3.5 Product Centres
3.5.1 Earth Orientation Centre

This section presents activities and main results concerning the Earth Orientation Centre located at Paris Observatory over the year 2007. According to the IERS Terms of Reference, the Earth Orientation Centre is responsible for monitoring Earth Orientation Parameters (EOP) including long term consistency, publications for time dissemination and leap second announcements. The Earth Orientation Centre is making available different products to a broad community of users in astronomy, geodesy, geophysics, space sciences and time, i.e. 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) and the operational smoothed solution Bulletin B at one-day intervals published monthly. Bulletin B is updated in the operational C04. So far, EOP and the terrestrial frame were separately computed. This led to increasing inconsistencies between both of them. On January 2005, these inconsistencies were significant for polar motion; the Bulletin B and C04 were recomputed and aligned to the EOP solution associated to the ITRF2005 (Altamimi et al. 2007). By the way, the procedure leading to the combined solutions was upgraded.

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

As stated in the previous IERS Annual Report for 2006, the EOP reference solutions were made consistent to the new realization of the ITRF, i.e. ITRF2005 (Altamimi et al. 2007). Due to the separate determination of both celestial and terrestrial reference frames and EOP, there has been a slow degradation of the overall consistency. Discrepancies at the level of 300 microarseconds were present at 2004.0 between the IERS C04 and the ITRF realization (Gambis 2004). This was as well an opportunity to upgrade the numerical combination procedure. The improvements concern routines, table dimensions and the generalization of double precisions. Using the combined polar motion solution associated with the ITRF 2005, the new solution is mainly based on the time series derived by technique centres IGS, IVS and ILRS. In addition, formal errors associated to EOPs are available. EOP series have been reprocessed since 1984. Pole coordinates are now fully consistent with ITRF2005. The nutation offsets and UT1 are made consistent with the International Celestial Reference Frame (ICRF) through the IVS combined solution. Tables 1 to 4 give statistics concerning the analyses of Bulletin B and 05 C04. A detailed description of the new solution can be found in Bizouard and Gambis (2008) and in the Technical Note available at <http://hpiers.obspm.fr/iers/eop/eopc04_05/C04_05.guide.pdf>.

Table 1: Estimated accuracies of individual solutions compared to the combined solutions Bulletin B and 05 C04 over 2007–2008.

Individual solutions		Estimated uncertainties				
		Time	Terrestrial Pole µas	UT1 µs	LOD µs	Celestial Pole µas
VLBI - 24 h						
EOP (AUS)	01 R 01	3-4d	204	–		222
EOP (BKG)	03 R 02	1-4d	105	7.0		129
EOP (GSFC)	07 R 01	1-4d	135	5.7		86
EOP (IAA)	05 R 02	1-4d	107	6.0		118
EOP (MAO)	03 R 01	1-4d	99	7.0		152
EOP (OPA)	07 R 01	1-4d	86	6.2		60
EOP (SPBU)	05 R 01	1-4d	260	6.8		118
EOP (USNO)	06 R 02	1-4d	95	5.8		86
EOP (IVS)	02 R 01	1-4d	100	5.4		96
VLBI - Intensive						
EOP (BKG)	03 R 02	1-3 d		12.4		
EOP (GSFC)	06 R 01	1-3 d		11.3		
EOP (IAA)	05 R 01	1-3 d		13.0		
EOP (SPBU)	05 R 01	1-3 d		14.3		
EOP (USNO)	05 R 01	1-3 d		13.1		
SLR						
EOP (ASI)	03 L 02	1d	220		54.1	
EOP (IAA)	02 L 01	1d	169		31.4	
EOP (MCC)	97 L 01	1d	147		–	
EOP (OCA)	05 L 01	1d	133		–	
EOP (ILRS)	05 L 01	1d	66		17	
GPS						
EOP (CODE)	98 P 01	1d	35		14.1	
EOP (EMR)	96 P 03	1d	55		17.8	
EOP (ESOC)	96 P 01	1d	50		36.3	
EOP (GFZ)	96 P 02	1d	40		16.3	
EOP (IAA)	01 P 01	1d	190		30.1	
EOP (JPL)	96 P 03	1d	76		116.3	
EOP (NOAA)	96 P 01	1d	75		15.9	
EOP (SIO)	96 P 01	1d	47		17.9	
EOP (USNO)	03 P 01	1d	-		23.0	
EOP (IGS)	07 P 01	1d	19		9.5	
EOP (IGS)	96 P 02	1d	39		10.0	

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.

Maintenance of the consistency between the current EOP 05 C04 solution in the ITRF2005 system

Introduction

The maintenance of the consistency between 05 C04 with the ITRF is essential in the field of geodynamics and satellite orbit computation. The ITRF2005 was the first rigorous combination ensuring ITRF and EOP consistency, based on time series of station positions and Earth Orientation Parameters (Altamimi et al. 2007). Its release was the opportunity to re-align the C04 to the ITRF2005 system. IERS reference EOP series, based on the combination of astro-geodetic techniques products are currently independently computed from the ITRF. This leads to the existence and increase of small

Table 2: Uncertainty of the current solution of Bulletin B and the estimated accuracies of the predictions for horizons of 5 days to 1 year for 2007–2008.

