348553
2013.	0.110120	0.347955
2014.	0.116401	0.347271
2015.	0.122942	0.346502

The characteristic 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 a 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.

Development of a leap second Web service

A simple ASCII file giving the dates of insertion of leap seconds is available on the front page of the IERS EOP product Center at <http://hpiers.obspm.fr/iers/bul/bulc/Leap_Second_History.dat>.

The information about the potential introduction of a leap second is currently broadcast via Bulletin C. However, a procedure more adapted to the development of networks of servers becomes necessary and in particular, for programs like the NTP daemon which can use this file as authoritative server source. Such a procedure of providing and maintaining a leap second file via a secure protocol is now being developed at the Earth Orientation Center.

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