Solutions		Terrestrial Pole mas	UT1 ms	Celestial Pole mas
Analysis daily	1-d	.040	.006	0.10
Prediction	1-d	.50	.18	0.10
	5-d	2	.60	0.10
	10d	4	1.40	0.10
	30d	12	5.	0.10
	90d	50	30.	0.10
	180d	60	70.	0.10
	1-yr	76	140.	0.10

Table 3: Mean and standard deviation in microarcsecond of the differences between various combined techniques solutions and IERS 05 C04 over 2007–2008.

EOP	IGS Comb – IERS 05C04		ILRS Comb – IERS 05C04		IVS Comb – IERS 05C04	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
X (μas)	3	21	–133	166	–39	91
Y (μas)	–60	19	–118	156	8	114
UT1 (μs)	9	28			4	6.6
LOD (μs)	0	11	22	54		
Dψsinε (μas)					5	50
Dψ (μas)					–4	51

Table 4: Mean and standard deviation for Pole components and UT1 of the differences between various solutions and Bulletin B over 2007.3 to 2008.3.

EOP	Unit	Bull A – Bull B		Comb JPL – Bull B	
		Mean	Standard deviation	Mean	Standard deviation
X	μas	–29	27	–176	50
Y	μas	–15	31	–57	13
UT1	μs	–1	13	8	11

inconsistencies between the terrestrial reference frame and EOP. After two years, it was important to assess the level of accuracy reached for the consistency between the current 05 C04 and the ITRF2005 system.

In cooperation with the ITRS Centre we have developed a combination strategy allowing to check the ITRF2005 and IERS 05 C04 consistency with time.

Strategy of the maintenance of 05 C04 in the ITRF2005 system starting at 2006.0 using a SINEX combined extension of EOP (ITRF2005)

The 05 C04 EOP series is derived from the combination of series derived by technique centres, IGS, ILRS and IVS.

The process includes the following steps:

1) CATREF computation by the ITRS Centre of updated EOP solutions based on SINEX files of GPS and VLBI techniques
2) Comparison of this EOP solution to the current 05 C04 EOP series operationally computed by the Earth Orientation Centre.

Conclusion

Results were presented at various conferences (Altamimi et al. 2008, Gambis et al. 2008). Figure 1 gives the level of consistency obtained. It appears that after two years we are able to maintain the overall consistency within the level of 40 microarseconds between the updated series of EOP derived from CATREF processing and the 05 C04 independently computed. This is at the level of the inaccuracy reached for the current pole components estimation.

Long-term series: C 01 (1846–2007)

EOP(IERS) C 01 is a series of the 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 1960s, new geodetic techniques were used for geodynamics. Now, the global

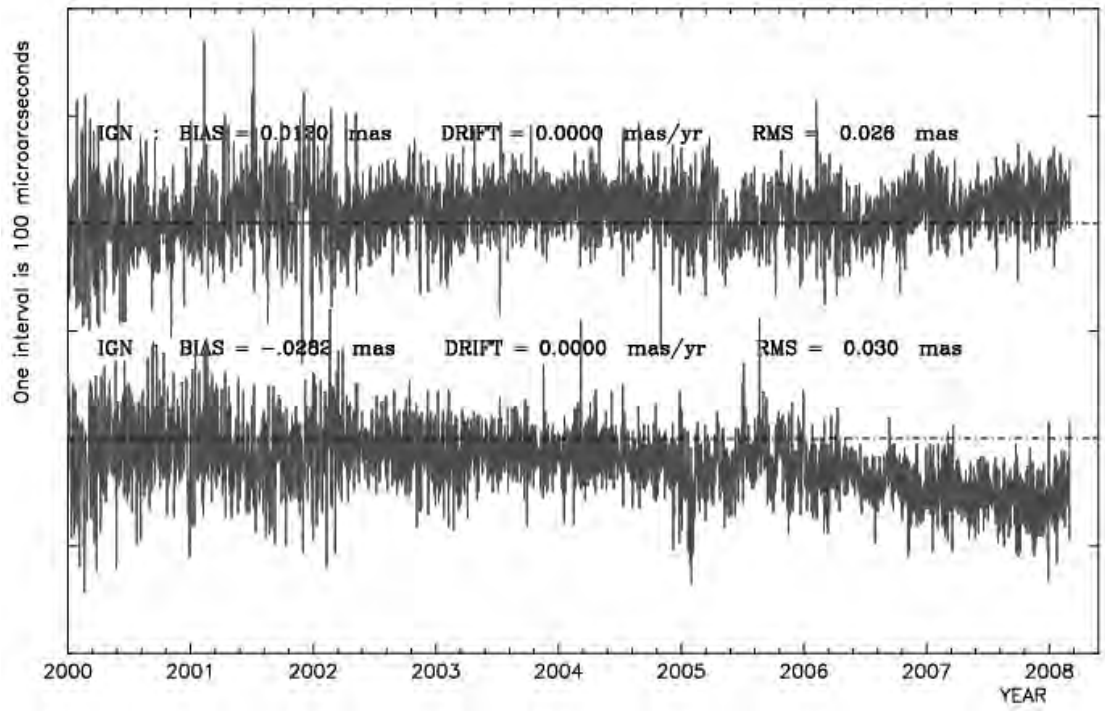

Fig. 1: Polar Motion over 2000–2008, CATREF(2008) – 05 C04

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 2003. 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).

1962–2007: 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 performing the transformation between both terrestrial and celestial frames via the Earth Orientation Parameters. Gravity field models include the tesseral coefficients C21 and S21. 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 polar motion is affected by a long-term drift westward (direction 70.7 deg West, rate: 4.2 mas/yr). The mean rotation axis

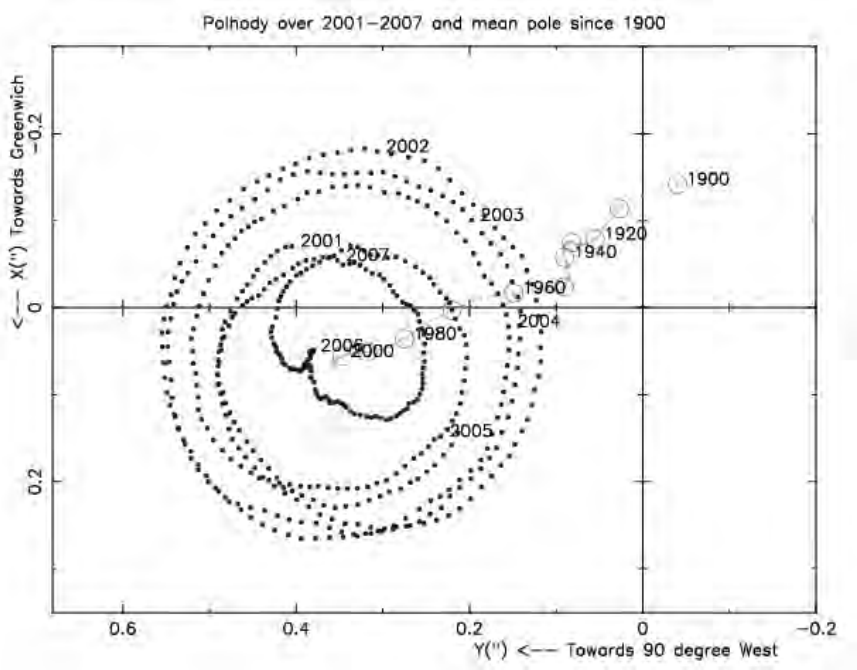

Fig. 2: Mean polar motion (1900–2010) and IERS C04 polhody over 2002–2007

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 2007 (Shiskin *et al*, 1965). Figure 2 represents the polar motion over 2001–2006 and the path of the mean pole since 1900. The table is available in Conventions 2003 (McCarthy and Petit 2004) and at <http://hpiers.obspm.fr/eop-pc/>.

Staff

Daniel Gambis	Astronomer, Head
Christian Bizouard	Astronomer
Gérard Francou	Astronomer
Teddy Carlucci	Engineer
Jean Yves Richard	Engineer (since November 2007)
Olivier Becker	Engineer (since November 2007)
Morad Saïl	Engineer (until December 2007)
Mireille Bougeard	Mathematician
Pascale Baudoin	Secretary

References

Altamimi, Z., Collilieux X., Legrand J., Garayt B., Boucher, C., 2007: ITRF2005: A new release of the International Terrestrial Reference Frame based on time series of station positions and Earth Orientation Parameters, *J. Geophys. Res.* 112, B09401, doi: 10.1029/2007JB004949.

Altamimi, Z., Gambis, D., Bizouard Ch., 2008: Rigorous combination to ensure ITRF and EOP consistency, *Proceedings of the Journées 2007 Systemes de Référence Spatio-Temporels: The Celestial Reference Frame for the Future,* N. Capitaine (ed.), Paris, pp. 151–154.

Bizouard, C., Gambis, D., 2008: The combined solution C04 for Earth Orientation Parameters, recent improvements, Springer Verlag series, accepted.

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., Biancale, R., Carlucci, T., Lemoine, J.M., Marty, J.C., Bourda G., Charlot, P., Loyer, S., Lalanne, L., Soudarin, L., 2008: Combination of Earth Orientation Parameters and terrestrial frame at the observation level, Springer Verlag series, accepted.

McCarthy, D.D., Petit, G. (eds.), 2004: *IERS Conventions (2003)*, BKG, Frankfurt am Main (*IERS Technical Note* No. 32; Website: <http://tai.bipm.org/iers/conv2003/conv2003.html>).

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, Christian Bizouard, Jean Yves Richard, Teddy Carlucci, Morad Saïl, Olivier Becker